GLASS BEADS IN AFRICAN ARCHAEOLOGY:
RESULTS OF NEUTRON ACTIVATION ANALYSIS,
SUPPLEMENTED BY
RESULTS OF X-RAY FLUORESCENCE ANALYSIS

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ABSTRACT

Glass beads from archaeological sites of sub-Saharan Africa were analyzed by neutron activation and by X-ray fluorescence, and the results interpreted archaeologically. The glass beads from Igbo Ukwu (Nigeria), dated approximately to the ninth century A.D., were mostly soda-lime glasses, but a few potassium glasses were found. The glass artifacts from Ife (Nigeria), dated to approximately the tenth to twelfth centuries A.D., were mostly potassium glasses, with some soda-lime glasses. Some close resemblances were found between the glasses of the two sites. Evidence for glassworking which exists at Ife is interpreted as evidence of reworking, rather than manufacture from raw materials. A European provenience is suggested for the potassium glasses, but the provenience of the soda-lime glasses is unclear.

Blue-green glass beads from Bambandyanalo (Republic of South Africa), dated approximately to the eleventh century A.D., chemically match large beads known as garden roller beads found at Bambandyanalo and other sites.

The hypothesis, known in the literature, that the garden roller beads were made at Bambandyanalo by reworking the blue-green beads is supported by this chemical match. Certain other glass beads found at Bambandyanalo, but not typical there, were found chemically to match glass beads from the nearby site of Mapungubwe.

Samples from a large series of glass beads known as trade wind beads were found to be chemically alike. These beads occur in archaeological sites of southern and eastern Africa, and in the Philippine Islands, and are dated archaeologically from c. the eleventh century A.D. at Bambandyanalo to c. the end of the seventeenth and early eighteenth centuries A.D. at Dambarare, Dhlo Dhlo, and related sites (Rhodesia), with a possible archaeological occurrence in the nineteenth century at Kilwa (Tanzania), and with a twentieth-century occurrence as heirlooms among the Lovedu and probably other groups of the Transvaal (Republic of South Africa). The long time span of archaeological dating of this group is difficult to reconcile with the chemical similarity of the beads. If the archaeological dating is correct, the long time span of the group indicates that chemical groups of glass may not always be sensitive indicators of relative date. The hypothesis, known in the literature, of Indian manufacture of these beads was tested despite its questionable nature, and the available evidence was found inconclusive.

The beads found in archaeological sites of eastern and southern Africa are all soda-lime glasses. The origins of all beads of soda-lime glass found in African archaeological sites are unclear. Soda-lime compositions are undiagnostic and could be consistent with European or Near Eastern origins. Suggestions of provenience hinge on the dating of the samples rather than on links to factory sites, and even so are only conjectural. It is noted that data from glass factory sites are needed, and it is suggested that future research turn in this direction.

PREFACE

This dissertation presents the results of research into the chemistry of glass beads found in archaeological sites of sub-Saharan Africa. In the earlier stages of the research a great many beads were examined, and selections were made for chemical analysis. The institutions at which the author examined glass beads are related material were as follows: the British Institute in Eastern Africa, Nairobi; the Fort Jesus Museum, Mombasa; the National Museum of Tanzania, Dar es Salaam; the National Museum of Rhodesia, Bulawayo; the University of the Witwatersrand, Department of Archaeology, Johannesburg; the University of Pretoria, Department of Anthropology; the Museum of Man and Science, Johannesburg, the Museum of Carthage; the National Museum of Bardo, Tunis; the University of Allahabad; the Allahabad Museum; the Deccan College Postgraduate and Research Institute, Poona; Benares Hindu University; the Government Museum, Madras; the Archaeological Survey of India, Madras and New Delhi; the Asutosh Museum, Calcutta; the Hyderabad Museum; the M. S. University of Baroda, Department of Archaeology; the Department of Historical Archives of Goa; the National Museum of the Philippines; the Victoria and Albert Museum; the British Museum; the University Museum of Archaeology and Ethnology, Cambridge; the Pitt-Rivers Museum, Oxford; the Corning Museum of Glass; the Museum of Industrial Arts, Prague; the Museum of Glass and Bijouterie, Jablonec nad Nisou; the Museo del Vetro, Murano; the Musée des Antiquités, Rouen; the Musée du Verre, Liège; the Vleeshuis Museum, Antwerp; the Tropical Museum, Amsterdam; and the Museum of Geography and Ethnography, Rotterdam.

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PART I. INTRODUCTION AND BACKGROUND

CHAPTER 1. RESEARCH GOALS

A Classification

Glass beads are a frequently-encountered class of artifacts in sub-Saharan African archaeological sites of the past two millennia. These glass beads are considered to be imports, and in many sites they form the only tangible evidence of links between sub-Saharan African peoples and the outside world. If these beads could be linked to distribution networks or to places of origin, they might be of great value to the archaeologist in elucidating patterns of trade and contact in the past, as well as dating. Such a hope has often been expressed, but little actual ground has been gained.

In the course of an attempt to cull information from the variety of beads that exists in African sites, it is necessary to order them. A desirable system of order, or classification, would be a system based on principles which are clearly communicable to others, so that others may carry out continuing or comparative investigations.

It is for the lack of a suitable classification that so little ground has heretofore been gained in the study of African beads. Systems previously proposed, often only for limited use, have utilized such classification criteria as shape, size, and color. All too often these criteria have not been clearly communicable to others. In recent years a realization of the need for a common terminology has led some authors to adopt the Beck typology (1928), often simplified, and it is used in the descriptive aspects of this investigation.

However, because beads are often very simple to make, the same shapes, sizes and colors may be made in many different places. A classification in the Beck pattern may have no relationship to the manufacturing source of the beads. Therefore, the Beck system is unsuited for a classification which has as its goal the reflection of manufacturing origins. Therefore also, a classification designed to reflect common manufacturing origins should be one in which the attributes of shape, size and color are irrelevant.

We have taken the position that a classification based on the chemical ingredients of the glass will reflect the origins of the beads. The goal of the present research has been to initiate such a chemical classification.

As a result of our analysis of nearly four hundred glass beads from African sites, we have been able to distinguish a number of chemical groups of beads, and to organize these groups into a hierarchical, if fragmentary, classificatory system. In this system, bead groups can nest into more inclusive groups, but on the same classificatory level all groups are mutually exclusive. There is a residue of unclassified beads which do not fit into any except the most general groups, but the nature of the residue is not such that it would question the validity of the classification. Presumably the left-over beads fit into groups that are not yet discovered.

This classification does not represent the result of random sampling. Where it has been successful as a chemical classification, it represents the result of sampling from a very few visually-recognizable bead assemblages. Such beads were picked because they looked alike. In other cases beads were analyzed simply because they came from a particular site. By and large these beads form an unclassified residue, for example, Ife Class II (below). We shall have more to say on this subject in our last chapter.

The classification which has resulted from this research is shown in Figure 1. This classification, although hierarchical, should not be construed to reflect any evolution, development, chronology, or distance between factories. The diagram is not drawn "to scale", metaphorically speaking. The exact placement of the nodes, or levels, is not important except as they show mutual exclusion and nesting. Hopefully, future research will be able to intersperse levels within the fragmentary system here presented. With much more information such a diagram could reflect actual glassmaking "genealogies", but for now its main purpose is conveniently to show mutual exclusion and nesting.

In this classification, by definition, <u>an origin is that entity or entities, of whatever duration and distribution in space-time, that is responsible for the manufacture of a chemical (bead) group</u>. If the products of two or more manufacturing endeavors in space-time cannot be distinguished from each other and are therefore included in the same chemical group, these indistinguishable endeavors will count as one origin. On the other hand, a chemical classification may give a number of origins that is inflated with respect to the "true" number of glass works, because one glassworks may have produced more than one chemical group.

It follows from our definition of origins that origins will fall into groupings exactly corresponding to bead groupings. Nested bead groups will have correspondingly nested origins. We believe that the more

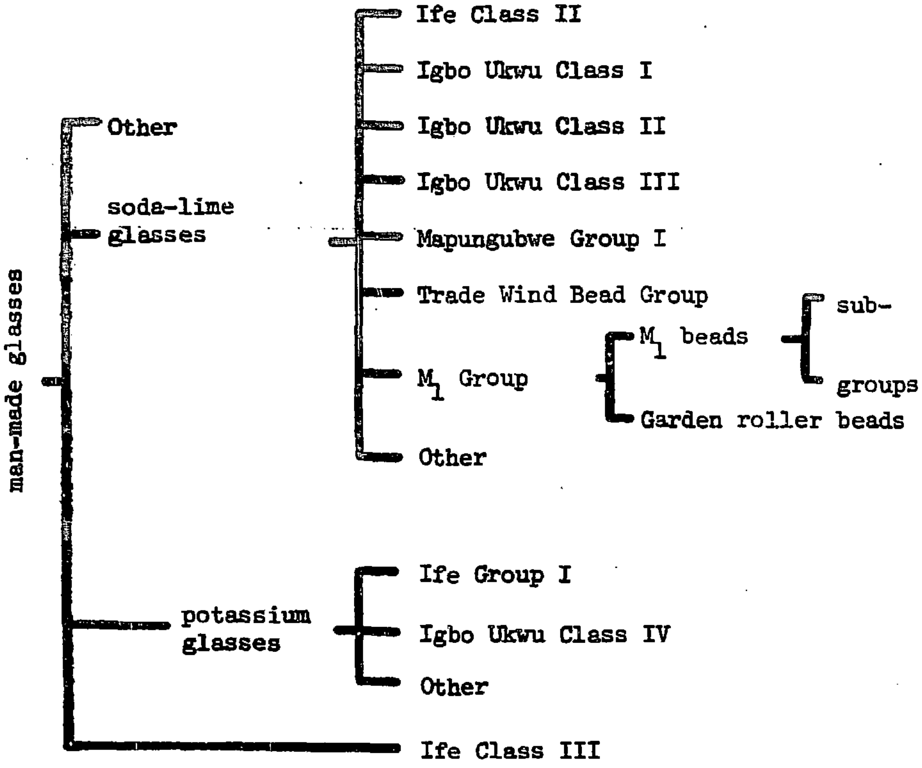

Figure 1. Chemical grouping of glasses analyzed. This diagram shows mutual exclusion and nesting of groups. It is not to any scale: degrees of homogeneity, dissimilarity, ranking, or other such features are not represented.

XBL 728-1599

specific the bead group, the more limited in space-time its origin must be.

In an investigation involving such chemical groups, it is important to consider groups at levels of generality which are appropriate for the problem being investigated. In historical studies, we are often concerned with entities that reflect human behavior, for instance, the behavior of the glassmakers. We are not necessarily interested in the most specific chemical groups we can find. The latter will often be a function of the limit of resolution of our techniques and not necessarily historically meaningful. As archaeologists we are usually interested in that group, at whatever classificatory level it happens to be, which is relevant to human behavior, or which is heuristic for a particular investigation.

An intelligent choice of the classificatory level which will figure in one's investigation would seem to require that our classification be interpretable in terms of glass manufacture, in other words, how a chemical bead group relates to a glass factory. One cannot safely assume, for example, that chemical groups whose members look alike correspond to single product lines of a factory, and that their subgroups correspond to different batches of the same product, and that our techniques do not resolve intra-batch differences into further subgroups.

We are not yet able to interpret our classification in terms of glass manufacture, and it is largely for this reason that we adopted our tautological definition of origin. We have carried out no deliberate control investigations. For example, extensive analysis of samples from factory sites would presumably yield information about the chemical variability reasonably expectable between batches of the same product from year to year. Were such an investigation carried out, it may still be difficult to evaluate whether the factory investigated was representative or peculiar. Therefore it may well be necessary to investigate a large number of factories, in order to acquire information in the nature of a control which would place our bead classification into perspective. Such investigations are a life's work, as yet undone, and not available for us here. For these reasons our classification remains largely uninterpreted and open to further research.

Specification of Origins

Some investigators may wish to attempt to specify the origin of a bead group, that is, name the factory, despite the difficulties in interpreting bead groups as discussed above. No doubt, if a specification were successfully made, it would aid in the interpretation of groups in general. However, presently there is not enough information about glass factories to enable one systematically to search out an origin as if "keying" a biological organism. Stylistic and chemical criteria can often place glass artifacts in broad traditions, such as "medieval European" or "art nouveau". However, when it comes to more specific origins, each group will be pinned to its origin on the bases of empirical--and even eclectic--studies. There is no theoretical principle by which one can tie glasses to very precise origins, neither to a geographical region, nor to a culture. Ties will have to be made empirically. Let us see why this is so.

The main reasons for the difficulty in tracing glass to a very precise geographical region of origin lie in the fact that glass is often made by mixing ingredients from disparate sources. Such a "fingerprint" as the glass may display need have no recognizable relation to the geographical region in which the factory lies. The written history of glass contains numerous notices of an international commerce in all the classes of materials used for glassmaking: *silica* (ibn Yakut, al Biruni, in Lamm 1941), *alkalis* both soda and potash (Neri 1612, Kunckel 1679), *cullet* or other scavenged material (Hetteš 1960, Honey 1946, Chambon 1958a, Kunckel 1679, Theophilus, in Chambon 1955, Dikshit 1969), *colorants* (Kunckel 1679), and even possible glass *ingots* and similar material (Pliny, in Winbolt 1933, Charleston 1963, Lamb 1965, Hall *et al*. 1964, Newton 1971). Locally-obtained ingredients may have already been somewhat refined before even reaching the hands of the glassmaker. A glassmaker might buy his copper colorant in the form of copper sheets from his local coppersmith (Neri 1612), but the coppersmith may have obtained his ores from distant places, and he may have even mixed different ores together. Much of the material that has gone into glasses may be derived from mines which are now exhausted, so that samples from them will never be available for research.

Even if such samples were available, it may be doubted whether an extensive knowledge of ores would actually be very often helpful. The ores may have been refined beyond recognition before use in the glass. But in any case, when materials are placed in a glass their trace element patterns become "scrambled" with the trace element patterns of other ingredients. In favorable cases it may be possible to "unscramble" these patterns if suitable samples are available (many samples of glass of each color plus colorless from one factory site), but in other cases the fluctuations in trace elemental concentrations may be so great and the "scrambling" so intricate that the "unscrambling" cannot be accomplished with acceptable statistical certainty on the number of samples available.

It is possible that some glasses were made entirely from local ingredients, particularly in times and places where the glassmaker's occupation was rather undifferentiated from other occupations, or when a crude glass was all that was required. Examples include some glasses made in medieval Europe (Rademacher 1933), in the country of the Nupe in Nigeria (Passarge 1895 :470-472; Nadel 1942 :274-278), or in rural India (Dikshit 1969). In such situations trace element patterns may exist which it may be possible to show are attributable to the geochemical region in which the factory lies.

However, it seems unlikely that the glass beads found in African archaeological sites came from such primitive enterprises. Because ideal ingredients, particularly colorants, are not universally distributed, such primitive enterprises are often restricted to the manufacture of crudely fashioned items in only one or two colors. The bead assemblages found in Africa indicate much greater proficiency in the glassmaker's art than that. Moreover, these primitive enterprises are characterized by relative isolation from long distance trade routes. To some extent it may be their isolation which restricts them to local ingredients. It is simply not plausible that a distribution and marketing system which could get its beads hundreds of miles into Africa did not have opportunities for commerce in glassmakers' materials, and was not interested in buying its materials in the cheapest market.

Then, if glass cannot easily be tied to a geochemical or geographical region, one might ask if it can be tied to a cultural region, perhaps through consideration of styles and recipes. In a broad and imprecise way this can be done. For instance, one can say that as a rule of thumb potassium glasses are characteristic of medieval Europe. But we are interested in a more specific designation of origin than that.

The rule of thumb, that potassium glasses were made in medieval Europe, rests on no theory but on generalization from empirical data. If we are interested in rules-of-thumb for cultural regions more specific than "medieval Europe" then we shall require empirical data from more limited regions. Perhaps, after future comparative investigations, it may be possible to demonstrate cases of regionalism in custom and recipe, as well as in trace elements.

However, it is most necessary not to lose sight of two factors which counteract regionalism in glassmaking. Firstly, factories may have acted independently of one another in the procurement of ingredients and in the choice of methods, particularly if there were secrets to be guarded. Secondly, a factor which counteracts regionalism in glassmaking is the international character of this art.

In some respects glassmakers participated in a common body of knowledge akin to some international cult. They visited one another, copied one another, and attempted to learn each other's secrets. There are frequent accounts of rather large-scale migrations of glassmakers and their families, and to a large extent the occupation itself spread along family lines. The ingredients used in glass were objects of commerce. Because of the communication among glassmakers, styles and techniques were quick to spread. For example, patterns which have been discerned in the use of manganese and antimony (Sayre 1963) are international. Indeed it has been remarked that it is sometimes easier to judge the date of a piece than its place of manufacture.

A quest to name the origins may be complicated by the possibility that different stages of bead manufacture may have been carried out in different places. Around the beginning of the sixteenth century, canes made in Venice (from imported ingredients no doubt--for mines do not exist in Venice) were sent to "Germans" for formation into beads (Gasparetto 1958). An analogous situation existed in the twentieth century, when canes made in Venice were sent to Czechoslovakia for cutting and shaping (Pešatová n.d.). Other examples might be given (Newton 1971).

Another variable interposed between bead factory and archaeological site is the marketing system by which the bead arrived at the site. A host of middlemen may have complicated the situation in ways difficult to evaluate. For example, in the early twentieth century the Czechoslovakian firm of A. Sachse and Company was purchased by the Venetian firm now entitled Società Veneziana Conterie e Cristallerie (Pasquato 1953) and thereafter, beads made in Venice were sold under the name of the Sachse company (Lukaš 1970).

Another complication in a search for origins is the possibility that successful styles might be made by several factories, particularly if they were simple. This situation is observable in preserved nineteenth-century bead sample sets.

In sum, the specification of origin of a bead group requires empirical evidence from sources which have not yet been identified or investigated.

In any case, it depends on the nature of the research being attempted whether or not the "name and address" of origin of a bead is crucial information. Although useful information may be gained from specification of the source of a bead, it is important to keep source identification in proper perspective. The ultimate goal of the archaeologist is the elucidation of a history, in our case the history of trade with Africa. Identification of the place of manufacture of certain glass beads is a servant of our ultimate goal and is not itself the goal. Information pertaining to the history we seek may often be gained by other means. It is to such matters that we turn in the chapters to follow.

CHAPTER 2. A BACKGROUND ON GLASS

This chapter presents general information concerning glass and glass beads, so that the reader will have some background for the material to follow. We shall first discuss the ingredients of glass and their history, so that the reader will be able to place our chemical analyses into perspective. We then define our terms in a short discussion of bead nomenclature.

Glass Ingredients

Glass is considered to be a state of matter, rather than a particular substance. Morey (1954:28) defines a glass as

> ...an inorganic substance in a condition which is continuous with, and analogous to, the liquid state of that substance, but which, as a result of a reversible change in viscosity during cooling, has attained so high a degree of viscosity as to be for all practical purposes rigid.

Several different materials can exist in the glassy state. The present research is concerned only with man-made siliceous glass.

Man-made glass is a mixture of ingredients rather than a chemical compound. Therefore it has no single formula, and the proportions of its ingredients may vary. Nevertheless there are some general rules, which allow the ingredients of glass to be divided into the following three classes, designated by Roman numerals.

I. The basic ingredients are:

a. silica (SiO_2). In a conventional soda-lime glass SiO_2 may form about 60% of the glass by weight. This is obtained from siliceous rock or sand.

b. an ingredient which lowers the temperature of fusion of the silica. One or both of the alkalis Na_2O or K_2O, obtained from soda or potash respectively, serve this purpose. PbO also serves this purpose.

c. other ingredients which provide chemical stability or act as a flux, such as oxides of calcium or aluminum. Some major ingredients, often iron, may be considered impurities.

The most commonly-encountered glass composition is probably the soda-lime glass, which conventionally contains $\sim$ 60% SiO_2, $\sim$ 15% Na_2O, and $\sim$ 5% CaO.

Another commonly-encountered composition, with which we will be concerned, is the potassium glass, characterized by $\sim$ 15% K_2O rather than Na_2O as in the soda-lime glasses. Although one does not often see the term "potassium-lime" glasses, it is usual for potassium glasses to contain $\sim$ 5-20% CaO.

II. The glassmakers' additives.

In addition to the basic ingredients there exist the glassmakers' additives. These are added for an artistic or technical purpose, such as to color, to decolorize, to opacify, or to clarify. Certain elements have traditionally been used in these capacities for centuries, and they are discussed further below. When the additives are present in a high range of concentration, such as percent or tenths of percent, they may be considered to have been intentionally used. When present in a low range of concentration (parts per million), they may be considered unintentionally-included trace elements. Exceptions must be made, of course, in the case of additives which perform their desired function at a low concentration, such as cobalt, which gives a very dark blue when present only as a few hundred parts per million.

III. Trace elements.

A third class of ingredients is formed by the trace elements, or impurities. These are the elements present in low concentration (parts per million) over which presumably the glassmakers exerted no control.

Some scrap glass, or cullet, was and is almost always included in glass batches in order to aid vitrification. If imported, cullet may have introduced elements, including glassmakers' additives and trace elements, which might not have arrived in the glass otherwise, obscuring regional patterns.

Glassmakers of the past probably did not see their ingredients with our perspective--indeed modern chemistry did not exist before the eighteenth century. It has been said that glassmakers were not always aware that lime (CaO) is desirable for stability, but their ingredients were so impure that they put in sufficient lime unawares (Turner 1956a: 45-47; 1956c:277). Similarly, the fact that alkalis could be divided into tyo types, soda and potash, was not clearly understood until the eighteenth century (Turner 1956a:44T), although some had an inkling of it (Kunckel 1679). Our analysis and discussion are carried out in terms of pure elements, but it should not be thought that glassmakers used pure elements to make the glass. Indeed, some glassmakers may have been aware only of the silica, alkali, and additive, the latter two probably added as salts to the silica (sand). Only in the case of common metals, such as copper, might the glassmakers have added an ingredient as a fairly pure element.

It may be convenient to think of past glassmaking as a craft carried out according to a good deal of unwritten lore. Glassmakers were aiming at a result, not a chemical composition. Alchemist and glassmaker had much in common, and even today not every glassmaker's trick is understood according to modern chemical precepts.

The Additives

The glassmakers' additives responsible for coloring and opacity require further discussion. This subject is extensive, and the interested reader is referred to Weyl (1951) for further information. In order to understand most beads found in Africa, it is necessary to know only a few simple facts about the additives. Indeed up until the nineteenth and twentieth centuries the common conventional means of coloring glasses were very few, and these traditional methods are reviewed below.

Opaque red, also known as Indian red, sealing wax red, brick red, terra-cotta red, or oxblood red, is the range of color created by suspended particles of metallic copper and/or cuprite (Cu_2O) (Weyl 1951, Brill 1970). This range of color approximates No. 7.5R,3/6 on the Munsell scale (Munsell 1961).[1] Glasses of this color, viewed grossly, virtually always look opaque, but under magnification the red particles can be seen, in an often transparent matrix, if the specimen examined is a thin chip.

Blue-green results when copper is present as Cu^{++}. This color can range from about No. 2.5BG to No. 10BG on the Munsell scale, but it is typically around No. 7.5GB,6/8 on this scale. The same copper-containing

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[1] The Munsell system of color notation is described and explained in the work referenced, especially pages 13-24. It is also presented in Webster's Dictionary, 3rd edition, under "color". A useful and inexpensive color scale for the daily use of the investigation is known as the Nickerson Color Fan, available from the Munsell Color Company of Baltimore, Maryland.

glass will be Indian red if melted and cooled in a reducing atmosphere, and will be blue-green if melted and cooled in an oxidizing atmosphere.

Green is caused by Cu^{++} or by iron (Fe^{++} and Fe^{+++}). Iron impurities in glass commonly give a greenish color. The color from iron can range from brown to a bluish-green, but are typically near No. 10Y on the Munsell scale.

It is often desirable to remove the greenish tinge from glass, and for this purpose a decolorizer may be used. Until the twentieth century the chief decolorizers were manganese or antimony.

Besides serving as a decolorizer, manganese, as Mn^{+++}, is the agent used to achieve purple. This color may range from pink to brown, but it is typically about No. 7.5RP on the Munsell scale.

Cobalt blue, also known as royal blue if dark, and powder blue if light, about No. 7.5PB,3/11 and No. 5PB,6/8 respectively on the Munsell scale, is caused by cobalt. An experienced observer can usually easily discriminate a pale cobalt blue from a copper blue-green.

Opaque yellow is created from undissolved compounds of antimony and lead or of tin and lead. This color is about No. 2.5Y,8/12 on the Munsell scale. These same elements are also used to achieve opaque white.

Opaque orange (amber) glasses may be considered as yellow glasses which include zinc, as indicated in Chapters 5 and 7. The orange color is approximately No. 7.5YR,7/11 on the Munsell scale.

Black, upon close examination, usually consists of either exceedingly dark green, purple, or cobalt blue.

Horizons in the Use of Ingredients

A complete survey of the history of glass is not entirely appropriate here. Such surveys can easily be found in the literature (e.g., Honey 1946, Derry and Williams 1960, Turner 1956a,1956b,1956c). However, it is appropriate here to review, from the history of glass, that information which is useful for purposes of "diagnosing" the origin or affinities of glass artifacts. For example, the date of invention of a certain process may be important in estimating the date of beads which show evidence of that process. Therefore we shall review the horizons and landmarks of glass history up until approximately the nineteenth century, that seem relevant to this research, in order that the basis of our "diagnoses" may be clear to the reader.

Most glass ingredients are not diganostic of time and place of manufacture, but there are a few ingredients which are helpful in this regard. These are reviewed below.

Alkalis. Most ordinary glasses are soda-lime glasses containing a preponderance of sodium over potassium. Some potassium, however, usually appears in soda-lime glasses, and patterns of the use of potassium in ancient and very early medieval soda-lime glasses have been discerned (Sayre and Smith 1967). Soda-lime glasses are typical of the ancient Near East, the ancient Occident, the medieval Near East, and the modern world. Only medieval Europe is a well-known exception: here the potassium glass is typical.

The date of beginning of manufacture of potassium glass in medieval Europe is poorly known, but informed estimates place the onset in approximately the ninth to tenth centuries A.D. (Geilmann 1955:150; Chambon

1958:100; Turner 1956c:288T; Sayre and Smith 1967:279). During the centuries after the Renaissance, potassium glass gradually ceased to be used generally, but continued to be used for certain specialized types of glass, including luxury and utilitarian types (Honey 1946). Its use for utilitarian objects, such as bottles, persisted well into the colonial period (Honey 1946). Although potassium glasses are chiefly associated with medieval and modern Europe, they cannot be restricted to this time and place. For example, they are known from the U.S.S.R. (Besborodov and Zadneprovsky 1967) and a specimen presumably made in China in Han times was found to be potassium glass upon analysis in our laboratory (in preparation).

Opacifiers and Decolorants. Antimony was used both as a decolorant and as an opacifier in glasses from the second millennium B.C. until the fourth to fifth centuries A.D., after which time it dropped out of use (Sayre 1963, 1964). Its use as a decolorant may have persisted until the end of Sassanid times in Persia (Sayre 1963), and it very occasionally occurs as an opacifier in medieval specimens in combination with a tin opacifier (Turner and Rooksby 1962). The common use of antimony reappeared around the seventeenth century A.D. (Turner and Rooksby 1962, Neri 1612, Kunckel 1679), and it is commonly used today. Thus, antimony was out of use from about the fifth to seventeenth centuries A.D.

Presumably antimony opacifiers were replaced by tin opacifiers when antimony went out of use in about the fifth century A.D., but evidence for the use of tin opacifiers is scant. They are not thought to occur earlier than the fourth to fifth centuries A.D. (Sayre 1963, Sayre and Smith 1967), but our Chapter 7, Part 2, mentions some possible exceptions to this generalization in India. Tin is found in occasional medieval specimens (Turner and Rooksby 1962), and is rather well-attested after the fourteenth century A.D. (Turner and Rooksby 1962, Neri 1612, Frothingham 1956). It did not drop out of use when antimony was rediscovered around the seventeenth century A.D.

The use of manganese as a decolorant was introduced in Roman times (Sayre 1963) before antimony had gone out of use. Both were used for a few centuries. Manganese remained in use after antimony disappeared, and it has remained in use ever since.

Arsenic received its first undoubted literary references in the seventeenth century A.D. (Neri 1612, Kunckel 1679), and came into considerable use in the eighteenth century as an opacifier (Turner and Rooksby 1962). A possible Assyrian reference to arsenic has been discounted by Turner (1956b:179T) because of difficulties in translation, and because arsenic has not been found in analyzed specimens of ancient or medieval glasses except in cobalt-containing glasses where it may have been associated with the cobalt.

Barium in amounts greater than tenths of percent as the oxide has sometimes been thought to be diagnostic of ancient (pre-Han and Han) Chinese glass (Ritchie 1937:219). Its occurrence in glass beads found at Lo Yang is well known (Seligmann 1937). However, high amounts are also found in glass of medieval European cathedral windows (work in preparation) and glass from Tripuri (Dikshit 1969). Therefore high amounts of barium cannot be considered diagnostic of Chinese manufacture, as some have thought (Seligmann (1937). It has been used in modern glass since 1829 (Turner 1956a: 48T).

Boron is best known today as a constituent of modern laboratory and kitchen glassware which can withstand sudden and extreme temperature changes. Its mention by Kunckel (1679) is usually considered the earliest evidence of its use, but there is a thirteenth-century Chinese mention of borax, as a substance used in the Middle East to make an elastic glass (Hirth and Rockhill 1912:227). Glass from Aphrodisias, a factory site in Turkey, shows close to 1% B_2O_3 (Brill 1968:52).

Aventurrine, not an ingredient but a special effect, was invented in the seventeenth century A.D. in Murano (Zecchin 1955:63). In this glass, small flakes of copper are dispersed which can be seen with the unaided eye and which give the glass a specular appearance. Aventurrine is commonly used in beads and trinkets. It is said that the Bohemians discovered how to make it in 1887 (Urban n.d.).

Bead Terminology

The modern name for mass-produced glass beads is the collective noun "conterie". Its first known appearance in a glass context (Zecchin 1955, 1964) is in some correspondence dating to the period 1601-1611 between the Portuguese Emanuel Ximenes and the Italian Antonio Neri. The latter is considered the father of modern glassmaking and author of the first modern text of glassmaking, L'Arte Vetraria, first published in 1612. The term conteria appears in Neri's book.

The meaning of this term was not understood by Merret, who translated Neri's book into English (1662). The historical implications of his mistake are discussed by Zecchin (1964).

During the century or so preceding Neri, the word, conta, for bead(s), was used in numerous Portuguese documents and accounts (e.g., Lobato 1960, Pigafetta c. 1589). Thus one might speculate that the word conteria may have entered the Italian language from the Portuguese. All during the sixteenth century the Portuguese purchased glass beads, sometimes Venetian (e.g., Lobato 1960), and many opportunities may have arisen for such a linguistic borrowing to have taken place.

In its original meaning in Portuguese, conta, meant "count" or "account". Such a meaning may easily be transferred to beads, which were often used as currency by diverse peoples, particularly during the period of exploration and discovery.

The referent of the term "conterie" has changed since the term was first used. In the letters of Ximenes it referred to large cane beads (defined below), probably not reheated, or if so, probably reheated individually on a spit and not by tumbling in pans or barrels. To the eighteenth-century encyclopedist Savary des Bruslons it meant "large" trade beads (Savary des Bruslons 1723:I, col. 1481-2). To the nineteenth-century Bussolin (1842) it meant all trade beads except margarite and beads made a lume (Zecchin 1955:91). Margarite is another term whose meaning has changed over centuries, but to Bussolin it meant quite small cane beads used for embroidery. Beads made a lume are those which are wound and/or individually decorated a lume, that is, at the glassmakers lamp, or flame. At present the term "conterie" includes all these varieties of glass beads.

Descriptive Terminology

The beads of this report are described according to the system of Beck (1928) as simplified by Chittick (1967). The descriptions indicate method of manufacture, dimensions, shape, and color. No discrimination is made among discs, short barrels, or short cylinders.

The Beck report does not deal at length with method of manufacture, but these processes have been frequently described elsewhere in the literature (van der Sleen 1958, 1967; Harris and Harris 1967, Zecchin 1955, Gasparetto 1958, and others). The two methods most commonly encountered in African beads are the "cane" and "wound" methods.

In the cane method, the iron blowpipe is dipped into the molten glass and a "gather" of glass obtained on the end. The gather is blown to form a hollow ball. The end opposite the blowpipe is then attached to an iron rod (a "puntil"), and the hollow ball is pulled to form a long hollow tube, known as a cane. The cane, after cooling, is broken into segments which constitute the beads. The beads may be reheated to round off the sharp edges, or they may be left sharp. In Neri's day, if one may judge by his vocabulary (see Zecchin 1955:81-99), beads were reheated by manual stirring in shallow pans held over a fire. In Bussolin's time (1842) beads were reheated by tumbling in large barrels suspended over a fire (see Zecchin 1955:81-99). This method is still in use in Murano (Venice) today, where the author observed it in 1969. The difference between the two methods may give some indication of the relative amounts of beads which may have been produced in the nineteenth century compared with the early seventeenth.

In the wound method, a solid rod of glass is wound around an iron rod called a "mandrel" like thread on a spool, thus constituting the bead. When cool, the bead may be slipped off the mandrel.

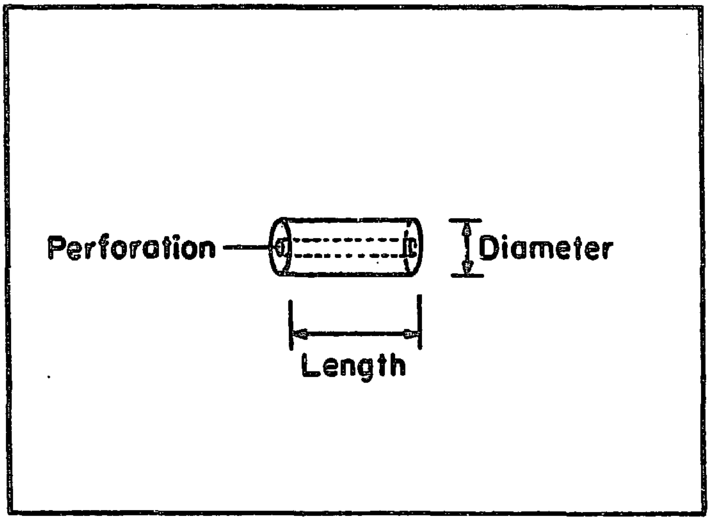
Less commonly encountered in Africa are beads made in various kinds of molds.

Figure 2 diagrams the measured dimensions of a bead. The length measured is ordinarily that of the performation, and the diameter is the maximum, except that imperfections should be avoided.

Figure 3 diagrams some shapes of beads. The shapes are idealizations to which few beads correspond perfectly, since they are not precision-made. Reheated cane beads in particular are quite variable with respect to the exact conformation of their ends, since their shape depends on the rounding-off of an accidental geometry. In general, any shape can occur in any size.

In a chemical taxonomy the exact size of a glass bead is not of major importance. Generally the manufacturers make the beads first and sort them into size ranges later, by means of sieves. Therefore approximate designations of size are sufficient for ordinary purposes. The size ranges we have distinguished are "extra large", "large", "medium", "small", and "minute". Extra large beads are those which are trapped in a Tyler Standard Screen Scale U.S. No. 3. Large beads are trapped in No. 4, medium in No. 7, and small in No. 16. Beads which pass through No. 16 are minute. For a general comparison, a walnut is extra large, a garden pea is large, a coriander seed is medium, a sesame seed is small, and a poppy seed is minute. In practice we usually judge the size of beads by eye and not by sieving.

All destroyed beads were precisely measured to the nearest millimeter, except in cases of samples judged to be alike on account of mass-production. In such cases a few typical specimens were measured.



XBL714-3286

Figure 2. Diagram of a bead.

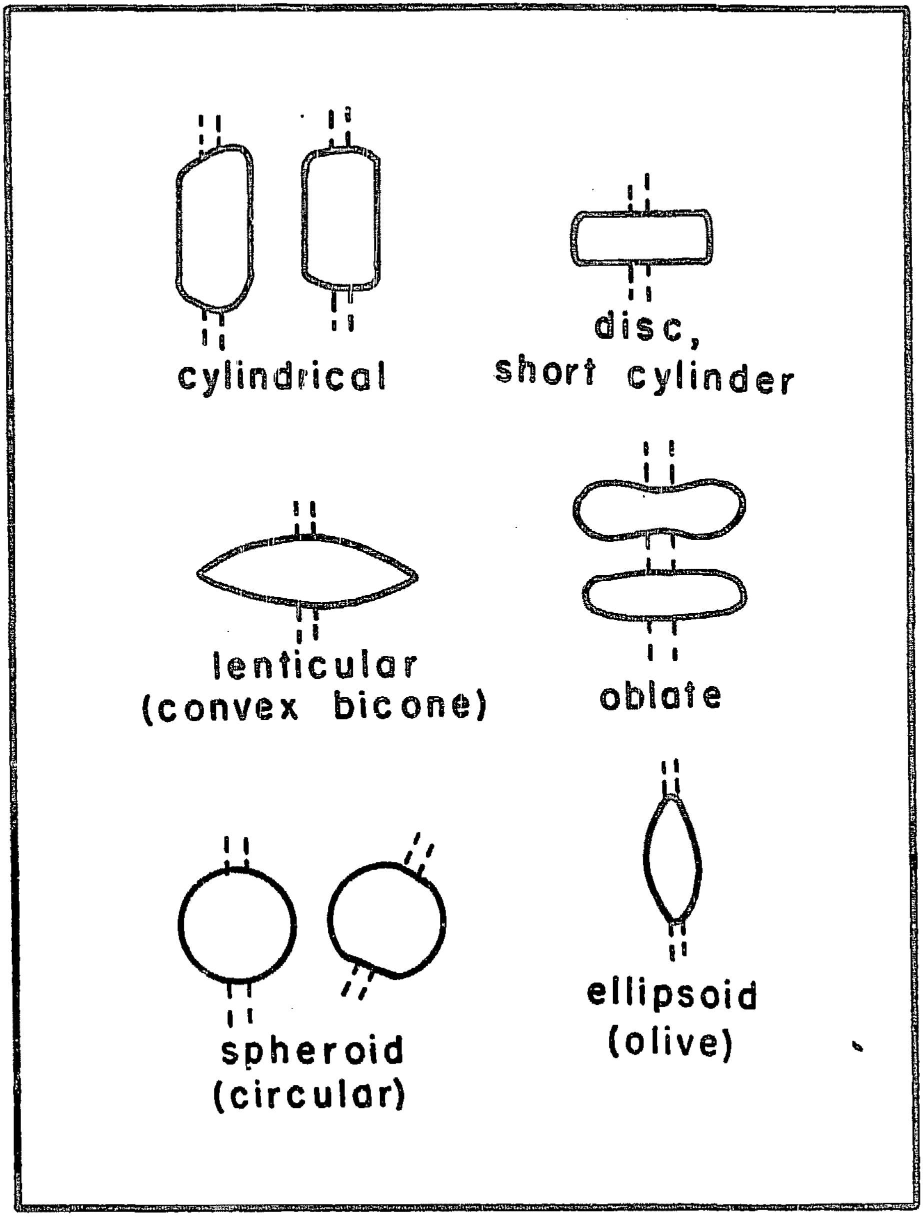


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Figure 3. Common bead shapes, by profile. All display circular perimeter (not shown).

Structural Aspects of Coloring

A glass bead may be monochrome or polychrome. The first case is self-explanatory. The second case may be layered, striped, or decorated.

A layered, or "flashed", bead, most often a cane bead, has one or more outer coats, each one monochrome, over an inner core, usually of another color. Common forms of this type are "Indian red over green", or "clear red over opaque white".

Striped beads are akin to the layered, insofar as the stripes may be regarded as a discontinuous layer.

In mass production stripes and outer layers were usually placed on the gather before it is drawn out into a cane, and thus the layers and stripes stay with this type of bead throughout its manufacture.

A decorated bead exhibits designs which have been applied by hand to the individual bead _a lume_. Decorated beads, as found in Africa, are frequently wound and usually polychrome.

This research has concentrated on monochrome cane beads.

PART II. METHODS

CHAPTER 3. METHODS OF ANALYSIS

This report presents the results of neutron activation analysis. This method of analysis of archaeological ceramics has been described in detail by Perlman and Asaro (1969).

In the present context a brief explanation of the technique may be helpful. Each bead is analyzed individually. The bead, or bead fragment, is ground and mixed with cellulose and silicon dioxide or silicon metal. It is pressed in a die to form a disc-shaped pill. This pill, along with others, is subjected to two neutron bombardments in the nuclear reactor of the Nuclear Engineering Department of the University of California at Berkeley, and the resulting gamma radiations are detected in the Lawrence Berkeley Laboratory of the same University. The first bombardment is brief, and the pills are analyzed immediately afterward for short-lived radioactive isotopes. The second bombardment is intense and lasts for eight hours. After it, the pills are set aside for a few days, then analyzed for medium-lived isotopes, set aside again, and later analyzed for long-lived isotopes.

The data from the analyses are put directly onto magnetic tape. Computer programs read the data from the tape and calculate the relative abundances of the elements detected in the sample. The results can be presented in several ways, but usually they are printed on paper, while the gamma-ray spectra are printed on microfilm for reference and permanent storage. The data on magnetic tape is permanently stored.

The elements are detected from their characteristic gamma radiations, represented as peaks on a gamma-ray spectrum (Figure 4). The magnitude of the peak indicates the abundance (amount) of the element. For

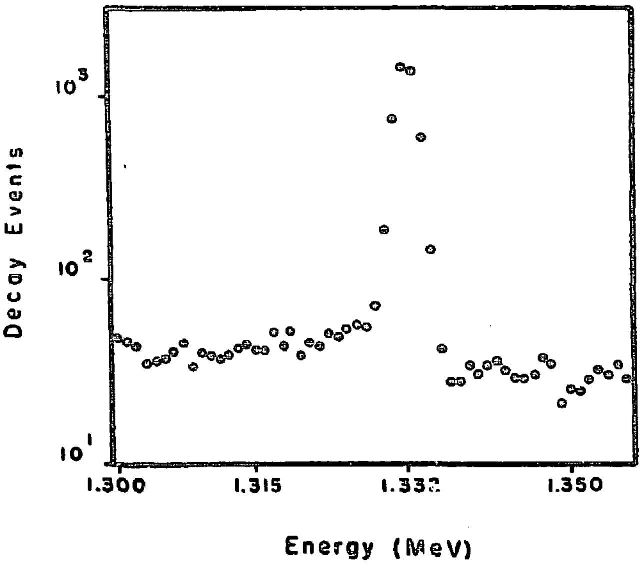
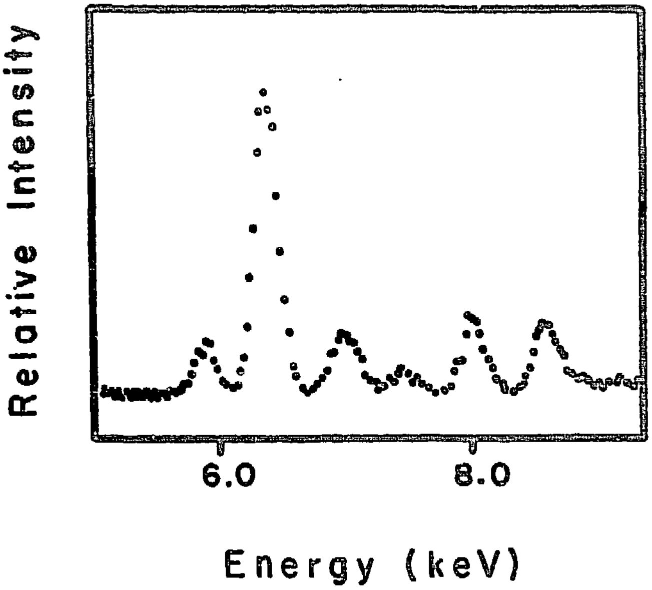


Figure 4. Segment of a gamma-ray spectrum.



XBL 721-84

Figure 5. Segment of an X-ray spectrum.

every element, factors which enter the calculation of its abundance in the sample include: the net number of detected decay events in the gamma-ray peak(s) belonging to the element, the gamma-ray abundance (or, the probability that the gamma ray will be emitted), the efficiency of the detector, the neutron flux during bombardment, the element's cross-section for neutrons (or, the probability that a neutron will be absorbed in the elemental nucleus), the duration of bombardment, the time elapsed since bombardment, the duration of the detection period, the half-life of the element, and the weight of the sample. With appropriate standards several of the above factors cancel out. Complications can occur when radiations from different sources have a similar energy, but these complications can be recognized and corrected for.

The accuracy of the method rests largely on the use of standards. One important standard is known as "standard pottery", developed and calibrated to include the elements normally encountered in pottery at appropriate concentrations (Perlman and Asaro 1969). This standard is appropriate for man-made glass as well, since glass contains many of the ingredients found in pottery.

The results of neutron activation analysis are supplemented by results of non-destructive X-ray fluorescence analysis. This is the only method by which lead was analyzed for all the specimens. The method has been described by Bowman et al. (1966, 1970). In this technique, X-rays of variable known energy are directed at the sample. These X-rays stimulate X-ray emission from the elements contained in the sample. The emitted X-rays are detected, and are used to identify the elements present and calculate the amount of each (Figure 5). Again, the accuracy of the results rests on the use of standards of known composition.

Types of Errors

Counting Error. This is the error given after each determination of an element by neutron activation. Radioactive decay events occurring in the irradiated samples are, obviously, counted by our equipment or we would not be able to tell the amount of an element present. The statistical error in counting is given by the square root of the total number of counts detected. Clearly the counting error is a minimum error, and it does not consider other sources of experimental error which may combine to make the true error larger than the counting error. The counting error represents the precision of the elemental determination.

Root Mean Square Deviation. This error, abbreviated RMSD, is also known as the standard deviation. In all manipulations of activation analysis data, the RMSD is consistently calculated as

$$\mathrm{RMSD} = \sqrt{\frac{(\bar{X} - X_1)^2 + (\bar{X} - X_2)^2 + (\bar{X} - X_3)^2, \ldots, (\bar{X} - X_n)^2}{n - 1}}$$

where X_1, X_2, $X_3, \ldots, X_n$ are the values being averaged, $\bar{X}$ is their mean, and n is the number of samples being averaged. In suitable cases the standard deviation of the mean (standard error) is used. It is calculated as $\frac{\sigma}{\sqrt{n}}$, where σ is the RMSD of the sample and n is the number of items in the sample.

The error given with the results of X-ray fluorescence is not a simple counting error, but is a standard deviation taking into account all anticipated experimental errors.

Choice of Elements

The elements presented in the tables differ from group to group, that is, from table to table. The reasons for these differences arise from the following three considerations.

Precision. The analytical tables present the results of neutron activation analysis of all elements precisely determined. The definition of precision which was adopted for consistent use is as follows. If, within a set of results relevant to a particular investigation, such as the heirloom bead investigation of Chapter 6, the counting error for a particular element is greater than 20% of the concentration in one-third or more of the samples, then that element is considered imprecisely-determined. This situation is almost always the result of an elemental concentration near or below the lower limit of detection by our method. The actual identity of these elements varies from group to group; these imprecisely-determined elements are presented in the notes to each of the tables.

The Lanthanide Series. In addition, it is desirable to avoid over-representation from the lanthanide series of elements (the rare earths, or those elements from lanthanum to lutetium inclusive in the periodic table), because these elements tend to show common "behavior" in their occurrence. Therefore, when comparisons are drawn up as in Figure 6, only two elements from the lanthanide series are included. The two chosen are those two precisely-determined elements which are furthest apart in atomic weight. The actual identity of these varies from group to group.

The Glassmakers' Additives. When comparisons among our samples are made that cross-cut color categories, such as in Figure 6, the colorants are left out of the comparison. This does not mean that they have not been considered. The colorants and other additives are considered at the time of group formation. The use of the glassmakers' additives must show a consistent pattern for specimens to be placed in the same group. For example, if a group contains specimens opacified with tin, then an antimony-opacified sample would not be admitted into the group.

Sample Designation

A straightforward naming method was adopted to reflect the provenience and identity of the samples in a name which would be brief, informative, and unique for each sample. The first three characters of the sample name refer to the site or source and usually consist of the first three letters of the site name. The following characters refer to identifying traits, such as particular localities on a site. Such characters may be omitted. Lastly are ordinal designations.

For example, a bead from Skeleton 26 at Bambandyanalo would receive the sample name BAM-S26. If more than one bead were analyzed from that skeleton, they may be named BAM-S26a, BAM-S26b, BAM-S26c, etc. Further subdivision may occur, e.g., BAM-S26a1, BAM-S26a2, BAM-S26a3, etc. To take another example, a bead of Type L3 from Igbo Ukwu would receive the designation of IGB-L3. If more than one were analyzed, the designations would be IGB-L3a, IGB-L3b, IGB-L3c, etc. The usual policy was to adopt the labels or other designations given to the beads by the excavator.

Sample Grouping

How are glass beads placed in a taxonomic group together? There are no rigid rules for this. Each chemical group must be approached as a unique thing. Chemical criteria are paramount, but visual criteria come into play. If the process of group formation must be summed up in one word, that word would be "judgment".

As a first approximation, a bead grouping is suggested chiefly by visual similarity, from the point of view of manufacture, and by evidence of approximate contemporaneity. Very often such tentative bead groups correspond to glass bead assemblages recognized in the literature, such as the "Mapungubwe oblates". There must be an initial judgment of this sort, or there would be nothing from which multiple samples could be taken.

Clearly a circularity in reasoning can occur if samples are taken from an already visually-recognized assemblage and then are later "found" to form a chemical group. However, in practice it frequently turns out that samples originally analyzed as members of a visually recognizable group are split up into different chemical groups after analysis. We are not the slaves of our first approximations.

As a rule of thumb, a chemical group must display likenesses in major ingredients, in the pattern of occurrence of glassmakers' additives, in trace elements, particularly in peculiarities in trace elements; and it must be distinct from all other such groups. In general, a glass group displays considerable scatter in the composition of samples which belong to it. This scatter is represented by the RMSD. The likenesses required by our rule of thumb are not blindly searched for, but are searched for in the form of a central tendency in a group. Allowance is made for scatter. Despite the scatter within groups, that is, the rather large RMSD's for each elemental average, we are able to recognize a number of mutually exclusive groups.

When a group is resolved, or proposed, it is then possible to compare a bead against it to see whether the single bead might match the group. In this process of comparison we have adopted the following criteria of matching. The single bead must be the same type of glass as the group (e.g., soda-lime glass, potash glass, or other), and the elemental concentrations of the single bead must fall within one standard deviation of the mean elemental concentrations of the group for two-thirds or more of the elements. The remaining elements must show similarity to the group.

For example, the garden roller bead designated BAM-P18a (from Bambandyanalo, Pit 18, our sample a) may be compared against the Group of M_1 beads (Chapter 5). The garden roller and the M_1 beads are soda-lime glasses with similar concentrations of the major glass ingredients. The elemental concentrations of BAM-P18a agree with those of the M_1 group within one standard deviation for the following elements, as may be seen from Figure 8 and Table 4: Al, Mn, Na, Cu, Sm, Co, Sc, Fe, Yb, Ta, Sb, Sn, Th, and Hf.

In addition, the remaining elements are similar and show no evidence that would render absurd the statement that BAM-P18a matches the M_1 group. Thus, by the criteria we have adopted, the bead BAM-P18a matches the group of M_1 beads. Material from this site is discussed in Chapter 5.

It is probably a truism to point out that in comparisons the classificatory level of the groups under study plays an important role. If a chemical group is exceedingly general and broad, then very many glasses will match it. If a group could consist of only one sample, then very little else would match it. In comparisons of this sort it is important to consider classificatory levels relevant to the problem under investigation.

Let us now turn to some investigations.

PART III. RESULTS AND DISCUSSIONS

CHAPTER 4. INTRODUCTION TO AFRICAN GLASS BEADS

Glass beads are found in sub-Saharan African archaeological sites of the past two millennia, chiefly the second millennium A.D. Sites and beads of this entire time span are of interest to archaeologists, although material from the nineteenth and twentieth centuries is usually omitted from archaeological consideration. The glass beads found in African archaeological sites are considered to have been brought to Africa by foreign traders.

In the study of African glass beads the main issue of interest has been, and is, the origins of the beads. This is of interest, not for any intrinsic value of the beads, but for the light which it may shed on African history and archaeology, as we stated in our opening chapter. Ultimately, a knowledge of the origins of the beads may shed light on trade routes to and within Africa, and it may help to date bead-containing sites. However, as pointed out before, little actual ground has been gained in pursuit of these ultimate goals. The present research was carried out in an attempt to initiate a classification of the beads which may reflect their origins and aid in the identification of these origins.

We have investigated problems which are somewhat unrelated to one another. Therefore the particular problems investigated are introduced and presented separately in Chapters 6 through 9, with a summarizing survey in Chapter 10. At the present time a brief general introduction is offered.

It has been said that sub-Saharan Africa is separated from the rest of the world by two seas: the sea of salt water that surrounds its coasts, and the sea of sand which forms the Sahara. For centuries traders have crossed these seas despite the distance, since the value of the goods exchanged made their impressive journeys worthwhile. Gold was a frequent item of trade, as well as ivory, leopard skins, slaves, and other things. In return, traders brought items needed or desired by Africans, such as salt, cloth, and the glass beads under study in this investigation.

For many centuries the only two "shores" which sub-Saharan Africa presented to traders were the southern edge of the Sahara and the east coast, facing the Indian Ocean. To the medieval Arabs, the zone south of the Sahara was known as <u>bilad es Sudan</u>, "the land of the blacks", while the east coast was known as <u>bahr el Zanj</u>, "the coast of the blacks". These names live on in "Sudan" and "Zanzibar".

It is not thought that regular andfrequent trade crossed the Sahara in ancient times, but the stage may have been set in Roman times by the introduction of the camel (Bovill 1958). It is usually thought that the important trans-Saharan trade grew up in the medieval or Islamic period, probably linked with the rise of far-reaching Arab commerce in North Africa (Bovill 1958, Mauny 1961, and others). Islamic kingdoms grew up at the southern termini of this trade (Bovill 1958).

After the Portuguese exploration of the Atlantic coast of Africa in the fifteenth century, traders began visiting West Africa by sea, and the medieval Saharan routes were gradually eclipsed in favor of sea routes in the sixteenth and subsequent centuries.

In East Africa, sea commerce existed by the time of the <u>Periplus of the Erythraean Sea</u> (Schoff 1912), a work of the first or second century A.D., describing navigation and trade in the Red Sea and beyond. At that time, trade with the East African coast was dominated by South Arabians, who in turn were dominated by the South Arabian kingdom of Himyar (Mathew

1963:95; Schoff 1912:28, 30, 34, 96, 106, 109). Afterwards, the power and influence are thought to have shifted to yet another kingdom of South Arabian ancestry, this one located in Ethiopia: the kingdom of Axum. This kingdom is thought to have dominated South Arabia and the trade to East Africa from about the third to the seventh centuries A.D. (Schoff 1912:63, 96, 103; Freeman-Grenville 1962:5). However, pertinent documented archaeological evidence from such early times in northeastern Africa is lacking.

The chief period of expansion of the trade to East Africa, as in West Africa, corresponds to the Islamic era (see Chittick 1965, Mauny 1961, Freeman-Grenville 1962). Beginning in the ninth to tenth centuries A.D., traders established entrepôt towns on the East African coast, where a number of mosques were built in stone. To this day inhabitants of the Arab-influenced coastal strip profess Islam and speak a language containing much Arabic vocabulary, although African in structure (Swahili).

There are a very few glass beads in sub-Saharan Africa which may antedate this medieval period. The earliest glass beads known are some dozen which belong to the Early Iron Age in Southeast Africa (Summers 1967), an industrial complex associated with radiocarbon dates ranging from the second to tenth centuries A.D. (Summers 1967). These beads are very few, and their significance is hard to weigh. In the present research we have concentrated on beads which exist in larger numbers, such as the hundreds or thousands. Once these beads are understood, it may be possible to form an understanding of the rare earlier beads.

Previous Investigations

Previous literature on African glass beads is very fragmented. Past reports have usually been rather straight-forward descriptions of beads and have usually been organized around specific sites or specific sets of beads. Even the longer articles are subdivided in this manner, so that, while they are comprehensive, they are not general (Beck 1931, 1937; Schofield 1938, 1942, 1958).

The important comprehensive treatments of the subject are those of Schofield (1938, 1942, 1958). He divided the beads found in archaeological sites in Southern Africa into three Series (1938, 1942). Later these Series names were dropped, but the concepts remained intact in his work (1958). The First Series largely corresponds to our Mapungubwe oblate group (Chapter 6). The Second Series no longer has integrity as a grouping. It is difficult to know exactly which beads Schofield included in his Second Series, but it probably corresponded in part to trade wind beads (Chapter 7) of small size. The Third Series corresponds to eighteenth and nineteenth century beads not the subject of this investigation.

Aside from the three Series, Schofield distinguished a variety of other sets of beads, such as ancestral beads, beads of the East Coast, beads of Malawi, and beads of the Zulu. These various sets and Series were never satisfactorily related to one another in his work, and indeed they were defined by different criteria: sometimes by use, sometimes by geography, sometimes by appearance.

Other authors have addressed particular subjects in African bead archaeology, such as van Riet Lowe on beads of Mapungubwe (1955) or on heirloom beads (1937), Robinson on beads of Zimbabwe (1961), Shaw on beads of

Igbo Ukwu (1971) and many others. Schofield (1938, 1942, 1943, 1958), Beck (1931), Laidler (1934), and van Riet Lowe (1955) all gave accounts of documentary mentions of beads with respect to Southern Africa.

These particularistic studies, and others, are treated in the appropriate chapters below, where we present summaries of the literature as relevant to the problems we investigated. A general classification, for further testing, is proposed in Chapter 10.

A persistent feature of the African bead literature has been attempts to identify beads known archaeologically with beads known from documents. Such a procedure can rarely yield defensible identifications because the documentary descriptions are ambiguous and incomplete. Moreover, it is rare that, solely on the basis of archaeological evidence, beads can be placed in contexts plausibly relevant to the documents.

If, for example, we should find by some means that the M_1 beads of Bambandyanalo belong to the early sixteenth century (!), only *then* would it be proper to ask whether they may be identified with blue transparent (*cristalina*) glass beads of Venice mentioned in Portuguese documents from Sofala of the period 1498-1508 A.D. (Lobato 1960:45) and only *then* would it be proper to ask if the approximately eight million beads which van Riet Lowe (1955:3) estimated were imported into Africa from Sofala during just one sample year, 1508-1509, might have something to do with the millions of beads at Mapungubwe.

CHAPTER 5. MAPUNGUBWE AND BAMBANDYANALO

Introduction

The closely neighboring sites of Bambandyanalo (K_2) and Mapungubwe lie in the Limpopo River valley of the Republic of South Africa (Figure 11, Chapter 7). Discovered and excavated in the 1930's, the sites are described by Fouché (1937), Gardner (1963), Fagan (1964), and others. Excavations presently being carried out may fill in some of the remaining gaps in our knowledge of these two related sites.

Mapungubwe is situated on a hilltop, while Bambandayanalo lies at its foot about a kilometer away. On the basis of stratigraphy, artifact content, human skeletal morphology, and radiocarbon dating, Bambandyanalo is thought to be akin to the Rhodesian Iron Age Industry Leopard's Kopje, phase 2 (Robinson 1966, Summers 1967) and to correspond more or less to Zimbabwe phase 2 (Period II). The major, or rich, habitation at Mapungubwe is thought to correspond to Leopard's Kopje phase 3 and to Zimbabwe phases 3 (Period III) and 4 (Period IV), but more especially to phase 3 if we may judge by the beads. Evidence for phase 4 at Zimbabwe itself is quite thin. Thus, Bambandyanalo pre-dates Mapungubwe.

A radiocarbon date from "Beast Burial"[2] No. 6 (B.4, S.6) at Bambandyanalo gave the result 1050 ± 65 A.D. (Y-135-17) (Fagan, 1964 and 1965), and the corresponding phase 2 at Zimbabwe is thought to date between 330 ± 150 A.D. (M-193, Summers et al. 1961) and 1075 ± 150 A.D. (M-914, Fagan 1965). For brevity, these first and third dates immediately above are referred to below as the "eleventh century" dates, although it is

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[2] The so-called beast burials are human burials containing fragments of bovids.

emphasized that the dates actually span approximately the early tenth to early thirteenth centuries in one case (M-914) and the late tenth to early twelfth centuries in the other case (Y-135-17). These "eleventh century" dates mark the border, or transition, between phases 2 and 3, both in the Limpopo River valley sequence under discussion, and at Zimbabwe.

The radiocarbon dates associated with the major habitation at Mapungubwe are 1420 ± 60 A.D. (Y-135-9, Fagan 1965) and 1380 ± 50 A.D. (Y-135-64, Fagan 1965). At Zimbabwe the corresponding phase 3 is "framed" by radiocarbon dates of 1075 ± 150 A.D. (M-914, Fagan 1965) and 1440 ± 150 A.D. (M-915, Fagan 1965). An additional date, stratigraphically between M-914 and M-915, gave a consistent result, 1390 ± 90 A.D. (SR-47, Phillipson 1970). These dates are consistent with others obtained for the Iron Age in southern Africa; and we shall return to the subject of radiocarbon dates below.

Part 1. Mapungubwe

Description of Beads

Mapungubwe is said to have yielded millions of glass beads, clearly mass-produced. Prominent among beads from that site is a series of small cane beads which has come to be known as the Mapungubwe oblate series. These beads are typically oblate, and we shall sometimes call the series the "oblates", but cylindrical forms do occur. The beads are about 1-4 mm in length and 3-6 mm in diameter. Extremely numerous, filling numerous jars and boxes, they occur in the common colors of glass, particularly in blue-green, green, yellow, dull orange (amber), black, and cobalt blue. Indian red is rare or absent. Clear colorless has been observed by the author in rare cases. The Munsell equivalents for the colors are:

blue-green, No. 5BG,6/7; yellow, No. 5Y,7/10; orange, No. 10YR,5/6; cobalt blue, No. 7.5PB,3/11; and green, No. 5GY,5/6.

This series of small beads, mostly oblate but with a small percentage of cylindrical beads, is visually indistinguishable from a series found in phase 3 at Zimbabwe (Test I, layers 10-14, Robinson, 1961a), a fact which has been previously noted (Robinson, 1961b). In part of what follows we provisionally assume that the series found at Zimbabwe is "the same" as that found at Mapungubwe whence came all our samples. The results of X-ray fluorescence analysis of beads from this series from Mapungubwe and Zimbabwe, presented in Table 1, are entirely consistent with this assumption. With this assumption it is possible to allow information from Zimbabwe to add to the small amount of satisfactory information available from Mapungubwe, and to elucidate the historical picture barely visible at Mapungubwe alone.

Plates I and IIillustrate the oblates under discussion. In Plate I, beads from Mapungubwe, Skeleton 14,[3] are shown adjacent to beads from Renders Ruin[4] at Zimbabwe. These beads from Renders Ruin are the "larger oblates...matched by those from the [Mapungubwe] Grave area" (Schofield 1958:202). The appearance of these beads is like that of phase 3 oblates from the 1958 excavations of Summers and Robinson, except that many samples from the 1958 excavations are smaller than those in the photograph in Plate I. Examples from the 1958 excavation are shown in Plate II.

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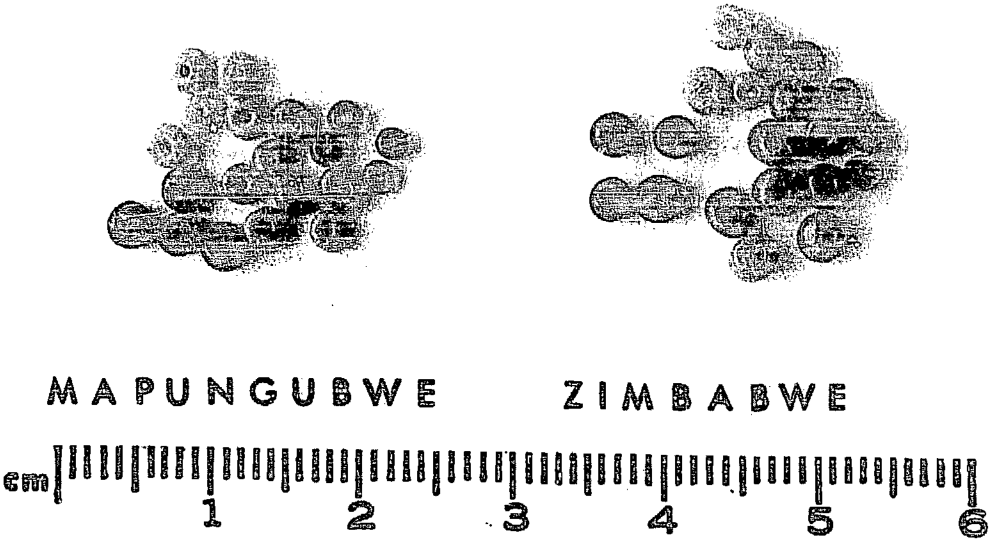
[3] Burial 14 is described in Fouché 1937:126, 149-151, and its location is shown on a map following p. 183.

[4] The Renders Ruin excavation was carried out in 1943 by Goodall. The circumstances of the recovery of the beads are described by Schofield (1958).



CBB 718-3676

Plate I. Beads of Mapungubwe and Zimbabwe.

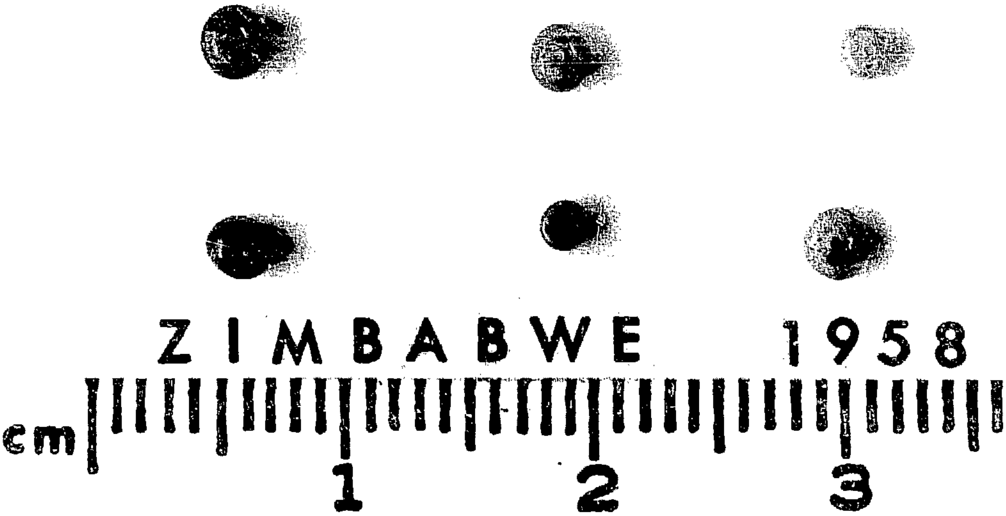


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Plate II. Beads of Zimbabwe, 1958 Excavations.

It has previously been noted that there existed at Bambandyanalo beads which resembled the Mapungubwe oblates (van Riet Lowe 1955, Schofield 1958, Gardner 1963). A number of these beads from Bambandyanalo were analyzed in order to test this observed resemblance.

Results

Results of X-ray fluorescence analysis of a number of beads from the Mapungubwe oblate series, as recognized visually, are presented in Table 1. The beads came from Skeleton 14 at Mapungubwe, the excavations of 1958 on the Zimbabwe Acropolis, and the excavations of 1943 at Renders Ruins at Zimbabwe. Further details of provenience are given in the Table. (These sites, particularly the last, yielded other kinds of beads which do not concern us here.) The results of X-ray fluorescence are not comprehensive enough to prove that the beads of Mapungubwe and Zimbabwe "match" each other, but the results are consistent with this judgment.

Nineteen samples from Mapungubwe, all from Skeleton 14, were subjected to neutron activation analysis, the results of which are presented in Table 2b. Table 2c gives one bead from the Mjelele Valley burial of Rhodesia (see Chapter 6).

An estimate of the Pb content of the beads, by color, is given in the notes to Table 2. This estimate was reached by X-ray fluorescence analysis of grouped samples of oblate beads from Skeleton 14 at Mapungubwe, not necessarily the same samples that received neutron activation analysis.

Discussion

The Mapungubwe Chemical Group. It is apparent from Table 2a that chemical resemblances exist among the beads analyzed from Skeleton 14 at Mapungubwe. These resemblances are sufficiently strong that we consider these Mapungubwe beads to form a group sharing a common origin. We designate this group the Mapungubwe Chemical Group I.

We shall use the term "chemical" when referring to our chemical group, and "oblate" when referring to the visually-distinguished series of beads. Again, we note that the term "oblate" is an heuristic short name; the series includes beads of a cylindrical shape, and likewise the chemical group does also (see Tables 1 and 2).

Some characteristics of the Mapungubwe Chemical Group are as follows. The beads are made from a soda-lime glass, occurring in different colors. The colorants and additives in use are manganese, copper, zinc, tin, lead and probably cobalt. Manganese is used intentionally only in the yellow and orange beads, where it probably serves as a decolorizer.

A cobalt blue oblate from Skeleton 14 was analyzed (Table 2a, notes). Because of the tiny weight of the sample (4.8 mg) we do not place confidence in the quantitative results, but certain qualitative traits are clear. The bead is a soda-lime glass, colored with cobalt, and not containing sufficient manganese, tin or antimony to indicate intentional inclusion of any of these elements as a glassmakers additive. Visual inspection of the numerous jars and boxes full of oblates from Mapungubwe revealed many cobalt blue examples. However, we cannot show that any cobalt blue bead belongs in the Mapungubwe Chemical Group, because the one sample we analyzed is simply too small to give reliable results. All the cobalt blue oblates at our disposal looked comparably tiny, and therefore we did not analyze further beads of this color.

We found one bead from Mapungubwe, Skeleton 14, which did not fit into the Mapungubwe Chemical Group I. Although it resembles the other blue-green beads visually, the bead MAP-18 (Table 2a and Figure 6) is slightly different from them chemically, having been made without the major additive tin. There are other chemical differences as well, of a sort which suggest a different coloring recipe and perhaps a slightly different set of raw material. This sort of variation might be reasonable to expect in one factory since glassmakers aim at a visual result rather than a chemical composition. This bead is omitted from the Mapungubwe Chemical Group I, and it indicates that there may be other chemical groups to be distinguished among the oblates at Mapungubwe.

The Occurrence of Beads Matching the Mapungubwe Chemical Group at Bambandyanalo. Comparison of some small beads from Bambandyanalo (Table 2b) with the Mapungubwe group indicates that some samples from Bambandyanalo chemically match the Mapungubwe Chemical Group. The three from Skeleton 18 were oblate in shape, and the two from Skeleton 21 were short cylinders (a shape so similar to oblate that the distinction is hardly worth making). Four of these five black beads fit into the Mapungubwe Chemical Group, and the fifth is very similar. The three purple ("plum") beads, all small oblates from Skeleton 29, show a general resemblance to the Mapungubwe Chemical Group, but do not fit into it.[5]

Figure 6 shows the mean concentration, with the root mean square deviations, of the precisely determined elements in the Mapungubwe Chemical Group I. In Figure 6 this mean concentration is compared with the concentrations (with counting errors) of eight individual beads from

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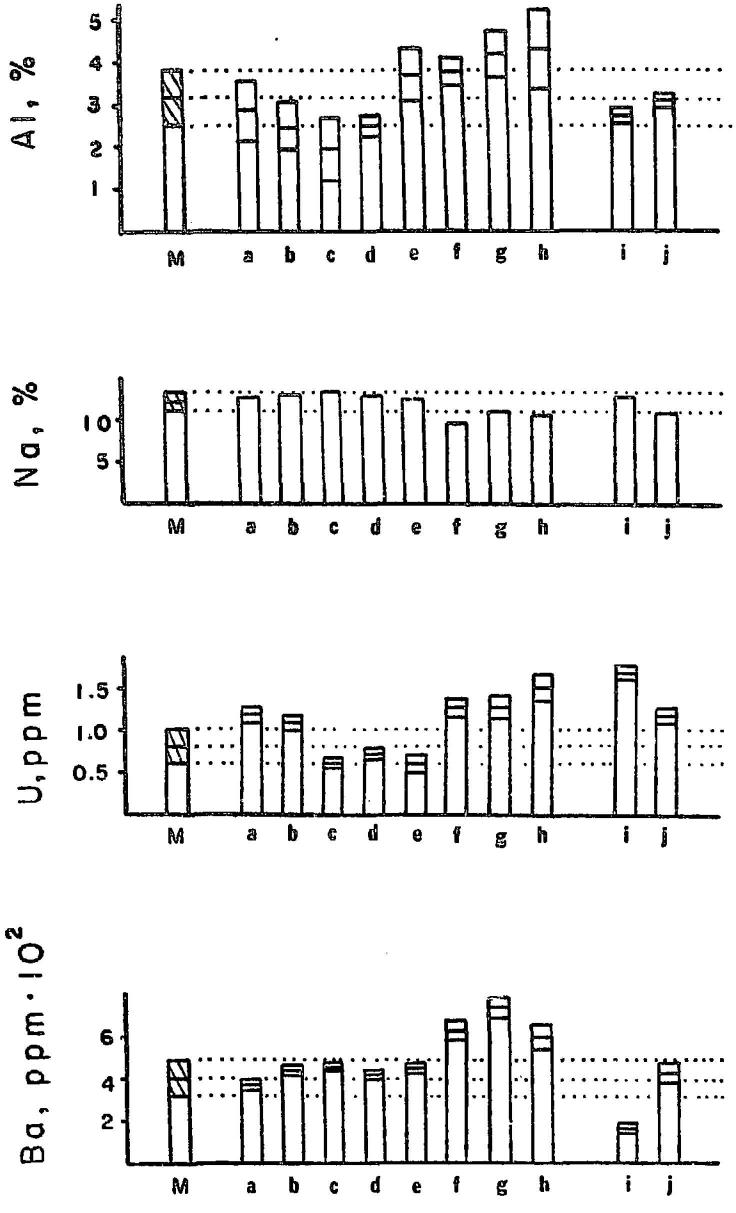
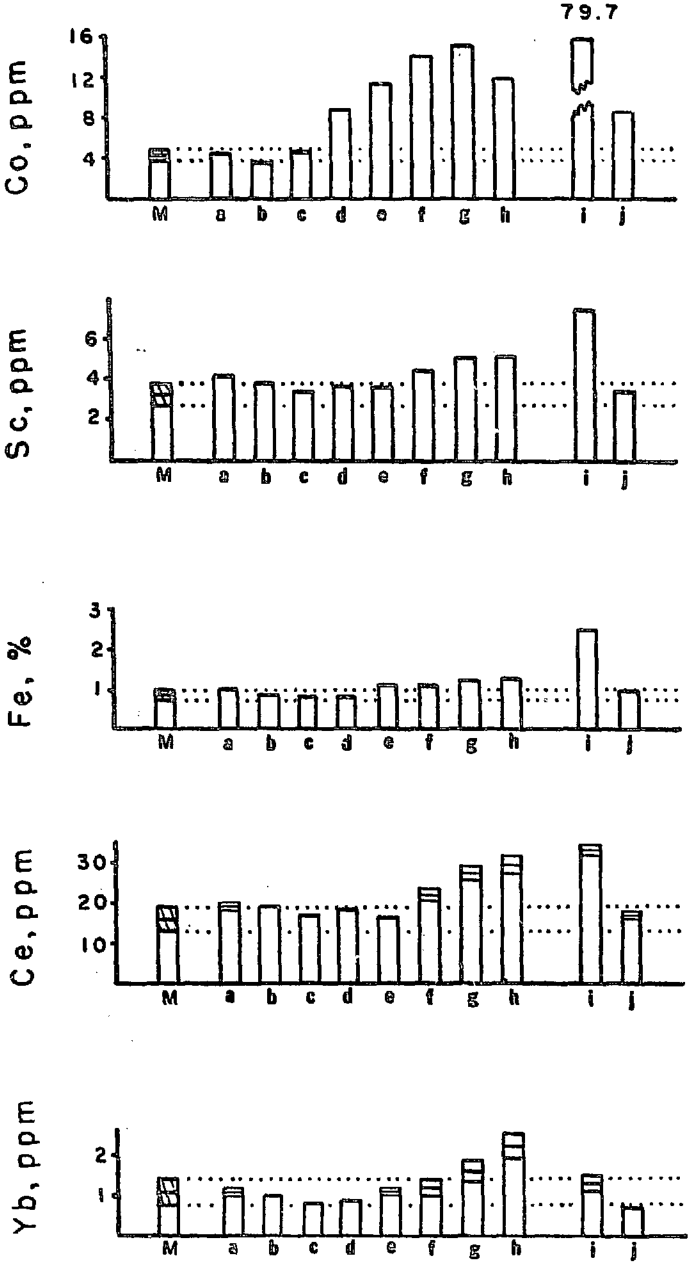
[5] It is curious that the three purple beads from Bambandyanalo contain tin in an additive range of concentration (average ∿ 0.2%). Tin is usually an opacifier, and yet these beads are very transparent.



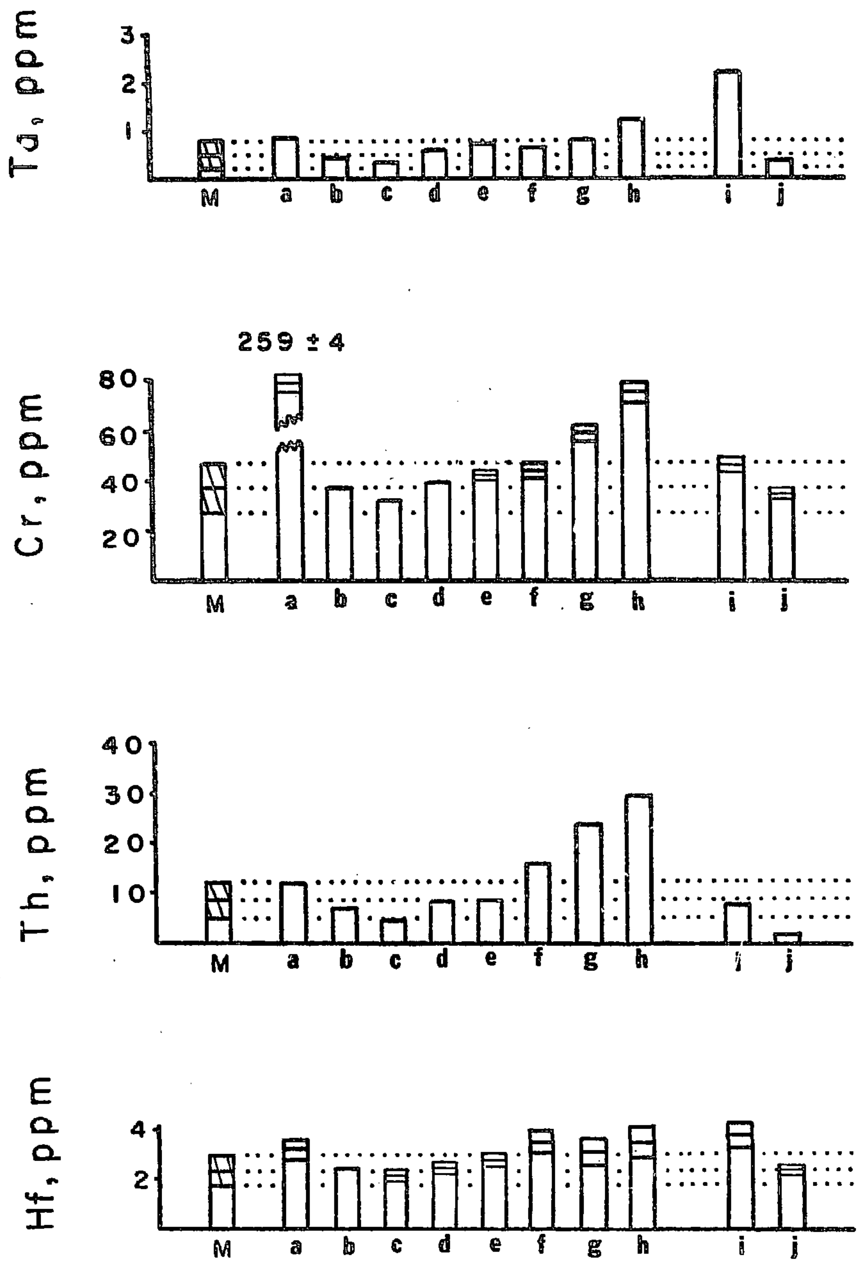
XBL 728-1551

Figure 6. Samples compared with the Mapungubwe Chemical Group I. The hatched area is the variance. The unhatched error region is the counting error, shown where large enough to



XBL 728-1550

Figure 6. (continued) be seen on the scale of the drawing. In alphabetical order, the samples are BAM-S18a, BAM-S18b, BAM-S18c, BAM-S21a, BAM-S21b, BAM-S29b1, BAM-S29b2, BAM-S29b3, MAP-18, and MJE-15b.



XBL 728-1559

Figure 6. (continued)

Bambandyanalo, plus the bead MAP-18 and the bead MJE-15b.

When the elemental concentrations of the five black beads from Bambandyanalo are compared with the mean elemental concentrations of the Mapungubwe oblate group, each bead agrees with the group for over two-thirds of its elements. That is, the elemental concentrations fall within or overlap the group concentration distributions in over two-thirds of the elements for each bead. One would not expect more than two-thirds of the elements to fall within ranges defined by standard deviations (our root mean square deviation), and therefore by this test each black bead from Bambandyanalo fits into the Mapungubwe Chemical Group I.

It is important to weigh the importance of the discrepancies in the few elements which do not agree. In our estimation the disagreements between four of the five black beads from Bambandyanalo and the Mapungubwe Chemical Group are not sufficiently large to bar inclusion in the group. The fifth black bead, BAM-S18a, is barred from the Chemical Group by its dramatic discrepancy in the concentration of chromium.

By the above line of reasoning it is concluded that four black beads from Bambandyanalo match the Mapungubwe Chemical Group, within the degree of scatter exhibited by that Group, as measured by the root mean square deviations of the mean elemental concentrations.

Thus we have indicated that four Bambandyanalo black beads match the Mapungubwe Chemical Group. We now turn to the three purple beads from Bambandyanalo. If one returns to Figure 6, one can see that each bead agrees with the Mapungubwe Chemical Group for far less than two-thirds of its elements. It is thus clear that the purple beads do not resemble the Mapungubwe Group as much as the black beads do. Similarly, the bead MAP-18 differs from the Group.

Of the nearly 400 beads that we have analyzed by neutron activation, we have found only one other bead that resembles the Mapungubwe Chemical Group as much as do the black beads from Bambandyanalo. This is a single black reheated cane bead (MJE-15b), short-cylindrical in shape, from a burial in the Mjelele Valley of Rhodesia, which is thought to date from the eighteenth or nineteenth centuries (discussed further in Chapter 6). The bead was larger than the typical Mapungubwe oblate, measuring 2 mm in length and 3.5 mm in diameter. Although this bead may belong to the Group, it is excluded on account of its dissimilarity of size. We think it advisable to wait to see if more such beads may be found from this burial before making a final judgment.

The finding that some beads from Bambandyanalo match beads from Mapungubwe confirms earlier judgments made on the basis of the appearance of the beads (Schofield 1938:349n; Schofield 1958:211; Gardner 1963:83).

Dating, Origin and Distribution. The date of the major occurrence of the oblate series from which our samples were drawn falls in the span of time in which occur the parallel and contemporary cultural phases Leopard's Kopje 3 (LK3), Zimbabwe 3 (Z3), and Mapungubwe M_1, if the latter is to be given independent status. Unless intrusions have occurred, the first occurrence of these oblates is towards the earlier part of this time span, even in LK2 and Z2. These first occurrences are at Bambandyanalo, as discussed immediately above, and at Zimbabwe, where the oblates typical of Z3 occur in a lower layer which belongs to Z2 (Test I, layer 14).

As previously pointed out, the border between LK2-LK3 and Z2-Z3 has been given approximately eleventh-century dating, by radiocarbon dates at Bambandyanalo, at Zimbabwe, and at other sites. The oblates at Zimbabwe that occur in the layer belonging to Z2 were found stratigraphically below the layer that yielded the eleventh-century radiocarbon date (Test I, layer 13). It thus appears that the earliest occurrence of these oblates is around the beginning of the second millennium A.D.

The manufacturing origin of these oblates is not known, and the ingredients of the glass, as they may be typified by our Mapungubwe Chemical Group I, are not narrowly diagnostic in this regard. For example, the absence of the use of Sb as an opacifier would hint that the glass may fall between the fourth and eighteenth centuries A.D. (Chapter 2 above). The use of a sodium rather than a potassium alkali would indicate that medieval Europe is not the source of the beads. The rarity or absence of Indian red is probably due to fashion rather than to manufacturing ability.

The distribution of these oblates is limited. Their main occurrences are at Mapungubwe and Zimbabwe. No such series has come to light on the East Coast. The oblates are appropriately dated to have been distributed by Arab traders, but possible Arab distribution does not prove Arab manufacture.

It is rather surprising to find such beads as the Mapungubwe oblates in contexts datable in their earlier portions to c. the eleventh century. By their vast numbers and uniform appearance they could serve as the very epitome of European mass-produced conterie of the periods of discovery and colonialism. It must be remembered that the contexts in which these beads occur have also received approximately fifteenth century radiocarbon dating, both at Mapungubwe and Zimbabwe, and one of the radiocarbon dates (M-915, 1440 ± 150) spans virtually the entire sixteenth century, which brings us into the period of European discovery.

A later dating is less surprising than the eleventh century dating. If the earlier dating is truly applicable to the beads it would be of very great interest to find the center where such manufacture was carried out at such an early date. Moreover if the dating is correct it is interesting to find a possible member of the Chemical Group in a site as late as the Mjelele Valley Burial. However, there is some reason to re-examine the "truth" of the eleventh-century dating, a matter best discussed in Part 2 of this chapter.

Part 2. Bambandyanalo

Description of Beads

The Bambandyanalo (K_2) site is best known in its aspects as a burial site, having yielded approximately seventy separate human burials. The anatomical traits of the skeletons place the population in a Khoisan phenotypic grouping (Galloway 1959), a group which is associated with several LK2 sites (Summers 1967, Robinson 1966).

Many of the burials contained glass beads, which were exceedingly similar from burial to burial.[6] The skeletons and associated finds are

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[6] Many criticisms have been directed at the excavations of Bambandyanalo and their documentation, to the extent that it may be doubted whether the beads were truly associated with the buried skeletons. There is every likelihood that the associations are valid. In some cases bead arrangements were recognizable as necklaces to Gardner, and in other cases where he doubted artifact associations, he said so (1963). In any case, it is of little consequence for our investigations if the associations are not valid. Bambandyanalo is the only presently-known site in Africa where the M_1 beads

individually described by Gardner (1963:40-51). The main type of bead present was a small transparent to translucent blue-green (∿ No. 7.5BG,8/5) reheated cane bead, as shown in Plate III, which has come to be recognized as a stylistic type (Gardner 1963, Lowe 1955, Robinson 1961, Schofield 1958, and personal observations). This type is here designated the M_1 type, a designation adopted from the excavator, Gardner, but restricted in meaning to only the small transparent to translucent reheated cane cylinders and short cylinders, and perhaps a few oblates (compare Gardner 1963:33).

Like the Mapungubwe oblates, the M_1 beads have a limited distribution. Their main occurrence is at Bambandyanalo. A few dozen occur in phase 2 at Zimbabwe[7]; a few occur at Mapungubwe; judging by published descriptions two occur at Leopard's Kopje (Robinson 1966), one occurs at the Gokomore Tunnel Site, and one, bearing the label "Sofala" exists in the collection of the late Dr. van der Sleen. The M_1 type does not include the blue-green snapped canes found in LK1 and LK2 sites (Robinson 1966, Summers 1967) or in Test V, layer 3 at Zimbabwe (Robinson 1961).

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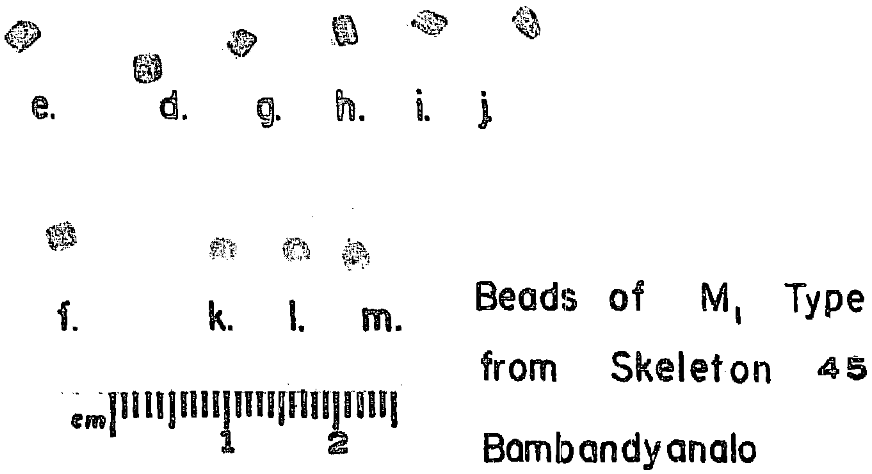
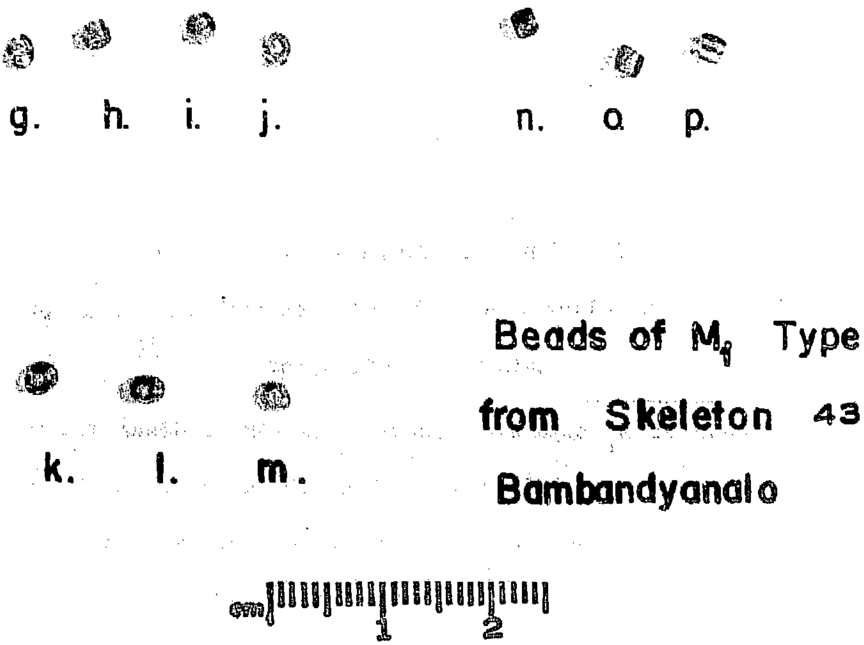
[6](continued) occur in large numbers. The site does not appear to represent a long period of cultural development, and the M_1 beads may be virtually contemporary with one another regardless of their association or lack of same with particular skeletons.

[7] The designation "M_1" beads corresponds closely to Robinson's blue-grey translucent cylinders and blue-green transparent cylinders, but probably with slightly less than 100% agreement. Robinson lists four blue-green transparent cylinders in Test I, layer 14 (phase 2), but the author, who saw all but one of the thirty-nine beads excavated from layer 14, noted no



Beads of M_1 Type from Skeleton 45 Bambandyanalo



Beads of M_1 Type from Skeleton 43 Bambandyanalo

XBB 729-4452

Plate III. Beads of M_1 Type from Skeletons 43 and 45 at Bambandyanalo.

Besides the beads of M_1 type other beads were present with the burials and in other parts of the site. Included among these were the so-called garden roller beads.

There is evidence that the garden roller beads were made on the site of Bambandyanalo. This evidence consists of clay ring-like objects, found at Bambandyanalo, interpretable as molds for the garden roller beads, plus possible firing pits at Bambandyanalo (Gardner 1963:7-8). Van Riet Lowe (1955:10-13) and Gardner (1963:7) have suggested that it was the M_1 beads, so numerous at Bambandyanalo, which provided the raw material for the garden roller beads, the latter being formed by the melting and reworking of M_1 beads. Some qualitative spectrographic analyses gave results consistent with that hypothesis (van Riet Lowe 1955:11).

Results

Results of X-ray fluorescence of M_1 beads from Bambandyanalo and from Zimbabwe (Text IX) are presented in Table 3.

Results of neutron activation analysis of M_1 beads from Bambandyanalo are presented in Table 4a. In Table 4b are presented the results of analysis of the garden roller beads. Results of analysis of a few other beads from Bambandyanalo are presented in Chapter 7.

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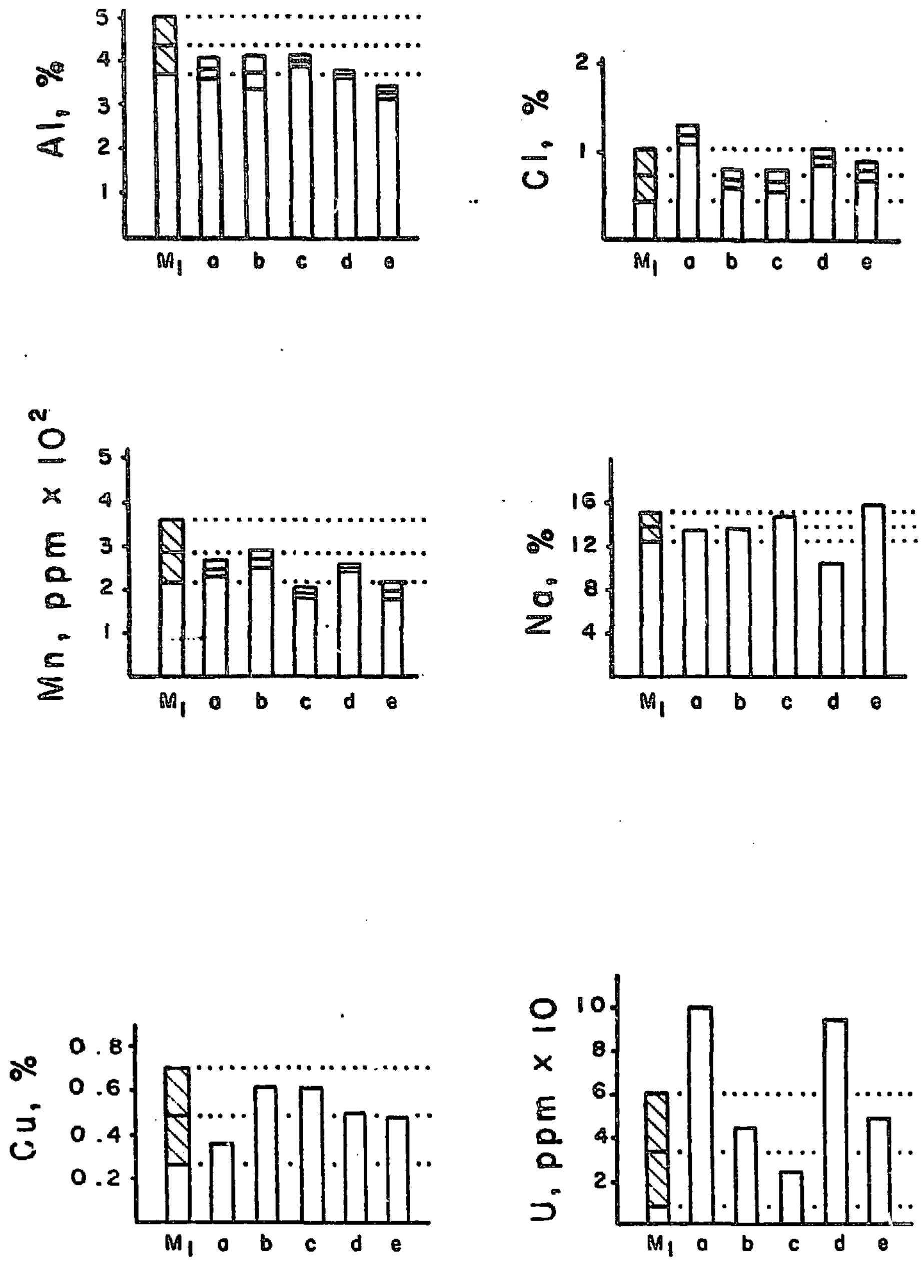
[7] (continued) beads of M_1 type among them. This small disagreement has little effect on the present discussion since the bulk of the M_1 beads at Zimbabwe (which the author does confirm) came from Test IX. The two which the author analyzed by X-ray fluorescence (Table 2) are rather large exemples of the M_1 type.

Discussion

M_1 Beads. The X-ray fluorescence presented in Table 3 are consistent with the previous usual observation that the M_1 beads of Bambandyanalo are the same type of bead as the "blue-green transparent cylinder" of Zimbabwe (Robinson 1961b), and, by extension, LK2 sites generally.

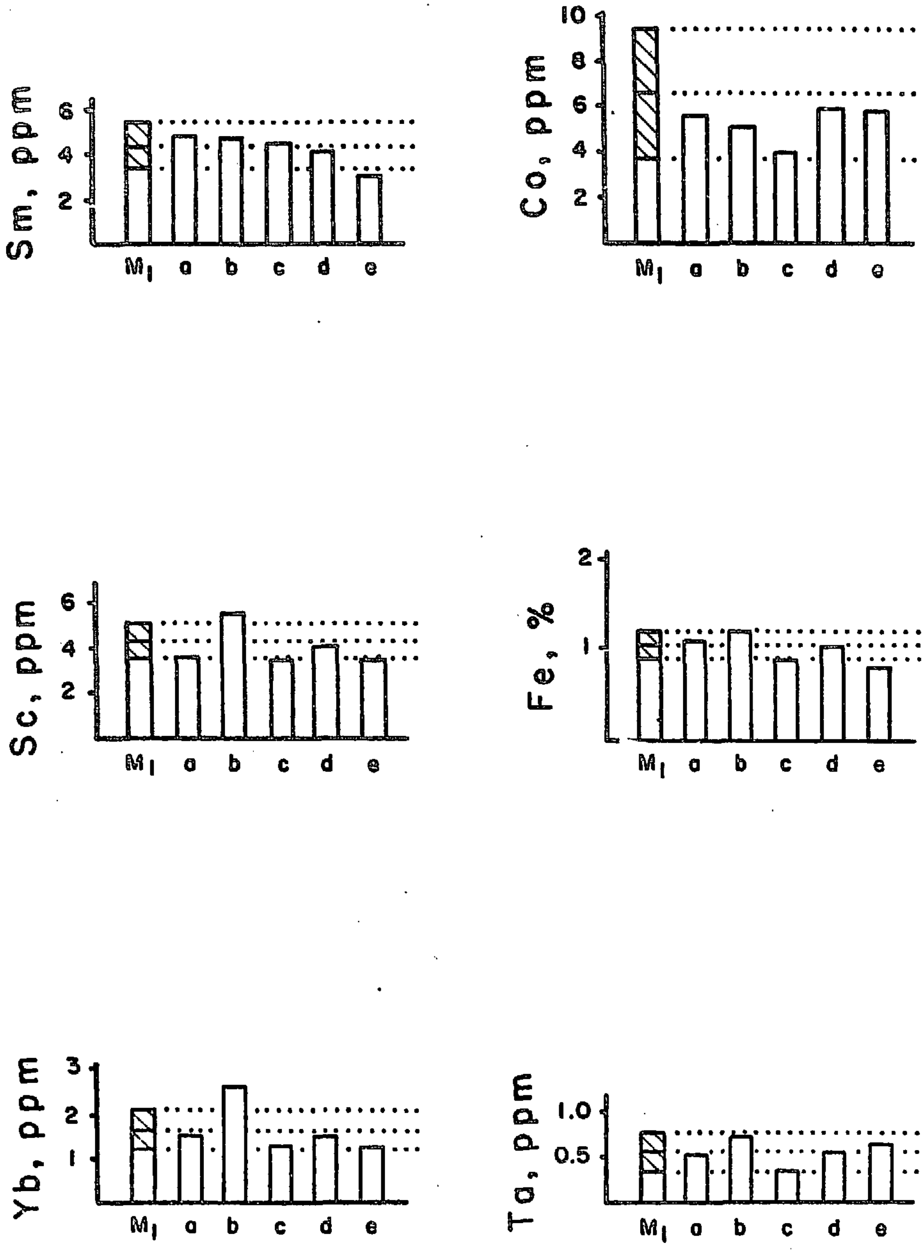
The Manufacture of the Garden Roller Beads. Our results cannot prove that the actual site of manufacture of the garden roller beads was or was not Bambandyanalo, but they can be used to judge whether or not the glass of the garden roller beads matches that of the M_1 beads, as it ought to if the former were made from the latter. Our results are also relevant to the question of whether or not any other beads besides the M_1 beads might have been included in the garden roller beads. Mapungubwe yielded a large number of blue-green oblate beads, and without chemical analysis it might seem reasonable to suggest that the Mapungubwe oblates may have been used in the garden roller beads. This might be suggested despite the fact that the occupation of Mapungubwe is considered to have been later than the occupation of Bambandyanalo, in the interest of thoroughness, and in view of the fact that Mapungubwe oblates are found on burials in Bambandyanalo (Part 1).

The following line of reasoning shows that the garden roller beads belong to the same chemical group as do the M_1 beads. When the elemental concentrations of the individual garden roller beads, with counting errors, are compared against the mean concentrations, with standard deviations (root mean square deviation), of the elements in the M_1 group, each garden roller bead agrees with the M_1 group for over two-thirds of its elements (Figure 7). One could not expect a higher percentage than about two-thirds



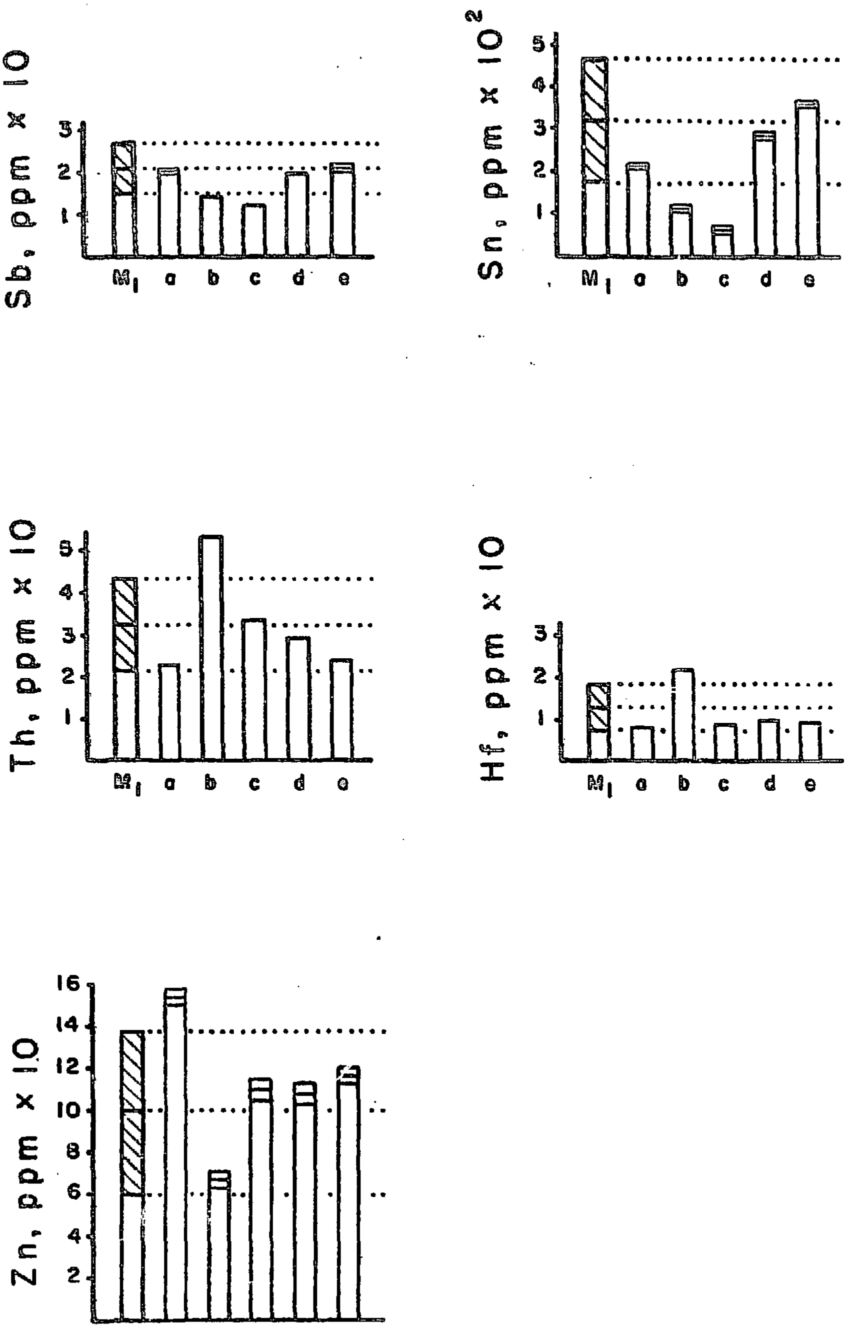
XBL 728-1548

Figure 7. Comparison of M_1 beads with garden roller beads. The hatched area is the variance. The unhatched error region is the counting error. In alphabetical order, the individual samples are BAM-P18a, BAM-P18b, MST-1, MAP-GRX1, and MAP-GRX2.



XBL 728-1549

Figure 7. (continued)



XBL 728-1547

Figure 7. (continued)

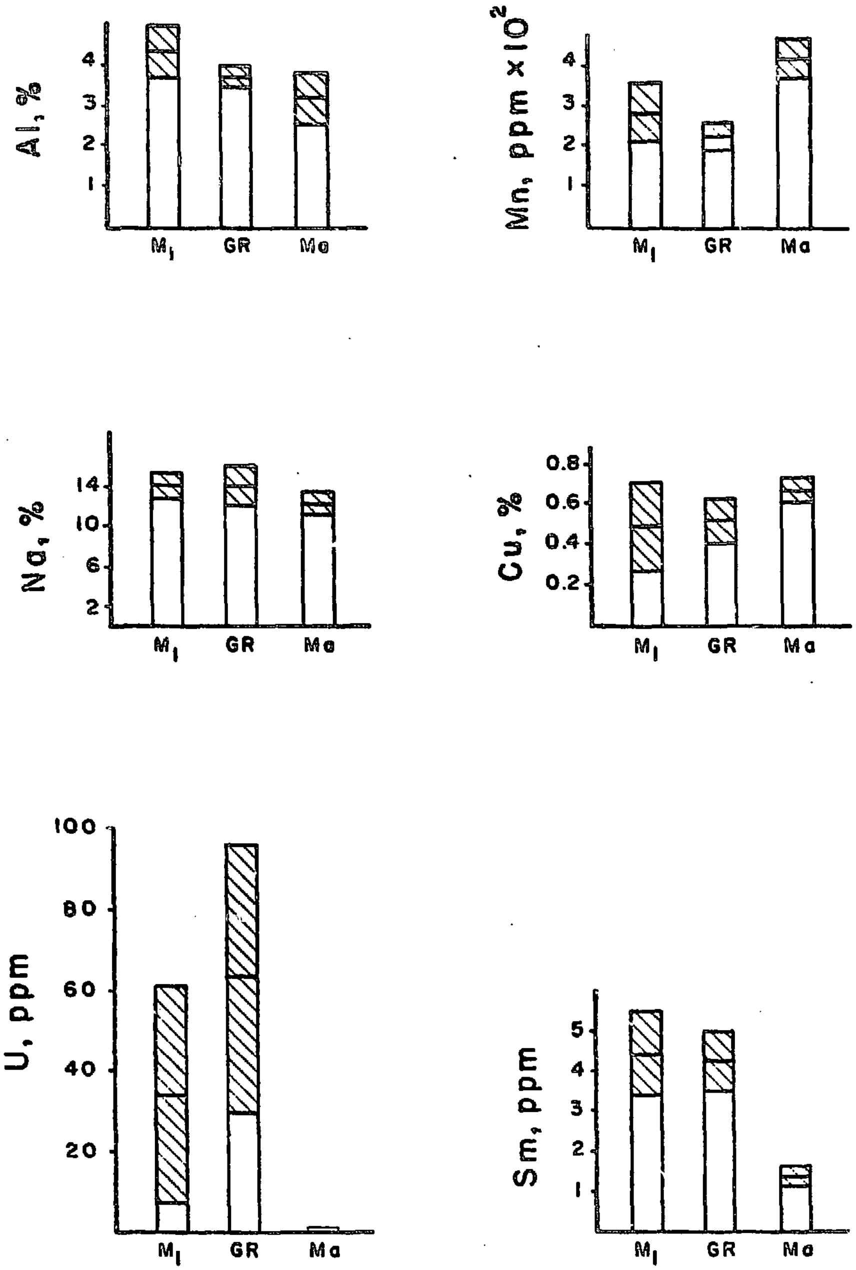
to fall within a range defined by a standard deviation, and therefore by this test the garden roller beads may be considered indistinguishable from the M_1 beads.

If the mean concentrations for each element, with standard deviations, are computed for the garden roller beads as a unit and compared with the means for the M_1 bead group, the mean concentrations agree within their standard deviations for all 15 elements. Moreover, it can be shown by calculation that the two groups agree within the standard deviations of the means (standard error) for ten of the fifteen elements. This behavior is consistent with what may be expected for two sets of samples from the same larger population (Young 1962:92-97).

For the above reasons, then, the garden roller beads are judged to match the M_1 beads chemically. Indeed of nearly 400 beads analyzed as a part of this study no other beads resemble the M_1 beads as closely as do the garden roller beads. This finding is consistent with the hypothesis that the garden roller beads were made from melted M_1 beads.

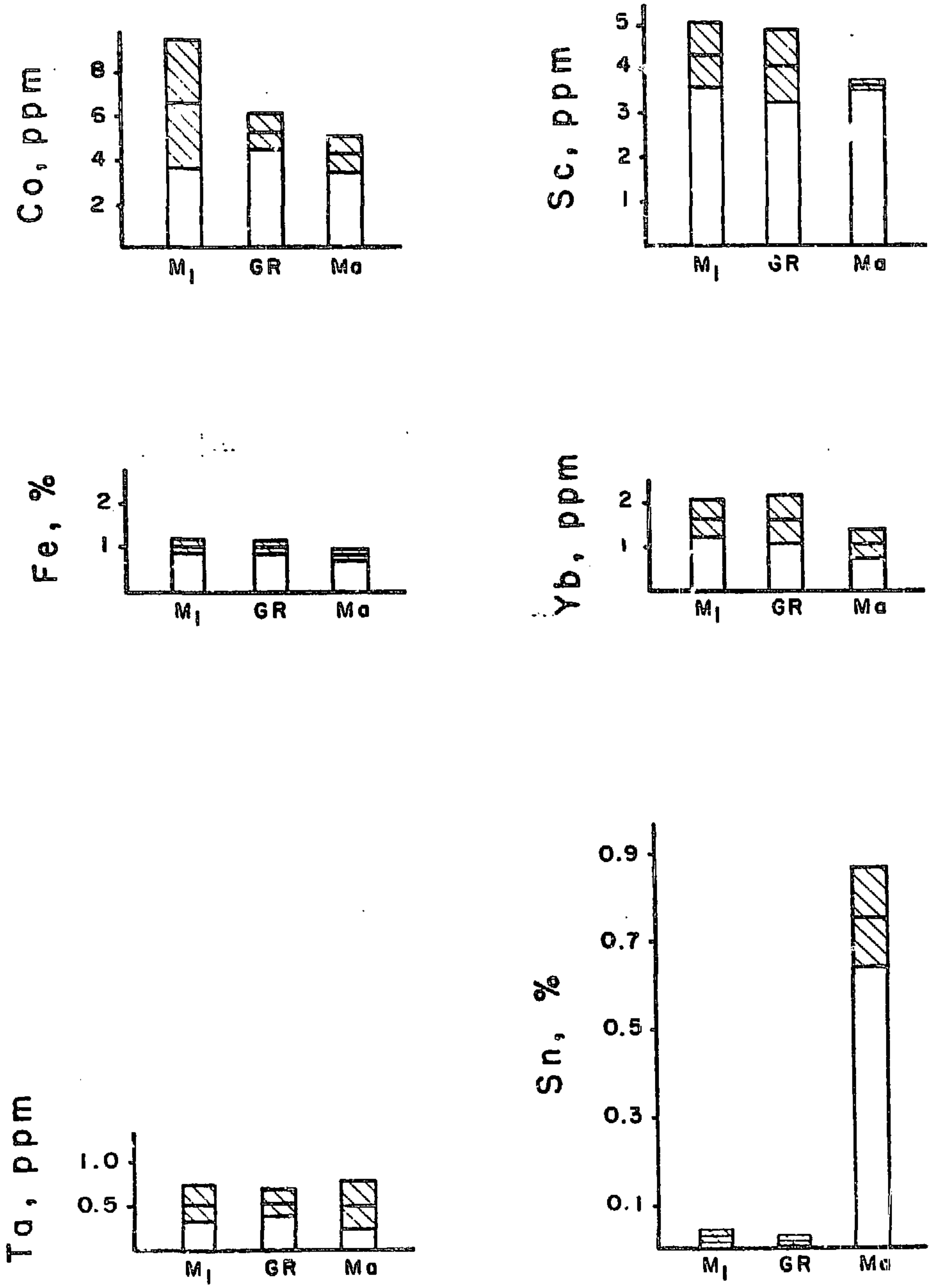
While the garden roller beads match the M_1 beads on comparison, they do not bear such a resemblance to the Mapungubwe Chemical Group I. When the mean elemental concentrations for the garden roller beads are compared against the mean concentrations for the Mapungubwe Chemical Group, the values, within their standard deviations, disagree for seven of the fifteen elements (Figure 8). In particular, the Mapungubwe Group has a high mean tin concentration, while the M_1 and garden roller beads do not (Figure 8).

Mixtures of Beads in the Garden Roller Beads. While it may be readily agreed that the garden roller beads resemble the M_1 beads chemically



XBL 728-1552

Figure 8. Comparison of M_1, garden roller, and Mapungubwe groupings. The hatched area is the variance. For the additives Cu and Sn, only blue-green samples of the Mapungubwe Chemical Group are reflected.



XBL 728-1553

Figure 8. (continued)

XBL 728-1554

Figure 8 (continued)

more closely than they resemble the Mapungubwe oblates (Figure 8), it might be suggested that the garden roller beads could have been made from a mixture of M_1 and Mapungubwe oblate beads. We do not detect such a mixture, on the basis of the following considerations.

One of the most dramatic differences between the M_1 and Mapungubwe oblate blue-green beads is in their Sn content. If the garden roller beads contained very many blue-green tin-containing Mapungubwe oblates, like those analyzed here, then the tin content of the garden rollers would be higher than the tin in the M_1 beads. As little as 3% Mapungubwe beads would be detectable, since this amount would give the garden roller beads ∿ 0.05% tin, which is more than one standard deviation higher than the M_1 mean for tin (Sn):

$$\frac{(97 \cdot 0.03\%\ \mathrm{Sn}_{M_1})+(3 \cdot 0.76\%\ \mathrm{Sn}_{Ma})}{100} = 0.05\%\ \mathrm{Sn}_{GR} \quad .$$

However, no such elevation of tin content is observed in the garden roller beads (Table 4b).

Our samples yielded one blue-green oblate bead from Mapungubwe, designated MAP-18 (Table 2), which did not show a high tin content. Is it possible that a number of beads like MAP-18 may have been included in the garden roller beads? Again we detect no contribution of beads from Mapungubwe. In this case, the limit of detection is ∿ 30% beads like MAP-18, and the clue is an expected dilution of the element uranium. Omitting the six highest uranium values, which are unusually high, the average uranium in M_1 beads 21.9 ± 4.0 ppm. The uranium content of MAP-18 is 1.69 ± 0.07 ppm. If many beads like MAP-18 were mixed with the M_1 beads to form the garden roller beads, one would expect a dilution of uranium in the garden roller beads. Thirty percent beads like MAP-18 and 70% beads having 21.9 ppm uranium would give the garden rollers 15.9 ppm uranium, which is more than one standard deviation less than the mean uranium (U) in the M_1 beads

$$\frac{(30 \cdot 1.69 \text{ ppm } U_{MAP-18}) + (70 \cdot 21.9 \text{ ppm } U_{M_1})}{100} = 15.9 \text{ ppm } U_{GR} \,.$$

However, we detect no such dilution in the garden roller beads.

On the basis of the foregoing, the inference is made that beads from the Mapungubwe Chemical Group I were not used in the manufacture of the garden roller beads from Mapungubwe and Bambandyanalo. The hypothesis that it was the M_1 beads of Bambandyanalo which were used to make the garden roller beads is borne out by our analyses.

Subgrouping Within the M_1 Beads. In order to test the hypothesis that garden roller beads match M_1 beads, it was appropriate to consider as one group all the M_1 beads that we have analyzed. These 29 beads form a chemical group which is clearly separable from all other beads we have analyzed except from the five garden roller beads that we analyzed.

It is possible to discern some subgroups of M_1 beads, which, however, are of no use at the present time. They are merely notable. The major subgroup contains thirteen beads from Skeleton 43 (BAM-S43a through -S43m, Table 4). These thirteen beads form a "tighter" group than is formed by the larger group of twenty-nine M_1 beads. Left over are three beads from Skeleton 43 and thirteen beads from Skeleton 45. Some of these sixteen left over beads combine into a few other small subgroups.

When our pre-analysis records were reviewed in the light of our results, no notes were recorded for the thirteen beads from Skeleton 43 which would have segregated them from the other M_1 beads on a visual basis. All 29 M_1 beads appeared to be nearly as alike in appearance as possible with conventional glass bead mass-production techniques (as done in the nineteenth and twentieth centuries). Although there were slight variations among the M_1 beads, these seemed to be the random variations found in a mass-produced item and not variations produced by design and recognizable independently to different archaeologists. The thirteen beads in the subgroup included both longer and shorter cylinders verging on oblates. Similarly the sixteen left-over beads included both longer and shorter cylinders verging on oblates. All lengths and diameters were approximately 2-3 mm. The thirteen beads were very transparent, as were all other M_1 beads except four.

Therefore we feel that it is not possible on the basis of appearance to divide the M_1 beads into groups that correlate with chemical groups. In other words it is not possible to predict the chemical grouping of the beads on the basis of small variations in their appearance.[8]

Dating and Relationships to Other Beads

Results from the M_1 beads raise questions about the "truth" of the "eleventh-century" radiocarbon dates customarily taken to represent the

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[8] There may be one partial exception to this generality. The four translucent beads had the four highest uranium concentrations (82.2 to 122.7 ppm). There may be some kind of relationship between the uranium concentration and the translucency, but nothing of this sort has been established.

date of Bambandyanalo and of the border between Z2 and Z3 at Zimbabwe. The problem, if we may anticipate subsequent chapters slightly, is this: in terms of their ingredients, these M_1 beads of the Middle Iron Age (Summers 1967) show a strong resemblance to the trade wind beads of the Later Iron Age, discussed in Chapter 7. This resemblance might be interpreted to mean that the M_1 beads and the trade wind beads are of the same manufacture even though there is a substantial chronological span involved.

If this is true then we face the possibility that glass beads of the degree of resemblance displayed by the uranium-bearing beads might have been made over centuries, a much longer time span than was previously felt to be reasonable. If bead groups or families of groups can span such a long time, then they may not be as useful an archaeological tool as had sometimes been envisioned. For a bead group to be useful archaeologically, especially in dating, it should reflect a period of manufacture considerably shorter than the time span of the archaeological entity under investigation. Similar considerations apply to the time span of the Mapungubwe oblates as well.

On the other hand, if bead groups cannot span such a long time, then there must be errors in the dating of at least some of the sites at which the uranium-bearing beads occur. Such an eventuality may have far-reaching implications in the southern African Iron Age sequence, which is dotted with radiocarbon, ceramic, and documentary dates consistent with those that have come into the discussion here.

A re-examination of southern African archaeological dates may not be warranted on the basis of the M_1 beads alone, since they are not indubitably stratified in a pre-"eleventh century" time span. At Bambandyanalo one might raise questions concerning the adequacy of the excavations and the relevance of the radiocarbon date, since the sample which was dated was obtained some twenty years after the original excavations (Fagan 1964). At Zimbabwe, most of the M_1 beads occur in Test IX, from which no radiocarbon-dated materials was obtained. Although Test IX yielded artifacts distinctive of Z2, it is possible that the beads do not belong with the artifacts, for the deposit was not sealed, and the excavator has expressed some doubts along this line (Robinson 1961b). At Leopard's Kopje itself (LK2) only two such beads, judging by descriptions in the literature, were found, and they are not among those which are considered as typical (Robinson 1966).

Although a re-examination of southern African archaeological dating may not be warranted on the basis of any M_1 beads or of any evidence from Bambandyanalo, there are other sites where trade wind beads indistinguishable from those of the Portuguese period occur in stratigraphically pre-Portuguese time levels with more certainty than do the M_1 beads in the sites discussed here. The present discussion of Bambandyanalo has provided a conveniently simple context in which to introduce a thorny dating problem, to which we shall return in Chapter 7.

Chapter Summary

This investigation has found one chemical group of beads consisting of Mapungubwe oblates, and another consisting of M_1 beads. Beads matching the Mapungubwe Chemical Group occur in burials at Bambandyanalo (Skeletons 18 and 21). Samples of garden roller beads from Bambandyanalo and from Mapungubwe match the M_1 Chemical Group.

In our discussions we have assumed that the bead groups here discussed cross-cut sites. In this particular case there is general agreement with our assumption that the M_1 beads and oblates of Bambandyanalo and Mapungubwe are "the same" as similar beads at Zimbabwe.

With this assumption it has been possible to bring interpretative evidence from Zimbabwe to bear on the beads from Bambandyanalo and Mapungubwe, sites for which much of the presently-available information is not satisfactory. In particular, the approximately eleventh century dating of the M_1 beads at Bambandyanalo is confirmed by similar dating from Zimbabwe. Therefore it is not possible lightly to dismiss such early dating when, anticipating slightly, it is found that chemically the M_1 beads resemble the trade wind beads, a group found in Portuguese sites. A rather thorny problem in the dating of sites and beads is introduced in this chapter, a problem which will be taken up again in Chapter 7.

Table 1a. Glass Beads from Mapungubwe: X-ray Fluorescence Analysis[a]

Color	Mn	Fe	Cu	Zn	Sr	Zr
black	< 0.3	0.6 ± 0.1	0.18 ± 0.04	< 0.1	0.04 ± 0.01	0.01
green	< 0.3	1.0 ± 0.2	0.6 ± 0.1	0.08 ± 0.02	b	b
orange	0.5 ± 0.1	1.0 ± 0.2	0.05 ± 0.02	0.6 ± 0.1	b	b
yellow	0.3 ± 0.1	1.0 ± 0.2	0.06 ± 0.02	< 0.1	b	b

[a] All data are given in percent. All samples were analyzed for Co and As but these were not detected. The lower limit of detection was 0.1% Co in all four samples, and 0.1% As in the black samples. For the others, the Pb content was too high to allow detection of a small amount of As. All samples consisted of several beads.

[b] Pb content too high to allow detection of small amounts of this element.

Table 1a. concluded

Color	Sn	Sb	Ba	Pb	Shape	Provenience
black	~ 0.007	< 0.02	0.05 ± 0.01	0.02	obl.	Skeleton 14[c]
green	1.1 ± 0.2	0.013 ± 0.004	0.05 ± 0.01	6.7 ± 1.0	obl.	Skeleton 14[c]
orange	1.2 ± 0.2	0.011 ± 0.004	0.06 ± 0.01	9.9 ± 1.5	obl.	Skeleton 14[c]
yellow	0.8 ± 0.2	< 0.02	0.06 ± 0.01	6.3 ± 1.0	obl.	Skeleton 14[c]

[c] See Fouché 1937:126, 149-151, map following p. 183.

Table 1b. Glass Beads from Zimbabwe, Acropolis:
X-ray Fluorescence Analysis[a]

Color	Mn	Fe	Cu	Zn	Sr	Zr
black	< 0.1	0.5 ± 0.1	0.12 ± 0.03	0.02	0.03	∿ 0.005
"	< 0.1	0.5 ± 0.1	0.15 ± 0.03	0.03	0.03	∿ 0.005
"	< 0.1	0.7 ± 0.2	0.03	0.03	0.04 ± 0.01	0.01
"	< 0.1	0.5 ±.0.1	0.03	0.03	0.03	0.01
"	< 0.1	0.5 ± 0.1	0.02	0.03	0.04 ± 0.01	∿ 0.005
"	< 0.1	0.4 ± 0.1	0.03	0.02	0.04 ± 0.01	0.01
"	< 0.1	0.5 ± 0.1	0.02	0.03	0.03	0.01
"	< 0.1	0.5 ± 0.1	0.02	0.03	0.04 ± 0.01	0.01
blue-green	< 0.1	0.6 ± 0.1	0.43 ± 0.08	0.03	0.04 ± 0.01	0.01
"	< 0.1	0.5 ± 0.1	0.48 ± 0.08	0.03	0.04 ± 0.01	0.01
orange	0.3 ± 0.1	0.7 ± 0.2	0.04 ± 0.01	0.6 ± 0.2	b	b
"	0.4 ± 0.1	0.7 ± 0.2	0.07 ± 0.02	0.5 ± 0.1	b	b

[a] All data are given in percent. All specimens were analyzed for Co, As, Rb, and Sb. These elements lay below the limits of detection, which were 0.05% Co, 0.03% As, 0.01% Rb, and 0.005% Sb. The Pb content in the two orange specimens was too high to allow detection of As and Rb in small amounts. All samples consisted of single beads.

[b] Pb content too high to allow detection of small amounts of this element.

Table 1b. concluded

Color	Sn	Ba	Pb	Shape	Provenience	No.[c]
black	< 0.005	0.06 ± 0.01	0.02	cyl.	A3, No. 49 midden	4561
"	∿ 0.005	0.06 ± 0.01	0.02	obl.	"	"
"	0.015 ± 0.005	0.05 ± 0.01	0.03	"	"	"
"	∿ 0.008	0.06 ± 0.01	0.02	"	"	"
"	∿ 0.006	0.05 ± 0.01	0.02	"	Test 1, layer 14	58413
"	∿ 0.006	0.05 ± 0.01	0.02	cyl.	"	"
"	∿ 0.005	0.06 ± 0.01	0.02	obl.	Test 1, layer 12	58390
"	0.010 ± 0.003	0.05 ± 0.01	0.02	cyl.	"	"
blue-green	0.8 ± 0.1	0.06 ± 0.01	0.9 ± 0.2	"	Test 1, layer 10	58356
"	0.9 ± 0.1	0.06 ± 0.01	0.9 ± 0.2	obl.	"	"
orange	2.1 ± 1.3	0.06 ± 0.01	10. ± 2.	"	"	"
"	1.4 ± 0.2	0.06 ± 0.01	6.5 ± 1.0	cyl.	"	"

[c] Accession number in the National Museum of Rhodesia. The first four beads were recovered in the excavations of 1929 (Caton-Thompson 1931), and the others were recovered in the excavations of 1958 (Summers, Robinson and Whitty 1961).

Table 1c. Glass Beads from Zimbabwe, Renders Ruins:
X-ray Fluorescence Analysis[a]

Color	Mn	Fe	Cu	Zn	Sr	Zr
black	0.05 ± 0.02	0.8 ± 0.2	0.13 ± 0.03	0.01	0.05 ± 0.01	0.01
green	<0.1	0.7 ± 0.2	0.6 ± 0.1	<0.01	0.05 ± 0.01	0.01
orange	0.5 ± 0.1	1.0 ± 0.2	0.04	0.45 ± 0.10	b	b
yellow	0.8 ± 0.2	0.9 ± 0.2	0.03	0.07 ± 0.02	b	b
cobalt blue	0.05 ± 0.02	1.1 ± 0.2	0.04 ± 0.01	0.01	0.04 ± 0.01	0.01

[a] All data are given in percent. The cobalt blue specimens contained 0.07 ± 0.02% Co and 0.06 ± 0.02% As. All other specimens contained less than the limit of detection of 0.05% Co. The black specimen contained less than the limit of detection of 0.03% As. For the green, orange, and yellow specimens the Pb content was too high to determine the As content. All specimens contained less than the limit of detection of 0.01% Rb. All samples consisted of several beads.

[b] Pb content too high to allow detection of small amounts of this element.

Table 1c. concluded

Color	Sn	Sb	Ba	Pb	Provenience	
black	0.07 ± 0.02	<0.01	0.05 ± 0.01	0.09 ± 0.03	No. 59/44,22	van Riet Lowe collection[c]
green	0.8 ± 0.2	∿0.01	0.06 ± 0.01	0.8 ± 0.2	No. 59/44,3	
orange	1.3 ± 0.2	<0.01	0.06 ± 0.01	8.8 ± 1.2	No. 59/44,18	
yellow	0.9 ± 0.2	<0.01	0.06 ± 0.01	6.5 ± 1.0	No. 59/44,14	
cobalt blue	0.02 ± 0.01	<0.01	0.05 ± 0.01	0.03	No. 59/44,20	

[c] Specimens donated by Goodall to the van Riet Lowe bead collection, 1944. The collection is in the Department of Archaeology, University of the Witwatersrand.

Table 2a. Mapungubwe Oblates: Neutron Activation Analysis[a,b]

Sample	Color	Al (%)	Mn[c]
MAP-16	blue-green	2.87 ± 0.71	411 ± 23
MAP-21	"	3.97 ± 0.31	439 ± 16
MAP-19	"	3.39 ± 0.23	423 ± 15
MAP-17	"	2.73 ± 1.01	417 ± 24
MAP-20	"	2.53 ± 0.70	371 ± 194
MAP-27	green	3.12 ± 0.26	418 ± 122
MAP-28	"	2.84 ± 0.41	379 ± 144
MAP-25	orange	2.49 ± 0.18	3,352 ± 129
MAP-26	"	2.14 ± 0.23	3,165 ± 124
MAP-23	yellow	3.39 ± 0.40	2,383 ± 46
MAP-24	"	3.93 ± 0.61	2,169 ± 43
MAP-11	black	3.55 ± 0.28	387 ± 16
MAP-13	"	3.54 ± 0.26	535 ± 27
MAP-10	"	2.91 ± 0.16	388 ± 13
MAP-12	"	2.80 ± 0.39	484 ± 19
MAP-14	"	3.28 ± 0.31	498 ± 32
MAP-15	"	4.59 ± 0.52	408 ± 34
Mean and RMSD[d]		3.18 ± 0.62	428 ± 50[e]
MAP-18	blue-green	2.76 ± 0.13	417 ± 15

Table 2a. continued

Sample	Color	Na (%)	$Cu^{b,c}$	U
-16	bl-gr	13.16 ± 0.12	6,123 ± 152	1.35 ± 0.10
-21	"	13.64 ± 0.13	7,351 ± 177	1.00 ± 0.11
-19	"	13.31 ± 0.13	7,345 ± 180	0.85 ± 0.11
-17	"	12.79 ± 0.12	6,699 ± 148	0.70 ± 0.09
-20	"	12.70 ± 0.14	5,993 ± 213	0.80 ± 0.14
-27	green	9.80 ± 0.10	8,644 ± 172	0.69 ± 0.11
-28	"	9.67 ± 0.10	8,659 ± 192	0.81 ± 0.12
-25	orange	11.28 ± 0.12	b	0.88 ± 0.11
-26	"	10.64 ± 0.11	b	0.64 ± 0.11
-23	yellow	12.47 ± 0.12	b	0.40 ± 0.06
-24	"	12.41 ± 0.12	b	0.79 ± 0.09
-11	black	13.03 ± 0.11	b	0.86 ± 0.06
-13	"	11.66 ± 0.11	b	0.77 ± 0.07
-10	"	12.78 ± 0.11	b	0.47 ± 0.04
-12	"	12.78 ± 0.11	b	0.85 ± 0.06
-14	"	12.39 ± 0.13	b	1.05 ± 0.16
-15	"	12.26 ± 0.13	b	1.00 ± 0.11
Mean and RMSD		12.16 ± 1.17	-	0.82 ± 0.22
MAP-18	bl-gr	12.95 ± 0.12	6,985 ± 152	1.69 ± 0.07

Table 2a. continued

Sample	Color	Eu^f	Ba	Sm^f
-16	bl-gr	0.455 ± 0.073	517 ± 38	1.518 ± 0.028
-21	"	0.533 ± 0.080	457 ± 41	1.542 ± 0.032
-19	"	0.644 ± 0.081	498 ± 41	1.508 ± 0.032
-17	"	0.411 ± 0.068	400 ± 35	1.459 ± 0.026
-20	"	0.240 ± 0.090	371 ± 48	1.590 ± 0.040
-27	green	0.404 ± 0.070	353 ± 36	1.379 ± 0.030
-28	"	0.496 ± 0.080	502 ± 42	1.438 ± 0.034
-25	orange	0.250 ± 0.074	471 ± 39	1.307 ± 0.032
-26	"	0.273 ± 0.069	426 ± 36	1.233 ± 0.030
-23	yellow	0.288 ± 0.042	283 ± 22	0.794 ± 0.018
-24	"	0.512 ± 0.060	478 ± 31	1.453 ± 0.025
-11	black	0.315 ± 0.041	320 ± 22	1.231 ± 0.017
-13	"	0.363 ± 0.052	317 ± 26	1.158 ± 0.022
-10	"	0.372 ± 0.032	297 ± 16	1.047 ± 0.012
-12	"	0.419 ± 0.043	302 ± 22	1.396 ± 0.018
-14	"	0.461 ± 0.053	340 ± 31	1.746 ± 0.058
-15	"	0.580 ± 0.074	515 ± 40	1.812 ± 0.033
Mean and RMSD		0.461 ± 0.132	403 ± 85	1.389 ± 0.249
-18	bl-gr	0.877 ± 0.061	170 ± 24	3.661 ± 0.027

Table 2a. continued

Sample	Color	Co	Sc	Fe (%)
-16	bl-gr	3.85 ± 0.72	3.67 ± 0.07	1.04 ± 0.08
-21	"	4.86 ± 0.48	3.67 ± 0.05	1.05 ± 0.06
-19	"	5.05 ± 0.52	3.72 ± 0.05	1.02 ± 0.06
-17	"	3.88 ± 0.52	3.42 ± 0.05	0.84 ± 0.06
-20	"	3.24 ± 0.77	3.74 ± 0.07	0.98 ± 0.09
-27	green	5.53 ± 0.46	3.33 ± 0.04	0.95 ± 0.05
-28	"	4.37 ± 0.72	3.38 ± 0.06	0.85 ± 0.08
-25	orange	4.51 ± 0.45	2.84 ± 0.07	0.82 ± 0.05
-26	"	5.81 ± 0.52	2.89 ± 0.08	0.70 ± 0.06
-23	yellow	3.31 ± 0.27	1.89 ± 0.03	0.61 ± 0.03
-24	"	4.94 ± 0.37	3.61 ± 0.05	1.03 ± 0.05
-11	black	3.53 ± 0.19	2.78 ± 0.04	0.74 ± 0.03
-13	"	5.19 ± 0.34	2.89 ± 0.05	0.70 ± 0.04
-10	"	2.98 ± 0.15	2.40 ± 0.03	0.70 ± 0.02
-12	"	3.87 ± 0.20	3.33 ± 0.04	0.72 ± 0.03
-14	"	3.37 ± 0.34	3.88 ± 0.07	0.93 ± 0.05
-15	"	4.69 ± 0.25	4.04 ± 0.05	0.94 ± 0.03
Mean and RMSD		4.29 ± 0.86	3.26 ± 0.57	0.86 ± 0.14
-18	bl-gr	79.67 ± 1.18	7.59 ± 0.08	2.46 ± 0.06

Table 2a. continued

Sample	Color	Ce	Yb	Ta
-16	bl-gr	17.0 ± 2.0	1.45 ± 0.31	0.388 ± 0.016
-21	"	20.0 ± 1.4	1.69 ± 0.21	0.378 ± 0.010
-19	"	17.6 ± 1.5	1.26 ± 0.22	0.371 ± 0.011
-17	"	17.8 ± 1.4	1.43 ± 0.22	0.941 ± 0.012
-20	"	15.2 ± 2.1	1.06 ± 0.34	0.381 ± 0.016
-27	green	16.3 ± 1.3	1.37 ± 0.21	0.406 ± 0.010
-28	"	17.1 ± 2.1	1.47 ± 0.32	0.381 ± 0.015
-25	orange	14.4 ± 1.7	1.00 ± 0.25	0.444 ± 0.012
-26	"	15.9 ± 2.0	1.15 ± 0.28	1.199 ± 0.015
-23	yellow	8.4 ± 0.9	0.43 ± 0.13	0.211 ± 0.007
-24	"	17.3 ± 1.3	1.15 ± 0.18	0.449 ± 0.010
-11	black	14.9 ± 0.7	0.73 ± 0.10	0.329 ± 0.007
-13	"	15.4 ± 1.1	0.82 ± 0.16	0.313 ± 0.011
-10	"	12.4 ± 0.5	0.63 ± 0.08	0.267 ± 0.005
-12	"	15.1 ± 0.7	1.00 ± 0.11	0.867 ± 0.008
-14	"	21.6 ± 1.4	1.31 ± 0.20	0.569 ± 0.014
-15	"	20.0 ± 1.0	1.06 ± 0.15	0.876 ± 0.011
Mean and RMSD		16.3 ± 3.0	1.12 ± 0.33	0.52 ± 0.28
-18	bl-gr	33.4 ± 1.3	1.34 ± 0.20	2.159 ± 0.013

Table 2a. continued

Sample	Color	Sb^c	$Sn^{b,c}$	Cr
-16	bl-gr	111.7 ± 5.8	7,040 ± 39	42.7 ± 4.3
-21	"	125.2 ± 6.4	9,440 ± 32	41.0 ± 3.0
-19	"	131.2 ± 6.8	7,634 ± 30	38.5 ± 3.2
-17	"	113.8 ± 5.7	6,441 ± 28	41.7 ± 3.1
-20	"	200.8 ± 10.4	7,355 ± 40	43.5 ± 4.8
-27	green	167.5 ± 8.5	10,740 ± 32	34.9 ± 2.9
-28	"	185.5 ± 9.6	12,141 ± 47	52.3 ± 4.7
-25	orange	78.6 ± 4.2	14,928 ± 45	29.9 ± 3.5
-26	"	73.5 ± 4.0	14,806 ± 49	30.6 ± 4.0
-23	yellow	18.9 ± 1.2	3,815 ± 19	17.0 ± 1.8
-24	"	40.9 ± 2.3	7,214 ± 29	37.1 ± 2.6
-11	black	1.3 ± 0.2	b	28.5 ± 1.4
-13	"	5.1 ± 0.5	b	33.4 ± 2.2
-10	"	1.2 ± 0.2	b	26.0 ± 1.1
-12	"	6.4 ± 0.4	b	28.7 ± 1.5
-14	"	9.7 ± 0.8	b	58.9 ± 2.9
-15	"	4.1 ± 0.4	b	48.6 ± 2.0
Mean and RMSD		-	-	37.3 ± 10.4
-18	bl-gr	22.2 ± 1.3	b	46.7 ± 3.0

Table 2a. concluded

Sample	Color	Th	Hf	Zn^c
-16	bl-gr	7.91 ± 0.24	3.12 ± 0.56	54 ± 17
-21	"	8.02 ± 0.16	2.50 ± 0.37	59 ± 11
-19	"	11.76 ± 0.18	2.35 ± 0.39	70 ± 13
-17	"	10.77 ± 0.18	2.47 ± 0.40	37 ± 13
-20	"	9.96 ± 0.26	2.34 ± 0.58	66 ± 18
-27	green	16.92 ± 0.18	2.75 ± 0.36	667 ± 15
-28	"	7.85 ± 0.24	3.65 ± 0.57	809 ± 24
-25	orange	8.49 ± 0.19	2.40 ± 0.46	7,167 ± 46
-26	"	6.78 ± 0.21	1.48 ± 0.52	6,912 ± 51
-23	yellow	3.62 ± 0.10	1.28 ± 0.24	33 ± 7
-24	"	7.52 ± 0.15	2.49 ± 0.35	40 ± 9
-11	black	4.33 ± 0.09	1.74 ± 0.22	48 ± 5
-13	"	6.94 ± 0.15	2.30 ± 0.32	52 ± 9
-10	"	2.96 ± 0.06	1.94 ± 0.17	35 ± 4
-12	"	6.47 ± 0.10	2.14 ± 0.23	57 ± 6
-14	"	12.71 ± 0.21	2.29 ± 0.42	63 ± 10
-15	"	13.13 ± 0.15	2.88 ± 0.29	81 ± 8
Mean and RMSD		8.60 ± 3.63	2.36 ± 0.57	54 ± 15^e
-18	bl-gr	8.07 ± 0.16	3.84 ± 0.47	344 ± 17

Table 2b. Beads from Bambandyanalo: Neutron Activation Analysis[a,g]

Sample	Color	Al (%)	Mn[c]
BAM-S18a	black	2.90 ± 0.74	387 ± 28
BAM-S18b	"	2.54 ± 0.60	530 ± 21
BAM-S18c	"	1.98 ± 0.76	472 ± 19
BAM-S21a	"	2.52 ± 0.25	554 ± 18
BAM-S21b	"	3.73 ± 0.63	581 ± 23
BAM-S29b1	purple	3.84 ± 0.32	13,738 ± 197
BAM-S29b2	"	4.25 ± 0.55	15,079 ± 231
BAM-S29b3	"	4.39 ± 0.93	14,074 ± 411

Table 2c. Beads from Mjelele Valley Burial: Neutron Activation Analysis[a,h]

Sample	Color	Al (%)	Mn[c]
MJE-15b	black	3.13 ± 0.16	610 ± 18

Table 2b. continued

Sample	Color	Na (%)	Cu^{c,g}	U
-S18a	black	13.44 ± 0.12	g	1.19 ± 0.09
-S18b	"	13.17 ± 0.12	g	1.11 ± 0.07
-S18c	"	13.52 ± 0.12	g	0.62 ± 0.06
-S21a	"	12.98 ± 0.12	g	0.73 ± 0.07
-S21b	"	12.96 ± 0.12	g	0.63 ± 0.08
-S29b1	purple	10.00 ± 0.10	g	1.28 ± 0.12
-S29b2	"	11.45 ± 0.12	g	1.29 ± 0.13
-S29b3	"	10.76 ± 0.13	g	1.53 ± 0.16

Table 2c. continued

Sample	Color	Na (%)	Cu^{c,h}	U
-15b	black	12.06 ± 0.05	h	1.19 ± 0.09

Table 2b. continued

Sample	Color	Eu^f	Ba	Sm^f
-S18a	black	0.465 ± 0.043	375 ± 24	1.746 ± 0.029
-S18b	"	0.465 ± 0.041	441 ± 24	1.602 ± 0.023
-S18c	"	0.472 ± 0.032	462 ± 19	1.404 ± 0.018
-S21a	"	0.421 ± 0.040	423 ± 23	1.522 ± 0.022
-S21b	"	0.498 ± 0.045	451 ± 25	1.571 ± 0.027
-S29b1	purple	0.540 ± 0.089	631 ± 48	1.833 ± 0.033
-S29b2	"	0.481 ± 0.099	741 ± 53	2.071 ± 0.039
-S29b3	"	0.312 ± 0.116	602 ± 62	2.161 ± 0.046

Table 2c. continued

Sample	Color	Eu^f	Ba	Sm^f
-15b	black	0.284 ± 0.126	432 ± 48	1.459 ± 0.020

Table 2b. continued

Sample	Color	Co	Sc	Fe (%)
-S18a	black	4.42 ± 0.26	4.08 ± 0.05	1.10 ± 0.04
-S18b	"	3.65 ± 0.13	3.86 ± 0.03	0.86 ± 0.02
-S18c	"	4.66 ± 0.18	3.42 ± 0.03	0.83 ± 0.03
-S21a	"	8.92 ± 0.30	3.67 ± 0.04	0.83 ± 0.03
-S21b	"	11.49 ± 0.37	3.64 ± 0.05	1.10 ± 0.04
-S29b1	purple	14.26 ± 0.57	4.49 ± 0.07	1.12 ± 0.05
-S29b2	"	15.35 ± 0.67	5.18 ± 0.09	1.25 ± 0.06
-S29b3	"	12.18 ± 0.70	5.32 ± 0.10	1.30 ± 0.07

Table 2c. continued

Sample	Color	Co	Sc	Fe (%)
-15b	black	8.59 ± 0.30	3.48 ± 0.04	1.01 ± 0.03

Table 2b. continued

Sample	Color	Ce	Yb	Ta
-S18a	black	19.0 ± 1.1	1.12 ± 0.11	0.859 ± 0.012
-S18b	"	19.0 ± 0.5	1.00 ± 0.05	0.471 ± 0.005
-S18c	"	16.9 ± 0.6	0.81 ± 0.06	0.378 ± 0.006
-S21a	"	18.2 ± 0.8	0.89 ± 0.08	0.605 ± 0.008
-S21b	"	16.4 ± 0.9	1.12 ± 0.09	0.717 ± 0.009
-S29b1	purple	22.4 ± 1.5	1.22 ± 0.22	0.688 ± 0.015
-S29b2	"	27.7 ± 1.8	1.63 ± 0.26	0.807 ± 0.018
-S29b3	"	29.8 ± 2.2	2.25 ± 0.31	1.211 ± 0.023

Table 2c. continued

Sample	Color	Ce	Yb	Ta
-15b	black	17.0 ± 0.9	0.71 ± 0.08	0.357 ± 0.008

Table 2b. continued

Sample	Color	Sb[c]	Sn[c,g]	Cr
-S18a	black	3.0 ± 0.3	g	259.3 ± 3.8
-S18b	"	1.2 ± 0.1	g	37.5 ± 1.1
-S18c	"	1.6 ± 0.1	g	33.2 ± 1.3
-S21a	"	3.6 ± 0.3	g	39.8 ± 1.7
-S21b	"	8.0 ± 0.5	g	42.8 ± 1.9
-S29b1	purple	12.7 ± 1.0	1,849 ± 21	45.1 ± 2.9
-S29b2	"	13.7 ± 1.1	1,977 ± 26	60.4 ± 3.5
-S29b3	"	16.9 ± 1.4	2,130 ± 31	76.7 ± 4.2

Table 2c. continued

Sample	Color	Sb	Sn[h]	Cr
-15b	black	7.1 ± 0.5	h	34.8 ± 2.2

Table 2b. concluded

Sample	Color	Th	Hf	Zn^c
-S18a	black	12.15 ± 0.15	3.29 ± 0.33	72 ± 8
-S18b	"	6.90 ± 0.07	2.46 ± 0.16	45 ± 4
-S18c	"	4.41 ± 0.07	2.23 ± 0.19	48 ± 5
-S21a	"	8.39 ± 0.11	2.50 ± 0.24	48 ± 7
-S21b	"	8.50 ± 0.12	2.85 ± 0.28	51 ± 8
-S29b1	purple	21.12 ± 0.24	3.54 ± 0.43	343 ± 16
-S29b2	"	29.15 ± 0.31	3.12 ± 0.52	335 ± 19
-S29b3	"	35.01 ± 0.39	3.54 ± 0.61	349 ± 22

Table 2c. concluded

Sample	Color	Th	Hf	Zn
-15b	black	1.92 ± 0.10	2.40 ± 0.25	58 ± 7

Notes to Table 2

a. All results are given in parts per million unless otherwise indicated.

b. Imprecisely-determined elements (defined in Chapter 3) are excluded from this Table. The following are imprecisely-determined elements for which a mean concentration (with root mean square deviation) could be determined for the Mapungubwe Chemical Group: Ca, 8.05 ± 3.14%; Cl, 1.132 ± 0.407%; Dy, 7.13 ± 5.87 ppm; Ag, for blue-green, 4.6 ± 2.5 ppm, for green, 23.0 ± 0.7 ppm, for orange, 10.6 ± 2.1 ppm, for yellow, 7.0 ± 2.3 ppm; Tb, 0.22 ± 0.10 ppm; Cs, 0.62 ± 0.26 ppm; La, 6.32 ± 3.15 ppm; Lu, 0.10 ± 0.04 ppm; As, 73.7 ± 71.8 ppm; Nd, 4.3 ± 3.3 ppm; Mo, 3.1 ± 2.5 ppm; Ho, 0.9 ± 0.5 ppm. The following are imprecisely-determined elements for which approximate upper limits of abundance for the Mapungubwe Chemical Group could be estimated. The approximate upper limit is given with an estimated representative counting error: Sn, where not used as an additive, 200 ± 15 ppm; Cu, where not used as an additive, 600 ± 200 ppm; Mg, 3.0 ± 3.0%; V, 50 ± 50 ppm; K, 2.0 ± 1.0%; Sr, 0.04 ± 0.04%; Ga, 300 ± 200 ppm; In, 5 ± 5 ppm; Ag, for black, 0.7 ± 1.3 ppm; Ir, 0.020 ± 0.010 ppm; Hg, assuming none is lost in the reactor, 0.4 ± 0.6 ppm; Ni, 50 ± 20 ppm; Rb, 60 ± 20 ppm; and W, 4.0 ± 4.0 ppm. A cobalt blue bead was analyzed by neutron activation, but its tiny weight (4.8 mg) does not allow confidence in all the results. However, the upper limits of concentration of the following elements of possible interest are: Na, 11.3 ± 0.1%; Mn, 434 ± 54 ppm; Cu, ~400 ppm; K, 4.1 ± 1.7%; As, 2558 ± 364 ppm; U, 1.7 ± 0.3 ppm; Co, 2134 ± 22 ppm; Sc, 5.2 ± 0.4 ppm; Fe, 1.6 ± 0.2 ppm; Sb, 9 ± 2 ppm;

Sn, ≤ 200 ppm. Pb was determined by X-ray fluorescence analysis on grouped samples of oblate shaped beads from Mapungubwe, Skeleton 14, with the following results: black, 0.02%; blue-green, 0.1 to 1.0%; green, 6.7 ± 1.0%; orange, 10.0 ± 2.0%; yellow, 6.3 ± 1.0%; cobalt blue, <0.1%.

c. Glassmaker's additive, or an element possibly correlated with a glassmaker's additive. Such elements are used in comparisons where appropriate.

d. Root mean square deviation (see Chapter 3).

e. A base-line mean, calculated from the specimens in which this glassmaker's additive is apparently not in use.

f. Element omitted from comparisons to avoid over-representation from the lanthanide series.

g. Imprecisely-determined elements are excluded from this Table. For the three purple beads, elements for which a mean concentration could be determined are (with root mean square deviation): Ca, 3.62 ± 3.02%; Cl, 0.74 ± 0.19%; Dy, 44.52 ± 17.57 ppm; Tb, 0.30 ± 0.06 ppm; Cs, 1.73 ± 0.67 ppm; La, 11.11 ± 0.94 ppm; Lu, 0.24 ± 0.05 ppm; Nd, 9.3 ± 1.4 ppm; Mo, 22.57 ± 10.16 ppm; Ho, 2.13 ± 1.72 ppm. For the three purple beads, elements for which approximate upper limits of abundance could be determined are (with an estimated representative counting error): Cu, 350 ± 230 ppm; Mg, 5.0 ± 5.0%; V, 100 ± 150 ppm; K, 4.0 ± 1.5%; Sr, 0.04 ± 0.04 ppm; Ga, 300 ± 150 ppm; As, 100 ± 90 ppm; Ag, 3 ± 2 ppm; Ir, 0.005 ± 0.010 ppm; Hg, assuming none is lost in the reactor, 0.5 ± 0.8 ppm; Ni, 70 ± 35 ppm; Rb, 40 ± 20 ppm; and W, 12 ± 4 ppm. Pb was determined by X-ray fluorescence analysis on grouped purple samples, with the result 0.5 ± 0.1%. For the five black beads, elements for which a mean concentration could be determined are (with root mean square deviation): Ca, 7.03 ± 2.70%; Cl, 1.06 ± 0.24%; Dy, 3.52 ± 0.93 ppm; Tb, 0.21 ± 0.02 ppm; Cs, 0.80 ± 0.12 ppm; La, 8.95 ± 1.09 ppm; Lu, 0.112 ± 0.029 ppm; Nd, 6.1 ± 2.9 ppm; Mo, 4.90 ± 2.33 ppm; Ho, 1.09 ± 0.29 ppm. For the five black beads, elements for which approximate upper limits of abundance could be determined are (with an estimated representative counting error): Cu, 400 ± 150 ppm; Sn, 180 ± 20 ppm; Mg, 5.0 ± 3.0%; V, 30 ± 60 ppm; K, 2.5 ± 1.0%; Sr, 600 ± 600 ppm; Ga, 250 ± 100 ppm; As, 70 ± 70 ppm; Ag, 1.0 ± 1.0 ppm; Ir, 0.010 ± 0.006 ppm; Hg, assuming none is lost in the reactor, 0.01 ± 0.40 ppm; Ni, 30 ± 20 ppm; Rb, 40 ± 15 ppm; and W, 1.2 ± 4.0 ppm. Pb was determined by X-ray fluorescence on grouped black samples, with the result $\lesssim$ 0.04%.

h. For MJE-15b, the imprecisely-determined results, with counting errors, are: Ca, 8.95 ± 1.64%; Cl, 0.81 ± 0.22%; Dy, 3.42 ± 0.61 ppm; Tb, 0.17 ± 0.05 ppm; Cs, 1.0 ± 0.2 ppm; La, 5.1 ± 1.8 ppm; Lu, 0.095 ± 0.055 ppm; Nd, 5.2 ± 6.2 ppm; Mo, 2.8 ± 1.5 ppm; Ho, 1.3 ± 0.5 ppm. Elements for which upper limits can be stated are: Cu $\lesssim$ 600 ppm; Sn, $\lesssim$ 400 ppm; Mg, $\lesssim$ 3%; V, < 70 ppm; K, $\lesssim$ 4%; Sr, $\lesssim$ 700 ppm; Ga, $\lesssim$ 200 ppm; As, $\lesssim$ 6 ppm; Ag, $\lesssim$ 1 ppm; Ir, $\lesssim$ 0.007 ppm; Hg, assuming none is lost in the reactor, $\lesssim$ 0.7 ppm; Ni, $\lesssim$ 35 ppm; Rb, $\lesssim$ 40 ppm; W, $\lesssim$ 2. ppm; Pb, as determined by X-ray fluorescence of grouped samples, $\sim$ 0.03%.

Table 3a. Beads of M_1 Type:
X-ray Fluorescence Analysis [a]

	Fe	Cu	Zn	Rb	Sr	Zr	Sn	Sb	Ba	Pb	U
1.	1.0 ± 0.2	0.49 ± 0.06	<0.01	0.01	0.03	0.06 ± 0.01	0.019 ± 0.004	0.002	0.06 ± 0.01	0.05	b
2.	0.8 ± 0.2	0.62 ± 0.07	<0.01	0.01	0.03	0.06 ± 0.01	0.021 ± 0.004	0.004	0.06 ± 0.01	0.05	b
3.	0.9 ± 0.2	0.42 ± 0.05	<0.01	0.01	0.02	0.05 ± 0.01	0.033 ± 0.006	0.003	0.06 ± 0.01	0.10 ± 0.03	b
4.	0.8 ± 0.2	0.23 ± 0.04	<0.01	0.01	0.02	0.06 ± 0.01	0.026 ± 0.005	0.002	0.06 ± 0.01	0.06	b
5.	0.8 ± 0.2	0.26 ± 0.04	<0.01	0.01	0.02	0.03 ± 0.01	0.07 ± 0.02	~0.004	0.06 ± 0.01	0.06 ± 0.02	b
6.	0.7 ± 0.2	0.5 ± 0.1	<0.01	0.01	0.02	0.03 ± 0.01	0.018 ± 0.004	~0.004	0.06 ± 0.01	0.03	b
7.	0.7 ± 0.2	0.16 ± 0.04	0.03	~0.01	0.02	0.04 ± 0.01	0.022 ± 0.005	<0.005	0.07 ± 0.02	0.09 ± 0.03	c
8.	0.9 ± 0.2	0.37 ± 0.07	0.03	<0.01	0.02	0.02	0.06 ± 0.01	<0.005	0.04 ± 0.01	0.17 ± 0.04	c

[a] Elements not detected (with limit of detection): Mn (0.1); Co (0.05); As (0.03). All data are given in percent.

[b] Not detected. Many of these samples were analyzed by neutron activation analysis (Table 4). The mean U concentration in beads of M_1 type analyzed by neutron activation was 34 ppm. This amount is near the expected threshold of U detection by the X-ray fluorescence method used.

[c] Detected.

Table 3b. Identification of Samples

Provenience	Number of Beads in Sample	Shapes
1. Bambandyanalo, K.S. No. 45 (Block 3, Strip 4)	6	cyl.
2. " " "	5	"
3. " " "	4	cyl. and obl.
4. " " "	4	cyl.
5. " K.S. No. 43 "	29	obl.
6. " " "	4	cyl.
7. Zimbabwe Acropolis, T. IX, below 24" (NMR 58705)	1	"
8. " " " "	1	"

Table 4a. M_1 Beads: Neutron Activation Analysis[a,b]

Sample	Al (%)	Cl (%)	Mn
BAM-S43a	4.24 ± 0.21	0.75 ± 0.17	256 ± 16
BAM-S43b	4.95 ± 0.38	0.78 ± 0.20	279 ± 26
BAM-S43c	3.93 ± 0.52	0.97 ± 0.20	267 ± 27
BAM-S43d	5.53 ± 0.39	0.82 ± 0.22	262 ± 22
BAM-S43e	4.45 ± 0.20	0.50 ± 0.18	263 ± 21
BAM-S43f	4.94 ± 0.57	0.65 ± 0.24	262 ± 26
BAM-S43g	3.82 ± 0.31	0.89 ± 0.25	263 ± 16
BAM-S43h	4.50 ± 0.49	0.66 ± 0.23	239 ± 15
BAM-S43i	3.77 ± 0.66	0.70 ± 0.24	254 ± 16
BAM-S43j	4.25 ± 1.23	0.53 ± 0.29	253 ± 21
BAM-S43k	4.22 ± 0.27	0.33 ± 0.31	251 ± 22
BAM-S43l	4.20 ± 0.21	0.41 ± 0.24	229 ± 17
BAM-S43m	4.09 ± 0.41	0.44 ± 0.31	242 ± 23
BAM-S43n	3.89 ± 0.54	0.22 ± 0.29	168 ± 23
BAM-S43p	5.82 ± 0.88	0.79 ± 0.35	475 ± 29
BAM-S43q	3.39 ± 0.31	0.66 ± 0.21	242 ± 12
BAM-S45a	5.04 ± 0.25	0.66 ± 0.23	279 ± 22
BAM-S45b	5.76 ± 0.31	0.71 ± 0.22	332 ± 22
BAM-S45c	4.73 ± 0.25	0.68 ± 0.18	324 ± 21
BAM-S45d	4.09 ± 0.26	0.64 ± 0.26	224 ± 18
BAM-S45e	4.22 ± 0.34	0.68 ± 0.27	285 ± 23
BAM-S45f	3.61 ± 0.38	1.70 ± 0.24	485 ± 21
BAM-S45g	4.68 ± 0.61	0.97 ± 0.30	323 ± 26
BAM-S45h	3.23 ± 0.93	1.12 ± 0.32	336 ± 34
BAM-S45i	4.59 ± 0.33	0.38 ± 0.26	219 ± 27
BAM-S45j	3.92 ± 0.46	0.88 ± 0.30	258 ± 32
BAM-S45k	4.82 ± 0.43	1.08 ± 0.23	394 ± 26
BAM-S45l	3.31 ± 0.65	0.65 ± 0.26	319 ± 30
BAM-S45m	4.45 ± 0.89	1.22 ± 0.25	384 ± 31
Mean and RMSD[d]	4.36 ± 0.67	0.74 ± 0.30	289 ± 72

Table 4a. continued

Sample	Na (%)	Cu[c]	U
-S43a	14.58 ± 0.13	3,245 ± 135	16.47 ± 0.18
-S43b	14.89 ± 0.14	3,073 ± 156	19.62 ± 0.22
-S43c	14.76 ± 0.14	3,355 ± 155	19.14 ± 0.21
-S43d	15.15 ± 0.15	3,742 ± 172	16.50 ± 0.21
-S43e	14.76 ± 0.14	3,338 ± 151	17.79 ± 0.20
-S43f	15.41 ± 0.15	3,724 ± 187	19.56 ± 0.25
-S43g	14.61 ± 0.14	3,392 ± 170	21.33 ± 0.24
-S43h	14.85 ± 0.14	3,426 ± 153	20.22 ± 0.21
-S43i	14.76 ± 0.13	3,470 ± 150	20.48 ± 0.21
-S43j	14.54 ± 0.14	3,298 ± 182	19.60 ± 0.24
-S43k	14.78 ± 0.15	3,271 ± 203	18.63 ± 0.26
-S43l	14.85 ± 0.14	3,098 ± 154	19.81 ± 0.21
-S43m	15.02 ± 0.15	3,784 ± 198	18.70 ± 0.25
-S43n	11.69 ± 0.12	9,297 ± 218	26.04 ± 0.30
-S43p	14.56 ± 0.15	6,873 ± 237	24.30 ± 0.31
-S43q	13.71 ± 0.12	5,581 ± 148	25.11 ± 0.23
-S45a	14.52 ± 0.15	4,631 ± 192	67.19 ± 0.55
-S45b	13.42 ± 0.13	5,568 ± 184	23.53 ± 0.27
-S45c	12.99 ± 0.12	5,023 ± 149	21.97 ± 0.22
-S45d	14.09 ± 0.14	5,110 ± 184	41.19 ± 0.36
-S45e	12.97 ± 0.13	8,169 ± 209	33.40 ± 0.33
-S45f	11.27 ± 0.11	4,807 ± 172	122.74 ± 0.80
-S45g	13.56 ± 0.14	9,848 ± 226	27.96 ± 0.31
-S45h	13.24 ± 0.14	9,570 ± 245	27.03 ± 0.33
-S45i	12.54 ± 0.13	6,905 ± 201	23.23 ± 0.28
-S45j	14.24 ± 0.15	7,127 ± 224	23.84 ± 0.29
-S45k	11.70 ± 0.12	3,179 ± 156	84.85 ± 0.58
-S45l	11.46 ± 0.12	2,791 ± 172	82.24 ± 0.59
-S45m	11.60 ± 0.12	2,875 ± 169	84.65 ± 0.60
Mean, RMSD	13.81 ± 1.27	4,882 ± 2,168	34.04 ± 26.88

Table 4a. continued

Sample	Sm	Co	Sc
-S43a	4.246 ± 0.048	4.40 ± 0.30	3.59 ± 0.05
-S43b	4.266 ± 0.059	5.34 ± 0.32	3.85 ± 0.05
-S43c	4.300 ± 0.058	4.41 ± 0.30	3.69 ± 0.05
-S43d	4.458 ± 0.059	4.98 ± 0.40	3.89 ± 0.06
-S43e	4.457 ± 0.055	5.34 ± 0.32	3.71 ± 0.05
-S43f	4.288 ± 0.067	5.58 ± 0.44	4.11 ± 0.07
-S43g	4.196 ± 0.054	5.17 ± 0.40	3.82 ± 0.06
-S43h	4.276 ± 0.049	5.37 ± 0.35	3.76 ± 0.05
-S43i	4.122 ± 0.048	5.45 ± 0.36	3.72 ± 0.05
-S43j	4.388 ± 0.055	5.60 ± 0.38	3.98 ± 0.06
-S43k	4.407 ± 0.060	5.49 ± 0.49	4.00 ± 0.08
-S43l	4.200 ± 0.049	5.44 ± 0.32	3.80 ± 0.05
-S43m	4.605 ± 0.059	5.70 ± 0.46	3.93 ± 0.07
-S43n	6.393 ± 0.072	13.82 ± 0.63	4.12 ± 0.07
-S43p	3.937 ± 0.068	6.38 ± 0.61	4.22 ± 0.09
-S43q	3.902 ± 0.050	4.95 ± 0.32	3.71 ± 0.05
-S45a	5.870 ± 0.140	6.34 ± 0.44	5.70 ± 0.07
-S45b	2.951 ± 0.068	5.08 ± 0.38	6.32 ± 0.08
-S45c	2.839 ± 0.057	4.65 ± 0.29	5.94 ± 0.06
-S45d	2.719 ± 0.076	6.07 ± 0.49	4.84 ± 0.07
-S45e	4.025 ± 0.071	8.34 ± 0.59	4.83 ± 0.09
-S45f	3.892 ± 0.178	6.69 ± 0.55	4.32 ± 0.07
-S45g	4.647 ± 0.068	7.28 ± 0.58	4.82 ± 0.08
-S45h	4.507 ± 0.072	7.26 ± 0.60	5.13 ± 0.08
-S45i	7.786 ± 0.068	18.02 ± 0.64	3.55 ± 0.06
-S45j	6.240 ± 0.068	4.56 ± 0.39	4.21 ± 0.07
-S45k	4.055 ± 0.028	7.07 ± 0.35	4.70 ± 0.05
-S45l	4.338 ± 0.129	7.59 ± 0.38	4.78 ± 0.06
-S45m	4.103 ± 0.131	8.03 ± 0.44	4.90 ± 0.06
Mean, RMSD	4.43 ± 1.03	6.57 ± 2.86	4.34 ± 0.73

Table 4a. continued

Sample	Fe (%)	Yb	Ta
-S43a	0.89 ± 0.04	1.40 ± 0.12	0.47 ± 0.01
-S43b	1.03 ± 0.04	1.55 ± 0.13	0.46 ± 0.01
-S43c	1.05 ± 0.04	1.39 ± 0.12	0.38 ± 0.01
-S43d	0.90 ± 0.05	1.49 ± 0.17	0.44 ± 0.02
-S43e	0.97 ± 0.04	1.42 ± 0.12	0.37 ± 0.01
-S43f	1.04 ± 0.05	1.42 ± 0.17	0.44 ± 0.02
-S43g	1.16 ± 0.05	1.57 ± 0.15	0.56 ± 0.02
-S43h	1.04 ± 0.04	1.76 ± 0.13	0.43 ± 0.01
-S43i	0.95 ± 0.04	1.55 ± 0.13	0.41 ± 0.01
-S43j	1.03 ± 0.04	1.43 ± 0.14	0.45 ± 0.02
-S43k	1.01 ± 0.06	1.33 ± 0.19	0.43 ± 0.02
-S43l	1.00 ± 0.04	1.45 ± 0.12	0.40 ± 0.01
-S43m	1.03 ± 0.05	1.25 ± 0.18	0.49 ± 0.02
-S43n	1.07 ± 0.05	1.66 ± 0.19	0.44 ± 0.02
-S43p	1.15 ± 0.07	1.48 ± 0.23	0.46 ± 0.02
-S43q	0.93 ± 0.04	1.72 ± 0.12	0.42 ± 0.01
-S45a	1.09 ± 0.05	2.53 ± 0.19	0.74 ± 0.02
-S45b	1.14 ± 0.05	1.69 ± 0.18	0.78 ± 0.02
-S45c	0.99 ± 0.04	1.18 ± 0.13	0.72 ± 0.01
-S45d	1.11 ± 0.06	1.25 ± 0.18	0.63 ± 0.02
-S45e	1.56 ± 0.07	1.54 ± 0.21	0.63 ± 0.02
-S45f	0.96 ± 0.06	1.26 ± 0.19	0.57 ± 0.02
-S45g	1.29 ± 0.07	2.03 ± 0.22	0.66 ± 0.02
-S45h	1.16 ± 0.07	1.70 ± 0.22	0.61 ± 0.02
-S45i	0.76 ± 0.05	2.77 ± 0.18	0.57 ± 0.02
-S45j	0.93 ± 0.05	2.48 ± 0.20	0.80 ± 0.02
-S45k	1.16 ± 0.04	1.61 ± 0.13	0.56 ± 0.01
-S45l	1.10 ± 0.04	2.64 ± 0.16	1.48 ± 0.02
-S45m	1.18 ± 0.05	1.74 ± 0.16	0.62 ± 0.02
Mean, RMSD	1.06 ± 0.15	1.67 ± 0.43	0.57 ± 0.22

Table 4a. continued

Sample	Sb	Sn	Th
-S43a	16.7 ± 0.9	431 ± 19	38.18 ± 0.30
-S43b	18.6 ± 1.1	439 ± 20	36.76 ± 0.31
-S43c	18.0 ± 1.0	436 ± 19	37.03 ± 0.31
-S43d	19.2 ± 1.2	493 ± 26	40.48 ± 0.39
-S43e	18.2 ± 1.0	485 ± 20	38.48 ± 0.32
-S43f	18.0 ± 1.2	435 ± 27	38.74 ± 0.39
-S43g	21.0 ± 1.4	480 ± 16	31.17 ± 0.30
-S43h	20.0 ± 1.3	479 ± 14	30.49 ± 0.27
-S43i	28.9 ± 1.7	485 ± 14	28.83 ± 0.26
-S43j	22.4 ± 1.4	489 ± 15	29.74 ± 0.28
-S43k	22.0 ± 1.6	477 ± 21	29.11 ± 0.34
-S43l	21.2 ± 1.3	461 ± 13	31.18 ± 0.25
-S43m	20.5 ± 1.4	490 ± 20	32.93 ± 0.34
-S43n	18.3 ± 1.4	99 ± 21	44.55 ± 0.41
-S43p	30.0 ± 2.1	133 ± 25	28.27 ± 0.39
-S43q	17.6 ± 1.1	76 ± 12	24.78 ± 0.23
-S45a	22.8 ± 1.4	297 ± 30	70.35 ± 0.54
-S45b	15.6 ± 1.0	145 ± 25	49.86 ± 0.44
-S45c	16.6 ± 0.9	174 ± 19	44.92 ± 0.35
-S45d	29.0 ± 1.9	399 ± 18	18.20 ± 0.29
-S45e	18.6 ± 1.4	208 ± 22	20.62 ± 0.34
-S45f	22.7 ± 1.6	255 ± 20	24.02 ± 0.33
-S45g	35.9 ± 2.3	190 ± 22	29.68 ± 0.37
-S45h	33.0 ± 2.2	168 ± 23	27.10 ± 0.37
-S45i	26.6 ± 1.7	334 ± 19	31.82 ± 0.33
-S45j	8.2 ± 0.8	163 ± 94	23.67 ± 0.32
-S45k	21.1 ± 1.3	250 ± 13	21.98 ± 0.23
-S45l	11.5 ± 0.8	116 ± 16	16.96 ± 0.24
-S45m	19.9 ± 1.3	259 ± 16	22.69 ± 0.27
Mean, RMSD	21.1 ± 6.0	322 ± 149	32.5 ± 10.9

Table 4a. concluded

Sample	Tb^e	Hf	Zn
-S43a	0.446 ± 0.081	11.10 ± 0.42	119 ± 9
-S43b	0.545 ± 0.082	10.36 ± 0.45	124 ± 9
-S43c	0.611 ± 0.080	10.77 ± 0.45	117 ± 9
-S43d	0.540 ± 0.107	12.07 ± 0.56	118 ± 12
-S43e	0.544 ± 0.081	9.54 ± 0.43	97 ± 9
-S43f	0.401 ± 0.111	10.31 ± 0.56	102 ± 13
-S43g	0.506 ± 0.099	9.64 ± 0.49	122 ± 11
-S43h	0.376 ± 0.087	12.50 ± 0.50	126 ± 10
-S43i	0.251 ± 0.084	10.94 ± 0.46	108 ± 10
-S43j	0.410 ± 0.092	11.65 ± 0.51	107 ± 11
-S43k	0.493 ± 0.116	10.62 ± 0.60	92 ± 14
-S43l	0.395 ± 0.078	9.46 ± 0.41	105 ± 9
-S43m	0.179 ± 0.113	12.11 ± 0.58	121 ± 13
-S43n	0.763 ± 0.124	12.22 ± 0.60	42 ± 13
-S43o	0.394 ± 0.137	7.46 ± 0.64	133 ± 17
-S43q	0.570 ± 0.077	7.42 ± 0.39	38 ± 8
-S45a	0.517 ± 0.132	21.92 ± 0.78	103 ± 12
-S45b	0.483 ± 0.116	24.86 ± 0.84	38 ± 11
-S45c	0.444 ± 0.089	14.70 ± 0.54	41 ± 8
-S45d	0.300 ± 0.105	8.48 ± 0.55	117 ± 14
-S45e	0.543 ± 0.122	11.21 ± 0.68	82 ± 15
-S45f	0.383 ± 0.114	8.98 ± 0.61	127 ± 14
-S45g	0.414 ± 0.128	13.67 ± 0.71	88 ± 15
-S45h	0.584 ± 0.128	12.37 ± 0.70	79 ± 15
-S45i	0.908 ± 0.105	19.37 ± 0.74	207 ± 14
-S45j	0.757 ± 0.109	22.53 ± 0.85	22 ± 10
-S45k	0.380 ± 0.075	11.11 ± 0.48	124 ± 9
-S45l	0.521 ± 0.086	30.28 ± 0.99	43 ± 9
-S45m	0.446 ± 0.091	11.59 ± 0.54	121 ± 11
Mean, RMSD	0.486 ± 0.150	13.07 ± 5.46	99 ± 39

Table 4b. "Garden Roller" Beads: Neutron Activation Analysis[a,f]

Sample	Al (%)	Cl (%)	Mn
BAM-P18a	3.83 ± 0.24	1.20 ± 0.11	249 ± 19
BAM-P18b	3.75 ± 0.38	0.71 ± 0.11	270 ± 21
MST-1	4.00 ± 0.13	0.69 ± 0.13	191 ± 13
MAP-GRX1	3.73 ± 0.08	0.96 ± 0.10	250 ± 10
MAP-GRX2	3.31 ± 0.15	0.81 ± 0.12	197 ± 20
Mean and RMSD[d]	3.73 ± 0.26	0.87 ± 0.22	231 ± 35

Table 4b. continued

Sample	Na (%)	Cu[c]	U
-P18a	13.67 ± 0.13	3,629 ± 94	101.93 ± 0.61
-P18b	13.74 ± 0.13	6,200 ± 109	44.70 ± 0.28
-1	14.87 ± 0.14	6,160 ± 125	25.36 ± 0.18
-GRX1	10.48 ± 0.10	5,055 ± 94	95.11 ± 0.58
-GRX2	15.88 ± 0.15	4,857 ± 107	48.95 ± 0.30
Mean, RMSD	13.73 ± 2.03	5,180 ± 1,064	63.21 ± 33.52

Table 4b. continued

Sample	Sm	Co	Sc
-P18a	4.819 ± 0.155	5.62 ± 0.13	3.63 ± 0.02
-P18b	4.702 ± 0.072	5.07 ± 0.13	5.49 ± 0.02
-1	4.448 ± 0.048	4.04 ± 0.16	3.48 ± 0.03
-GRX1	4.129 ± 0.149	5.96 ± 0.18	4.15 ± 0.03
-GRX2	3.018 ± 0.078	5.83 ± 0.16	3.59 ± 0.02
Mean, RMSD	4.22 ± 0.72	5.31 ± 0.79	4.07 ± 0.84

Table 4b. continued

Sample	Fe (%)	Yb	Ta
-P18a	1.09 ± 0.02	1.53 ± 0.05	0.534 ± 0.004
-P18b	1.21 ± 0.02	2.61 ± 0.07	0.741 ± 0.005
-1	0.90 ± 0.02	1.31 ± 0.06	0.361 ± 0.006
-GRX1	1.04 ± 0.02	1.53 ± 0.06	0.561 ± 0.005
-GRX2	0.82 ± 0.02	1.25 ± 0.05	0.656 ± 0.005
Mean, RMSD	1.01 ± 0.16	1.65 ± 0.55	0.57 ± 0.14

Table 4b. continued

Sample	Sb	Sn	Th
-P18a	20. ± 0.8	211 ± 8	23.34 ± 0.14
-P18b	14.3 ± 0.6	112 ± 8	53.40 ± 0.29
-1	12.2 ± 0.6	62 ± 10	33.81 ± 0.21
-GRX1	19.8 ± 0.8	285 ± 10	29.43 ± 0.19
-GRX2	21.2 ± 0.9	359 ± 8	24.21 ± 0.15
Mean, RMSD	17.5 ± 4.0	206 ±122	32.8 ± 12.2

Table 4b. concluded

Sample	Tb^e	Hf	Zn
-P18a	0.501 ± 0.032	8.21 ± 0.23	154 ± 4
-P18b	0.683 ± 0.056	22.20 ± 0.55	67 ± 4
-1	0.459 ± 0.048	8.11 ± 0.26	110 ± 5
-GRX1	0.374 ± 0.045	10.02 ± 0.29	108 ± 5
-GRX2	0.430 ± 0.037	9.92 ± 0.28	117 ± 4
Mean, RMSD	0.489 ± 0.118	11.69 ± 5.94	111 ± 31

Notes to Table 4

a. All results are given in parts per million unless otherwise indicated.

b. Imprecisely-determined elements (defined in Chapter 3) are omitted from this Table. For the following elements, a mean concentration in the M_1 group (with root mean square deviation) could be determined: Ca, 4.83 ± 2.82%; V, 106 ± 55 ppm; As, 45 ± 40 ppm; Ag, 4.7 ± 1.7 ppm; Cs, 2.1 ± 0.6 ppm; Eu, 0.72 ± 0.23 ppm. Approximate upper limits of abundance were estimated for the M_1 group for the following elements (given with an estimated representative counting error): Mg, 3.0 ± 3.0%; K, 3.0 ± 1.0%; Sr, 1000 ± 600 ppm; Ga, 200 ± 150 ppm; In, 4 ± 4 ppm; Ir, 0.010 ± 0.008 ppm; Hg, assuming none was lost in the reactor, 0.2 ± 0.8 ppm. Pb was determined by x-ray fluorescence of grouped samples with the following results: M_1 beads, Skeleton 43, < 0.08%; M_1 beads, Skeleton 45, < 0.13%.

c. Glassmakers' additive.

d. Root mean square deviation (see Chapter 3).

e. Element omitted from comparisons based on this Table in order to avoid over-representation from the lanthanide series.

f. Imprecisely-determined elements (defined in Chapter 3) are omitted from this Table. Those for which a mean concentration could be determined among the five garden roller beads are (with root mean square deviation): Ca, 3.6 ± 1.2%; V, 83 ± 49 ppm; As, 82 ± 44 ppm; Ag, 4.1 ± 0.4 ppm; Cs, 1.1 ± 0.2 ppm; Eu, 0.61 ± 0.09 ppm. For the following elements upper limits of abundance in the five garden roller beads are given (with estimated representative counting error): Mg, 3.0 ± 1.5%; K, 3.0 ± 1.0%; Sr, 400 ± 500 ppm; Ga, 200 ± 80 ppm; In, 5.0 ± 5.0 ppm; W, 5.0 ± 2.0 ppm; Ir, 0.003 ± 0.003 ppm; Hg, assuming none was lost in the reactor, 0.10 ± 0.20 ppm. Pb was determined by x-ray fluorescence of individual samples, with the result < 0.10%.

CHAPTER 6. HEIRLOOM BEADS

Introduction

Certain glass beads are reported to be regarded as heirlooms by members of the following Transvaal tribes: the Venda of the Zoutspansberg and Pietersburg districts (Stayt 1931b:26; van Riet Lowe 1937:368), the Lovedu of the Pietersburg and Letaba districts (Krige and Krige 1943:236; van Riet Lowe 1937:368; Stayt 1931b:27), the Pedi of Lydenburg district (van Riet Lowe 1937:368; Schofield 1958:193), and the Phalabora west of Kruger National Park (Krige 1937:364) (Figure 9). They are known as "ancestral" beads because they have a connection with the past among the above people, and we shall call them heirloom beads. They do not occur among beads of the Zulu except where, among the Ndebele near Potgietersrust, they were said to have been taken from the Venda (Schofield 1958:195; Dicke 1937:408). Stayt (1931b:27) reports that they may have once occurred among the Karanga of Rhodesia, and the evidence presented here would indicate that this is a credible possibility.

On the basis of both appearance and chemical ingredients the heirloom beads may be divided into two series, which we name Series A and Series B. The present research has found that Series A belongs to a group of beads found in Middle and Later Iron Age archaeological sites in southern Africa, that is, it belongs to the Trade Wind Bead Chemical Group discussed in Chapter 7. The other Series has not yet been related to any large chemical group of beads.

The heirloom beads, which are discoid in shape, show a particular resemblance towards discoid beads from two archaeological sites in

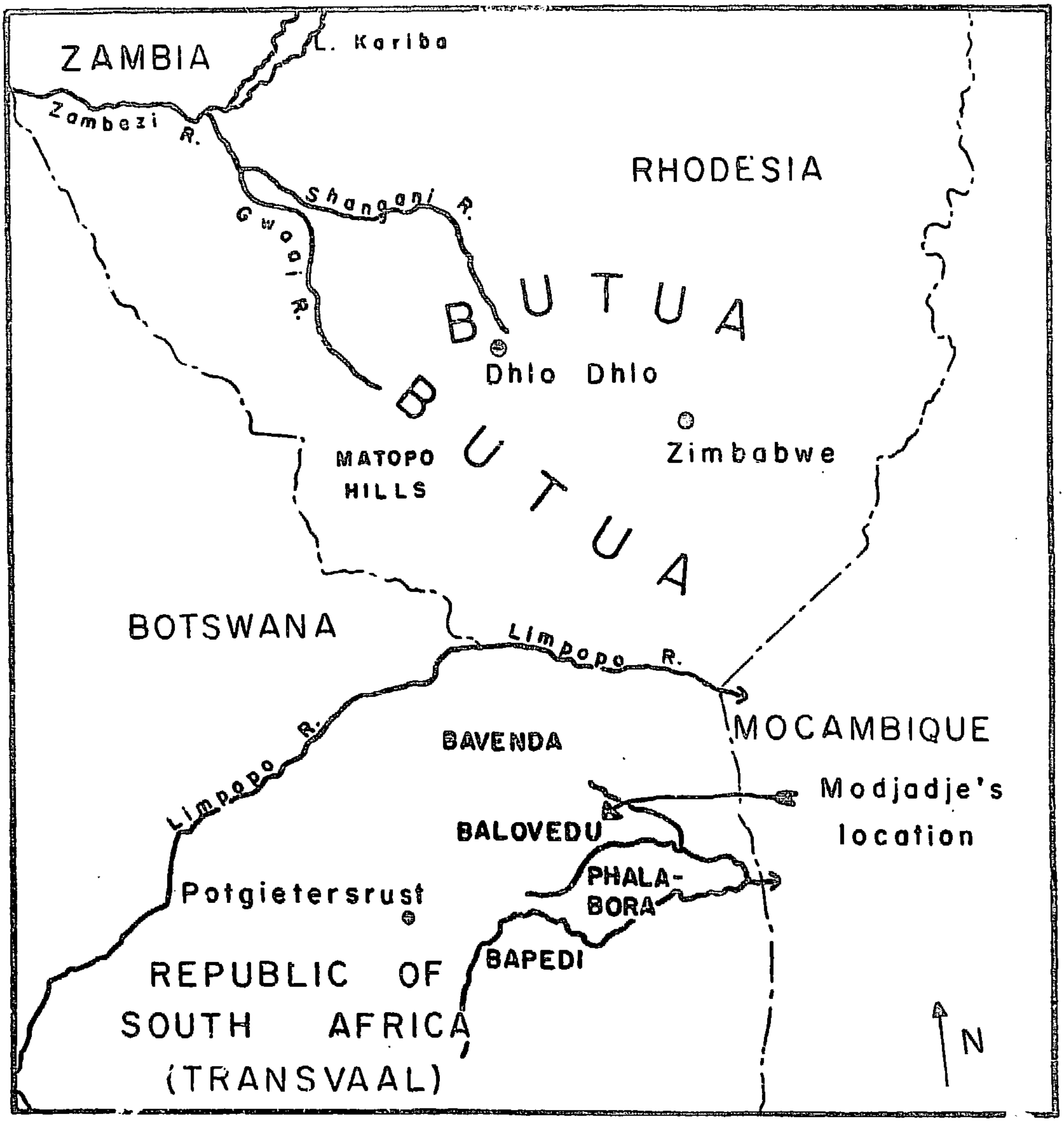

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Figure 9. Distribution of sites discussed in Chapter 6.

Rhodesia: Dhlo Dhlo and the Mjelele Valley Burial. This resemblance is the subject of the present chapter.

Heirloom Beads

History of Heirloom Beads and Their Owners. Heirloom beads seem to be most highly valued among the Venda. These are a composite people, who, before coalescence, came in small groups from north of the Limpopo River into the Njelele Valley of the Transvaal. They later moved to the Zoutspansberg.

Their heirloom beads are said to have been brought to the Transvaal from their earlier home north of the Limpopo. Before crossing the Limpopo, members of the Venda are said to have passed through the country of the Karanga (Rhodesia). They deny a kin relationship to the Karanga, but they consider themselves related by common descent to the Rozwi[9], who ruled the successor state which grew up in the southern provinces of the former Karanga kingdom of Mwene Mutapa.

Stayt (1931a, 1931b) points out that there are many place-name and other similarities between Vendaland and Rhodesia. Similarly, Lestrade (1927) has written on the Rhodesian affinities of the Venda, many others have remarked on the subject, and a dynastic succession linking the Venda and Lovedu to the Mutapa-Rozwi complex has been summarized (Alpers 1970).

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[9] The record is unclear on the origins of the Rozwi. They have been considered late-seventeenth-century conquerors (Fage 1958:24; Wieschoff 1941:11), but a more recent worker has considered them more or less autochthonous within the Karanga, although he has not consistently maintained this position (Abraham 1961:211; Abraham 1964:107). Others characterize the Rozwi as a dynasty collateral to the Mwene Mutapa dynasty (Alpers 1970:203-220).

Among one group of Venda there is a tradition of a more remote origin north of Karanga country, near water (Lestrade 1927:488-491). The great lakes region of east-central Africa has been proposed (Gottschling 1905:365) as this site of ultimate origin, but there is no archaeological evidence for that hypothesis. The glass beads from Sanga, judging by published description (Nenquin 1963), do not resemble heirloom beads.

The date given, estimated by counting back chiefs, for the migration into the Transvaal of people who eventually were to become Venda is c. 1700 A.D. (Krige and Krige 1943:305; Lestrade 1927:490; Stayt 1931b:12). Their name, Venda, is relatively new and applies to the composite group in the Transvaal (Lestrade 1927:492).

Among the Lovedu the beads seem to hold a place of honor similar to that which they hold among the Venda. Like the Venda, the Lovedu are considered to have entered the Transvaal from north of the Limpopo and to be related to the Rozwi. Krige and Krige (1943:304) estimated the time of crossing of the royal Lovedu, who were descended from a Mambo (the title of a Rozwi chief), as c. 1600 A.D. A previous estimate (J. D. Krige 1937: 329) placed the crossing in mid-seventeenth century.

Connections between the Lovedu and the Venda are strong. Aside from similar beads (Stayt 1931a, 1931b), they include similar historical traditions, including traditions apparently relating to the Mwene Mutapa kingdom, similar cultural activities, and mutual contact in the Transvaal in the eighteenth century, especially between 1750 and 1820 (Krige and Krige 1943).

The Pedi are also thought to have come down from the north (Mönnig 1967:16) and possibly ultimately from the great lakes region (Mönnig 1967:12).

Beads are often mentioned in accounts of the Pedi but are not further described. "Royal beads" are used in divination to help establish a link with the chief's ancestors (Mönnig 1967:85). Sekwati sent "a royal bead" to Morangrang (Hunt 1931:287; Mönnig 1967:23). A 1929 photograph of Chief Sekwati Mampuru (Mönnig 1967: facing 147) shows beads which look like the heirloom beads of this report. Probably unrelated is the story that Chief Thulare (Thulwana), who died in 1824, had his own beadmakers in a place on the Steelport River (Hunt 1931:284).

The Phalabora, also thought to have come down from the north (E. J. Krige 1937:358), have had much contact with the Lovedu (Krige and Krige 1943:305), especially between 1750 and 1870. The Phalabora possess the blue-green and cobalt blue beads we refer to as heirloom beads (E. J. Krige 1937:364).

The origin of the Venda name of the beads, "beads of the water", (Vhulungu ha madi) is not known. Dicke (1937:409) hinted that the expression referred to the ultimate origin of the beads from across a large body of water, which he interpreted as the Atlantic Ocean.

Until the present work the legendary age of the heirloom beads had not been supported by any evidence independent of oral tradition. They had been rather unsatisfactorily identified at three archaeological sites.

Schofield's observation (1942:98) that they resembled the beads of Dhlo Dhlo, not supported by the presentation of evidence, was lost by the wayside. Besides the lack of presented evidence, a factor which may have contributed to the neglect which befell his correct observation is the over-idealized conception of heirloom beads which was then current (van Riet Lowe 1937:368-369). Not all heirloom beads (as labelled in van Riet

Lowe's bead collection) measure up to this idealization and even fewer Dhlo Dhlo beads do, a situation which is understandable if Dhlo Dhlo beads were preserved by archaeological burial before centuries of wear and selection had taken their toll. This over-idealization may have been responsible for Beck's denial of the presence of beads resembling heirloom beads at Dhlo Dhlo (1931:238), a denial which, the author feels, was mistaken.

Dicke (1937:407) claimed to have seen unmistakable heirloom beads "on the West Coast of Africa and also at the Paris exhibition of 1900, in urns excavated from the ruins of Carthage." The author has examined thousands of West African beads and has also examined the beads excavated from Carthage now preserved in the museums near the site. Not one heirloom bead or facsimile thereof was observed in these contexts, nor would such a bead blend into these contexts.

Caton-Thompson's (1931:194) identification of heirloom beads at Zimbabwe was criticized by Schofield (1942:88) and, between the lines, by van Riet Lowe (1937:367-368). At the time Caton-Thompson wrote, heirloom beads had not been clearly described in the literature.

Caton-Thompson's report that heirloom beads are found "in the basal deposits of ruins generally" (1931:194) must be modified. After visual examination of the relevant specimens, the author feels that the only early deposit yielding a possible heirloom bead is the A3 No. 49 midden at Zimbabwe. This deposit, however, is no longer considered "basal", (Caton-Thompson 1970:16) but it is still thought to contain material from a time range much earlier than Dhlo Dhlo. Although ten beads from the A3 No. 49 midden were classified as heirloom beads ("beads of the water") (Caton-

Thompson 1931: Plate XLV, type 4c, row 2) we would follow this classification readily for only two of them. The remaining eight resemble the characteristic blue-green transparent cylinders of Bambandyanalo and of Period II (phase 2) at Zimbabwe (Summers and Robinson 1961:232). This fact was recognized by Schofield (1942:88) and by later authorities in personal communications.

Visual inspection indicated that the beads from Zimbabwe A4 No. 48c (Caton-Thompson 1931:84 and Plate XLV) and Hubvumi (Chibvumani) (Caton-Thompson 1931:159 and Plate XLVI), which were previously identified as heirloom beads ("4c") do not resemble heirloom beads.

Description of Heirloom Beads. Beads considered by members of the previously-named tribes to be old exhibit various colors and styles, but the kind thought to be oldest and most respected is a class of blue-green beads known as "ancestral" beads, or as "beads of the water", herein called "heirloom beads". Among the Venda they are known as Vhulungu ha madi (van Riet Lowe 1937; Stayt 1931a), and among the Lovedu as mudala, modzike, and thaganwe (van Riet Lowe 1937; Krige and Krige 1943:236). In addition to blue-green, they also occur commonly in cobalt blue. Similar beads occur occasionally in gray, green, yellow, and black.

The appearance of these heirloom beads is well-known from the description of van Riet Lowe (1937:368-369), following Dicke, who wrote (Dicke 1937:406):

> The exact color shade of the bead does not seem to matter very much to the natives. What they look for is a cloudy white substance which appears to be floating inside the bead. It is a wax-like cloud which makes the bead semi-opaque. Light seems to penetrate into the bead for only a little distance before it is reflected....

In other words, the glass is translucent, and the quality of its appearance is such that the beads often appear to be made of wax. They are cane beads, shaped like discs (discoid). Their ends are usually flat, but not in parallel planes. However, not all the beads display perfectly flat ends; some have slightly rounded ends, and it seems possible that the flat ends may have been created, or enhanced, by wear.[10] Strung correctly, the beads fit closely together, giving the curved necklace a streamlined, snake-like effect. The lengths of the beads vary from ∿1 to ∿4 mm, and the diameters from ∿3 to ∿6 mm (Figure 10).

The heirloom beads of Series A, as well as all archaeological beads belonging to Series A, are grossly opaque to translucent. In microscopic examination (72× magnification) the glass is fairly transparent, but bears many tiny bubbles which may be partly responsible for the translucency. The color of the blue-green examples varies about Munsell No. 2.5B,5/6; the cobalt blue about Munsell No. 5PB,3/8. Only Series A exhibits the waxy appearance which Dicke noted for heirloom beads, and it varies.

The heirloom beads of Series B, as well as all archaeological beads belonging to Series B, are more translucent than beads of Series A. Upon close examination the glass of Series B is transparent and contains bubbles, which, especially in the blue-green examples, are large enough to be seen clearly with the unaided eye and give the glass a slightly frothy

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[10] Cane beads are made from canes or tubes of glass, broken into segments, which constitute the beads. The segments may be reheated, softening the glass just enough to round off the sharp edges, or the segments may be sold unreheated. Subsequent wear may flatten the ends of any bead.

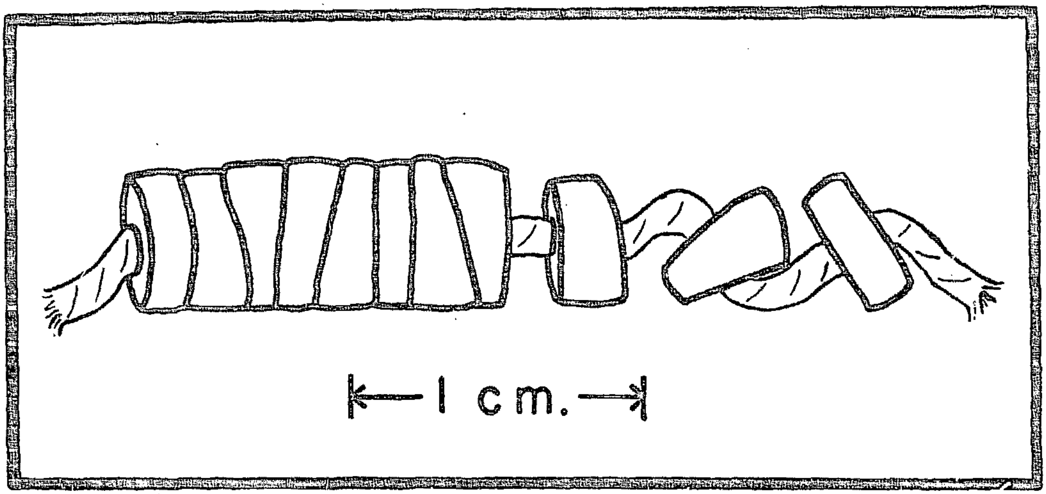

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Figure 10. Heirloom Beads.

appearance. Inclusions are also present. The blue-green color ranges about Munsell No. 2.5B,5/7 and the cobalt blue about 5PB,3/8.

Dicke (1937:407) proposed a method of manufacture for heirloom beads which seems partly erroneous, since it corresponds neither to conventional manufacturing practice nor to a realistic possibility. He proposed that canes were broken into beads and then strung immediately, so that the fitting neighbors, as it were, would stay together and give the necklace its streamlined effect.

The beads (of both Series) are clearly made from canes. However, probably at least since the time of Neri (1612), judging by vocabulary in his book (see Zecchin 1964:21-24), the operations of breaking the canes, reheating the segments if desired, sorting by size, and stringing finished beads have been separate and sequential (see Zecchin 1955, esp. 81-99). Neighbors would not be expected to stay together throughout these operations. The breaking process itself results in considerable "débitage" which is discarded, or perhaps remelted later. Because of the missing "débitage" it seems unlikely that neighboring segments of a cane would fit together after breaking any better than non-neighboring segments, and there would be no advantage in the proposed immediate stringing. The similarity in size of the beads may be explained by the conventional manufacturing process of sorting by means of sieves.

The Archaeological Site of Dhlo Dhlo

History. Dhlo Dhlo is the site of a stone ruin considered to belong to the Rozwi successor state to the former Mwene Mutapa kingdom. It is located in southwest Rhodesia (Map, Figure 9) in territory formerly known as Butua (Garlake 1968). On a map of mid-seventeenth-century HuKaranga, Abraham labels this site "Ringa raChangamire" (Abraham 1961:213).

It was known to be in ruins c. 1895, and was first excavated in 1905 by MacIver. A definitive excavation was carried out in 1929 by G. Caton-Thompson (1931).

The ruin was dated to c. 1700 A.D. originally on the basis of a square-sectioned dark green glass "Dutch gin" bottle found in the excavation and given that date by the British Museum (Caton-Thompson 1931:174 and Plate LXIV). Subsequent studies, including those of imported Chinese ceramics, have supported this dating (Garlake 1968). This bottle, some Chinese ceramics, and about two thousand beads came from between two floor levels. Most of the cobalt blue beads were found on a burnt human burial on the lower occupation level, that is, between the floors. These numbered about one thousand (Caton-Thompson 1931:172 and Plate XLVIII). A similar number of blue-green beads was found in "a pocket of soil" between the floors but not on the burial (Caton-Thompson 1931:169 and Plate XLVIII). About two dozen monochrome reheated cane beads of other colors also came from the lower occupation level, which would fit in easily with the trade wind beads discussed in Chapter 7.

Description of Beads. All the beads from Dhlo Dhlo that were analyzed fell into Series A. They are unreheated discoid beads in blue-green and cobalt blue (Munsell No. 2.5B,5/6 and 5PB,3/8 respectively). A photograph of a large number of such discoid beads from Dhlo Dhlo was published by Caton-Thompson (1931:Plate XLVIII). Our samples from Dhlo Dhlo resemble heirloom beads of Series A in respects of discoid shape, size, color, translucency, textural quality, variable waxy appearance, and microscopic appearance; and if they were mixed together it would be very difficult to sort them out, except for a few heirloom beads which closely approach van Riet Lowe's (Dicke's) idealized description. With respect to the visually-perceived traits listed above, the beads from Dhlo Dhlo show considerably less uniformity among themselves than do heirloom beads. Centuries of wear and selection among heirloom beads may have contributed to their relative uniformity of appearance compared to the "raw", as it were, beads of Dhlo Dhlo.

The Archaeological Site of the Mjelele Valley Burial

History. A group of samples was obtained from a human burial in the Mjelele Valley of the Matopo Hills of Rhodesia (Figure 9). The beads were found some years ago by one Graham Miller of a Bulawayo Boy Scout group. The burial yielded a large number of glass beads which were arranged on a chart which is now preserved in the National Museum of Rhodesia, Bulawayo. The label on the chart dates the beads after 1800 A.D. We are now investigating evidence that the bead assemblage may be typical of a slightly earlier period, perhaps the eighteenth century.

Description of Beads. Common among the beads of this burial were discoid beads resembling heirloom beads of both Series. From visual inspection, it is estimated that the majority of beads from this burial which resemble heirloom beads resemble Series B heirloom beads, whereas those resembling Series A are rarer.

All but two of the samples analyzed from this burial measured between 1.5-3 mm in length and between 3-4 mm in diameter. The two exceptions were MJE-1a and MJE-1b, measuring 4 mm in length and 5.5 mm in diameter, and 3 mm in length and 5 mm in diameter, respectively. The blue-green color is approximately Munsell No. 2.5-10B,6/6, the cobalt blue approximately No. 7.5PB,3/11.

Source of Ethnographic Samples

The heirloom beads analyzed here were obtained from the Lovedu of Modjadje's[11] location by Eileen Jensen Krige, who gave them to van Riet Lowe (1937:372), an expert on the Venda beads. We obtained them from the van Riet Lowe bead collection in 1968 for the purpose of this laboratory study. They were clearly labelled, often in van Riet Lowe's own handwriting. The judgment that Lovedu beads correspond in physical appearance to Venda beads has been made or implied by van Riet Lowe (1937:368), Krige and Krige (1943), and Stayt (1931a:253; 1931b:27). The author, after careful inspection, finds that Venda and Lovedu heirloom beads look exactly alike.

Results

Table 5b presents the results of neutron activation analysis of beads of Series A, and Table 5c presents the analogous data for beads of Series B. The two Series differ notably in their contents of sodium, uranium, antimony, and tin. The sodium content of Series A averages 15.12 ± 0.70%, whereas in Series it averages 9.62 ± 0.71%. The uranium content of Series A averages 66.65 ± 28.06 ppm, whereas in Series B it is 4.72 ± 9.81 ppm. Series A shows no evidence of the use of antimony, whereas Series B does, in some beads being present at quite high concentrations.

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[11] Modjadje is the hereditary name of the Queen of the Lovedu. According to tradition, Modjadje I repelled the invasion of Zwide, the Ndebele leader, in 1819 by sending him a basket of bewitched beads, which spontaneously gathered into a heap at the appropriate moment (Krige and Krige 1943:1; Bryant 1965:211). They were not like heirloom beads, however, for they were striped.

Discussion

Comparisons with Earlier Work. Our analysis of heirloom beads confirms and clarifies the chemical groupings of Venda heirloom beads previously proposed by van Riet Lowe and Schilz, utilizing an ultraviolet spectroscopic method (van Riet Lowe 1937:370). These early results are reproduced in Table 5a. If one compares Table 5a with Tables 5b and 5c, it seems evident that van Riet Lowe's V.3 group corresponds to our Series B, whereas his V.1, V.2, and V.4 samples correspond to our Series A. This judgment may be made by comparing their antimony results with ours.

The terminology and spectrographic results offered by van Riet Lowe and Schilz indicate that the Venda differentiate between the two Series in blue-green samples but perhaps not in cobalt blue samples. Our blue-green Series A beads may be equivalent to van Riet Lowe's Vhulungu ha madi (V.1 and V.2), our blue-green Series B beads to his Vhulungu ha madi: Luṱumbe lwa maḓi (V.3), and our cobalt blue of both Series to his Vhulungu ha maḓi: Mafhe (V.4).

Conversely, labels in the van Riet Lowe collection indicate that the Lovedu differentiate between the two Series in cobalt blue examples but not in blue-green. Our blue-green samples were invariably labelled mudala, whatever Series they later fell into; whereas our cobalt blue samples bore either of two labels: those labelled modzike fell into Series A and those labelled thaganwe fell into Series B. Of course, it must be remembered that small numbers of samples are concerned.

Schilz (in van Riet Lowe 1937:371) thought that the Venda heirloom beads were made from the same type of glass as the so-called garden roller (and M_1) beads from Bambandyanalo and Mapungubwe. There is a resemblance, as may be seen by comparison of our Tables 4 and 5. Both concern a very similar soda-lime glass with a remarkable uranium content, although Schilz was not apparently aware of the latter (van Riet Lowe 1955:11; van Riet Lowe 1937:371).

Distribution, Dating and Origin. The distribution of the Series A and Series B beads bears discussion. Blue-green beads of the discoid appearance of heirloom beads have not been reported on the East African coast nor has the author seen any. The author has seen cobalt blue examples from Fort Jesus which may belong to Series B. This clue is under further investigation.

As previously stated, Dhlo Dhlo lies in the territory formerly known as Butua. In this region there was an embargo against Portuguese trade during the time period from c. 1652 to the 1730's (Abraham 1962: 32-34; Garlake 1968:29). This is the time period in which Dhlo Dhlo probably belongs. Garlake (1968:29) feels that this embargo was probably not completely effective. Such an embargo would explain the scarcity of the typical Portuguese-supplied monochrome reheated cane beads at Dhlo Dhlo. The rarity of discoid beads like those of Dhlo Dhlo in East and Southeast Africa might indicate that the Dhlo Dhlo beads did not come from the east coast. It may be relevant to recall that c. 1640 Father Manuel de Sousa e Faria wrote, "It is thought that the blacks of Butua of the kingdom of Chicanga are those that carry the gold to Angola...." (Theal 1964:I, 23). Dicke (1937:409), as well, had some information that the heirloom beads came from the west.

However, the evidence of Chapter 7 shows that the beads of Dhlo Dhlo and all other Series A beads match the probably-Portuguese-supplied beads. If so, they must have come from the same source, although possibly by different routes. Since the Portuguese were supplying both east and west coasts, there is no difficulty in this hypothesis.

Archaeological evidence from Angola is needed in order to evaluate the possibility that the beads of Dhlo Dhlo (and possibly other items of trade) may have arrived from the west coast. One fragment of relevant evidence, but of unknown reliability, is at our disposal: displayed in a glass case in the National Museum of Tanzania, Dar es Salaam, are some beads resembling heirloom beads, bearing an old, yellowed label which reads "drawn beads resembling the beads first brought to Angola by the Portuguese c. 1500."

Besides the embargo hypothesis, another hypothesis which might explain the restriction of the Dhlo Dhlo bead assemblage to beads of a rather discoid shape is the possibility that they were already at the honored center of some cultural tradition c. 1700 A.D.

Summary and Conclusion

Samples of discoid glass heirloom beads from Modjadje's location fall into two Series, which we label Series A and Series B. Discoid beads from the Mjelele Valley Burial fall into the same two Series. Discoid samples from Dhlo Dhlo fall into Series A. These Series have visual and chemical integrity.

These findings show that the Lovedu have in their possession, as heirlooms, beads of chemical compositions that are represented in archaeological sites in Rhodesia. As will be shown in the next chapter, Series A belongs to a chemical group that is repeatedly found in archaeological sites north of the Limpopo: in and near Rhodesia, and on the east coast.

A reasonable interpretation of this situation is that the Lovedu Series A heirloom beads may have considerable antiquity. If we may draw from the traditions of the Venda, whose heirloom beads look exactly like Lovedu heirloom beads, then our interpretation may be broadened.

The estimated dates of Venda and Lovedu migration, c. 1700 A.D. and c. 1600 or c. 1650 A.D., respectively, put the Venda and Lovedu north of the Limpopo at the approximate time when Dhlo Dhlo was an inhabited site, c. 1700 A.D. It is therefore plausible that the Venda and Lovedu ancestors may have owned beads that were current in Butua c. 1700 A.D., beads that the inhabitants of Dhlo Dhlo owned as well.

Tradition states that the Venda ancestors brought their heirloom beads over the Limpopo into the Transvaal. The published traditions do not state whether or not the Lovedu brought their heirloom beads over the Limpopo, but the fact that the beads are considered ancestral among the Lovedu may indicate an underlying similarity of derivation.

The presence of Series A beads at Dhlo Dhlo, a Rozwi ruin, adds its weight to the previous evidence of Rozwi-Venda and Rozwi-Lovedu genealogical and cultural connections, supports the oral traditions of antiquity for heirloom beads, and gives the protohistoric archaeology of southern Africa a point of articulation with the present.

Table 5a. Ultraviolet Spectroscopic Analysis of Heirloom Beads by W. E. Schilz[a]

Group	I				II			III					IV		
	Na	K	Ca	Si	Fe	Mg	Mn	Cu	Pb	Sn	Sb	Co	Ni	Al	Zn
V.1	$+_{+}+$	$+_{+}+$	$+_{+}+$	$+_{+}+$	+	+	+	++	+	(+)	-	-	-	-	-
V.2	"	"	"	"	+	+	+	++	-	-	-	(+)	-	-	-
V.3	"	"	"	"	(+)	(+)	(+)	++	++	-	++	-	-	-	-
V.4	"	"	"	"	+	+	+	+	-	-	-	+	-	-	-

Where: (+) = In very small quantity
+ = In clear quantity
++ = Very clear
$+_{+}+$ = Great quantity

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[a] Taken from van Riet Lowe (1937:370).

Table 5b. Series A Heirloom Beads: Neutron Activation Analysis[a,b]

Sample	Color	Al (%)	Cl (%)
MOD-2a	blue-green	3.57 ± 0.16	1.06 ± 0.14
MOD-2b	"	3.73 ± 0.28	1.42 ± 0.17
MOD-2c	"	2.21 ± 0.62	1.17 ± 0.23
MOD-2d	"	3.30 ± 0.13	1.31 ± 0.19
MOD-2e	"	3.48 ± 0.19	1.70 ± 0.21
MOD-2f	"	3.13 ± 0.27	1.91 ± 0.25
DHL-1353a	"	4.55 ± 0.15	1.84 ± 0.23
DHL-1353b	"	2.77 ± 0.21	1.41 ± 0.27
DHL-1353c	"	3.91 ± 0.17	1.26 ± 0.17
DHL-1353d	"	2.99 ± 0.30	1.98 ± 0.21
DHL-1353e	"	2.06 ± 0.12	1.40 ± 0.19
DHL-1353f	"	3.18 ± 0.14	1.55 ± 0.17
MJE-3a1	"	3.17 ± 0.19	1.40 ± 0.18
MJE-3a2	"	2.78 ± 0.33	1.89 ± 0.22
MJE-3a3	"	3.09 ± 0.58	1.45 ± 0.27
MJE-5	"	3.17 ± 0.24	1.37 ± 0.24
MOD-5a	cobalt blue	3.84 ± 0.16	1.60 ± 0.19
MOD-5b	"	3.45 ± 0.24	1.44 ± 0.21
MOD-5c	"	3.71 ± 0.53	2.69 ± 0.32
DHL-1352a	"	3.30 ± 0.19	2.00 ± 0.31
DHL-1352b	"	3.56 ± 0.20	1.70 ± 0.25
DHL-1352c	"	4.37 ± 0.46	1.23 ± 0.35
DHL-1352d	"	4.42 ± 0.49	1.91 ± 0.29
DHL-1352e	"	2.95 ± 1.03	1.52 ± 0.38
Mean and RMSD[c]		3.41 ± 0.65	1.61 ± 0.36
DHL-1352f	cobalt blue	4.53 ± 0.18	2.06 ± 0.33

Table 5b. continued

Sample	Color	Mn	Na (%)	Cu[b,d]
-2a	bl-gr.	299 ± 20	14.93 ± 0.13	5,725 ± 125
-2b	"	286 ± 25	15.45 ± 0.14	5,205 ± 138
-2c	"	306 ± 35	14.42 ± 0.14	5,447 ± 182
-2d	"	322 ± 29	14.06 ± 0.14	4,217 ± 157
-2e	"	299 ± 33	15.11 ± 0.15	5,358 ± 174
-2f	"	259 ± 38	16.32 ± 0.16	4,354 ± 186
-1353a	"	351 ± 25	14.93 ± 0.19	5,192 ± 194
-1353b	"	286 ± 30	15.22 ± 0.20	4,537 ± 217
-1353c	"	280 ± 21	14.69 ± 0.18	4,977 ± 152
-1353d	"	376 ± 27	16.89 ± 0.21	5,272 ± 180
-1353e	"	172 ± 19	14,02 ± 0.13	3,847 ± 150
-1353f	"	253 ± 21	15.83 ± 0.14	5,132 ± 139
-3a1	"	236 ± 10	14.56 ± 0.12	4,841 ± 115
-3a2	"	272 ± 13	14.75 ± 0.13	4,045 ± 134
-3a3	"	267 ± 19	15.42 ± 0.14	6,207 ± 173
-5	"	247 ± 13	14.29 ± 0.13	3,940 ± 152
-5a	co bl.	365 ± 24	14.94 ± 0.14	b
-5b	"	368 ± 29	15.05 ± 0.14	b
-5c	"	272 ± 47	15.28 ± 0.16	b
-1352a	"	262 ± 30	14.42 ± 0.21	b
-1352b	"	299 ± 25	15.29 ± 0.20	b
-1352c	"	308 ± 36	15.67 ± 0.23	b
-1352d	"	311 ± 30	16.10 ± 0.22	b
-1352e	"	367 ± 41	15.34 ± 0.22	b
Mean and RMSD		294 ± 48	15.12 ± 0.70	4,871 ± 721[e] b,f
-1352f	co bl.	1,128 ± 42	16.54 ± 0.23	b

Table 5b. continued

Sample	Color	U	Sm
-2a	bl-gr.	102.66 ± 0.48	3.58 ± 0.16
-2b	"	58.15 ± 0.30	2.98 ± 0.10
-2c	"	98.82 ± 0.51	3.14 ± 0.16
-2d	"	30.22 ± 0.21	1.49 ± 0.06
-2e	"	76.22 ± 0.42	2.75 ± 0.13
-2f	"	31.11 ± 0.23	3.05 ± 0.06
-1353a	"	87.16 ± 0.43	3.50 ± 0.14
-1353b	"	117.40 ± 0.58	2.85 ± 0.18
-1353c	"	19.58 ± 0.12	2.12 ± 0.03
-1353d	"	31.90 ± 0.18	1.93 ± 0.05
-1353e	"	38.30 ± 0.24	1.34 ± 0.07
-1353f	"	37.07 ± 0.21	1.74 ± 0.06
-3a1	"	53.48 ± 0.31	2.67 ± 0.07
-3a2	"	74.13 ± 0.42	2.96 ± 0.10
-3a3	"	66.72 ± 0.42	3.37 ± 0.09
-5	"	106.31 ± 0.59	2.71 ± 0.14
-5a	co bl.	79.00 ± 0.47	4.17 ± 0.13
-5b	"	98.45 ± 0.58	3.36 ± 0.16
-5c	"	79.69 ± 0.58	3.45 ± 0.15
-1352a	"	80.33 ± 0.45	4.55 ± 0.13
-1352b	"	41.83 ± 0.23	2.26 ± 0.07
-1352c	"	64.17 ± 0.38	3.24 ± 0.11
-1352d	"	91.20 ± 0.46	3.68 ± 0.14
-1352e	"	40.62 ± 0.27	2.05 ± 0.07
Mean and RMSD		66.65 ± 28.06	2.87 ± 0.82
-1352f	co bl.	196.15 ± 0.96	4.80 ± 0.30

Table 5b. continued

Sample	Color	Co[d]	Sc
-2a	bl-gr.	48.43 ± 0.63	4.82 ± 0.04
-2b	"	71.02 ± 0.85	5.05 ± 0.04
-2c	"	42.72 ± 0.80	4.46 ± 0.06
-2d	"	63.98 ± 0.83	2.70 ± 0.03
-2e	"	136.32 ± 1.75	4.31 ± 0.07
-2f	"	51.23 ± 0.85	5.00 ± 0.06
-1353a	"	14.45 ± 0.35	5.23 ± 0.04
-1353b	"	138.23 ± 1.54	4.00 ± 0.05
-1353c	"	47.95 ± 0.55	2.52 ± 0.03
-1353d	"	48.18 ± 0.63	2.56 ± 0.03
-1353e	"	76.90 ± 1.10	2.03 ± 0.04
-1353f	"	28.12 ± 0.47	2.77 ± 0.03
-3a1	"	38.31 ± 0.64	4.69 ± 0.05
-3a2	"	92.95 ± 1.28	4.27 ± 0.06
-3a3	"	62.54 ± 1.14	4.81 ± 0.07
-5	"	188.24 ± 2.34	4.57 ± 0.08
-5a	co bl.	1,709.00 ± 14.71	6.01 ± 0.20
-5b	"	1,400.60 ± 12.45	4.93 ± 0.20
-5c	"	1,064.60 ± 10.33	5.44 ± 0.22
-1352a	"	929.32 ± 8.17	4.83 ± 0.14
-1352b	"	879.42 ± 7.47	3.24 ± 0.10
-1352c	"	968.27 ± 8.56	5.05 ± 0.15
-1352d	"	1,418.60 ± 11.88	5.70 ± 0.16
-1352e	"	780.42 ± 7.14	4.26 ± 0.14
Mean and RMSD		71.85 ± 46.20[e] 1,143.73 ±326.39[f]	4.30 ± 1.10
-1352f	co bl.	1,762.60 ± 14.95	6.26 ± 0.21

Table 5b. continued

Sample	Color	Fe (%)	Yb	Ta
-2a	bl-gr.	1.30 ± 0.03	1.30 ± 0.08	0.57 ± 0.01
-2b	"	1.38 ± 0.03	1.18 ± 0.08	0.55 ± 0.01
-2c	"	1.30 ± 0.04	0.89 ± 0.11	0.42 ± 0.01
-2d	"	0.78 ± 0.03	0.61 ± 0.07	0.31 ± 0.01
-2e	"	1.22 ± 0.05	1.04 ± 0.14	0.47 ± 0.01
-2f	"	1.36 ± 0.04	0.88 ± 0.11	0.99 ± 0.01
-1353a	"	1.45 ± 0.03	1.26 ± 0.08	0.48 ± 0.01
-1353b	"	1.06 ± 0.04	0.89 ± 0.11	0.46 ± 0.01
-1353c	"	0.69 ± 0.02	0.84 ± 0.05	0.32 ± 0.01
-1353d	"	0.79 ± 0.02	0.69 ± 0.06	0.31 ± 0.01
-1353e	"	0.62 ± 0.03	0.51 ± 0.09	0.38 ± 0.01
-1353f	"	0.80 ± 0.02	0.63 ± 0.06	0.34 ± 0.01
-3a1	"	1.27 ± 0.04	1.09 ± 0.09	0.62 ± 0.01
-3a2	"	1.14 ± 0.04	1.01 ± 0.12	0.48 ± 0.01
-3a3	"	1.27 ± 0.05	1.27 ± 0.15	0.54 ± 0.02
-5	"	1.28 ± 0.06	0.56 ± 0.16	0.46 ± 0.02
-5a	co bl.	1.60 ± 0.12	1.12 ± 0.34	0.58 ± 0.03
-5b	"	1.59 ± 0.13	0.82 ± 0.37	0.88 ± 0.27
-5c	"	1.40 ± 0.14	0.52 ± 0.44	0.62 ± 0.03
-1352a	"	1.40 ± 0.08	1.32 ± 0.24	0.72 ± 0.02
-1352b	"	1.04 ± 0.06	0.81 ± 0.17	0.41 ± 0.01
-1352c	"	1.34 ± 0.09	1.36 ± 0.26	0.60 ± 0.02
-1352d	"	1.70 ± 0.09	0.61 ± 0.24	0.57 ± 0.02
-1352e	"	1.21 ± 0.08	0.42 ± 0.24	0.45 ± 0.02
Mean and RMSD		1.21 ± 0.29	0.90 ± 0.29	0.52 ± 0.17
-1352f	co bl.	2.09 ± 0.13	1.11 ± 0.34	0.57 ± 0.03

Table 5b. continued

Sample	Color	Sb^{d}	Cr
-2a	bl-gr.	4.9 ± 0.3	21.4 ± 2.0
-2b	"	4.9 ± 0.3	16.8 ± 2.1
-2c	"	6.8 ± 0.6	26.4 ± 3.1
-2d	"	2.7 ± 0.3	14.0 ± 1.9
-2e	"	11.7 ± 0.8	29.6 ± 3.9
-2f	"	5.3 ± 0.4	26.2 ± 3.0
-1353a	"	9.1 ± 0.6	23.8 ± 2.4
-1353b	"	11.8 ± 0.7	26.0 ± 3.2
-1353c	"	2.7 ± 0.2	12.6 ± 1.4
-1353d	"	3.5 ± 0.3	15.4 ± 1.7
-1353e	"	7.5 ± 0.6	18.1 ± 2.5
-1353f	"	2.8 ± 0.2	10.3 ± 1.6
-3a1	"	19.2 ± 1.0	21.4 ± 2.4
-3a2	"	16.5 ± 1.0	26.0 ± 3.2
-3a3	"	8.2 ± 0.7	40.3 ± 3.8
-5	"	6.9 ± 0.6	39.9 ± 4.4
-5a	co bl.	2.9 ± 0.7	9.4 ±13.0
-5b	"	2.8 ± 0.7	32.5 ±13.2
-5c	"	8.2 ± 1.0	65.5 ±14.6
-1352a	"	3.7 ± 0.7	36.6 ± 8.0
-1352b	"	2.0 ± 0.5	15.7 ± 6.2
-1352c	"	3.1 ± 0.7	35.2 ± 8.6
-1352d	"	4.0 ± 0.7	30.0 ± 9.2
-1352e	"	3.2 ± 0.7	30.0 ± 8.0
Mean and RMSD		6.4 ± 4.5	26.0 ± 12.3
-1352f	co bl.	6.7 ± 1.1	27.0 ± 12.6

Table 5b. concluded

Sample	Color	Th	
-2a	bl-gr.	23.49	± 0.17
-2b	"	18.01	± 0.16
-2c	"	19.56	± 0.22
-2d	"	7.84	± 0.11
-2e	"	15.08	± 0.23
-2f	"	16.91	± 0.20
-1353a	"	21.16	± 0.17
-1353b	"	18.18	± 0.20
-1353c	"	17.56	± 0.12
-1353d	"	12.77	± 0.12
-1353e	"	10.84	± 0.16
-1353f	"	9.95	± 0.11
-3a1	"	14.95	± 0.17
-3a2	"	15.85	± 0.21
-3a3	"	22.80	± 0.27
-5	"	11.71	± 0.25
-5a	co bl.	25.07	± 0.66
-5b	"	20.93	± 0.66
-5c	"	36.72	± 0.78
-1352a	"	18.24	± 0.40
-1352b	"	14.06	± 0.31
-1352c	"	24.07	± 0.44
-1352d	"	21.08	± 0.46
-1352e	"	14.38	± 0.39
Mean and RMSD		18.0	± 6.1
-1352f	co bl.	32.23	± 0.63

Table 5c. Series B Heirloom Beads: Neutron Activation Analysis[a,g]

Sample		Al (%)	Cl (%)
MOD-1a	blue-green	1.08 ± 0.08	1.52 ± 0.13
MOD-1b	"	1.09 ± 0.10	1.45 ± 0.12
MOD-1c	"	0.98 ± 0.07	1.97 ± 0.15
MOD-1d	"	0.87 ± 0.18	1.78 ± 0.15
MOD-1e	"	0.96 ± 0.26	1.60 ± 0.15
MOD-1f	"	0.93 ± 0.09	1.95 ± 0.16
MJE-3b1	"	0.79 ± 0.09	1.55 ± 0.15
MJE-3b2	"	0.66 ± 0.19	1.94 ± 0.18
MJE-3b3	"	0.89 ± 0.17	1.92 ± 0.13
MJE-3b4	"	0.76 ± 0.26	1.60 ± 0.13
MOD-4a	cobalt blue	1.17 ± 0.21	1.13 ± 0.14
MOD-4b	"	1.02 ± 0.36	1.32 ± 0.17
MJE-19	"	1.08 ± 0.14	1.23 ± 0.20
MJE-1a	"	0.55 ± 0.33	1.04 ± 0.12
MJE-1b	"	0.42 ± 0.21	0.73 ± 0.12
MJE-1c	"	0.70 ± 0.13	1.35 ± 0.13
MJE-1d	"	0.86 ± 0.12	0.93 ± 0.14
Mean and RMSD[c]		0.67 ± 0.20	1.47 ± 0.38

Table 5c. continued

Sample	Color	Mn[d]	Na (%)
-1a	bl-gr.	503 ± 14	9.57 ± 0.09
-1b	"	308 ± 12	9.60 ± 0.09
-1c	"	567 ± 17	9.31 ± 0.09
-1d	"	584 ± 18	10.87 ± 0.10
-1e	"	350 ± 18	10.12 ± 0.10
-1f	"	315 ± 18	9.54 ± 0.09
-3b1	"	980 ± 14	8.59 ± 0.08
-3b2	"	296 ± 14	9.88 ± 0.09
-3b3	"	484 ± 11	9.81 ± 0.09
-3b4	"	266 ± 10	9.67 ± 0.08
-4a	co bl.	1,119 ± 30	8.39 ± 0.09
-4b	"	2,238 ± 45	10.82 ± 0.11
-19	"	3,066 ± 38	10.66 ± 0.11
-1a	"	1,015 ± 16	9.07 ± 0.08
-1b	"	2,358 ± 27	9.26 ± 0.08
-1c	"	339 ± 11	9.54 ± 0.09
-1d	"	457 ± 13	8.91 ± 0.08
Mean and RMSD		465 ± 216[e]	9.62 ± 0.71
		1,513 ±1,045[f]	

Table 5c. continued

Sample	Color	Cu[d,g]	U
-1a	bl-gr.	9,049 ± 140	1.80 ± 0.14
-1b	"	11,512 ± 141	1.33 ± 0.07
-1c	"	8,819 ± 148	1.45 ± 0.11
-1d	"	9,670 ± 152	1.54 ± 0.08
-1e	"	7,541 ± 137	1.31 ± 0.09
-1f	"	10,389 ± 157	1.55 ± 0.11
-3b1	"	10,533 ± 149	2.69 ± 0.12
-3b2	"	9,299 ± 141	2.31 ± 0.11
-3b3	"	10,520 ± 121	3.46 ± 0.08
-3b4	"	9,044 ± 108	1.17 ± 0.09
-4a	co bl.	[g]	1.69 ± 0.08
-4b	"	[g]	6.83 ± 0.15
-19	"	[g]	41.14 ± 0.34
-1a	"	[g]	[h]
-1b	"	[g]	1.61 ± 0.07
-1c	"	[g]	2.58 ± 0.20
-1d	"	[g]	3.07 ± 0.25
Mean and RMSD		9,638 ±1,132[e] [g,f]	4.72 ± 9.81[i]

Table 5c. continued

Sample	Color	Sm	Co^{d}
-1a	bl-gr.	0.74 ± 0.03	64.53 ± 1.27
-1b	"	0.67 ± 0.02	87.58 ± 1.15
-1c	"	0.62 ± 0.03	75.33 ± 1.19
-1d	"	0.53 ± 0.02	43.85 ± 0.82
-1e	"	0.71 ± 0.02	75.03 ± 1.14
-1f	"	0.62 ± 0.03	60.42 ± 1.07
-3b1	"	0.60 ± 0.03	91.11 ± 1.52
-3b2	"	0.67 ± 0.02	61.90 ± 1.08
-3b3	"	0.62 ± 0.02	43.42 ± 0.66
-3b4	"	0.58 ± 0.02	69.10 ± 0.96
-4a	co bl.	0.77 ± 0.02	394.50 ± 3.93
-4b	"	0.54 ± 0.04	403.87 ± 3.97
-19	"	1.52 ± 0.07	1,354.90 ± 13.24
-1a	"	h	518.15 ± 15.44
-1b	"	0.70 ± 0.01	383.69 ± 3.74
-1c	"	0.69 ± 0.04	513.75 ± 5.07
-1d	"	0.90 ± 0.05	630.56 ± 6.46
Mean and RMSD		0.72 ± 0.23[i]	67.23 ± 16.02[e] 599.92 ± 344.59[f]

Table 5c. continued

Sample	Color	Sc	Fe (%)	Yb[g]
-1a	bl-gr.	1.82 ± 0.05	0.78 ± 0.10	g
-1b	"	1.48 ± 0.04	0.54 ± 0.06	g
-1c	"	1.38 ± 0.05	0.31 ± 0.08	g
-1d	"	1.09 ± 0.04	0.28 ± 0.05	g
-1e	"	1.55 ± 0.04	0.43 ± 0.07	g
-1f	"	1.38 ± 0.04	0.45 ± 0.08	g
-3b1	"	1.39 ± 0.05	0.49 ± 0.09	g
-3b2	"	1.46 ± 0.04	0.56 ± 0.06	g
-3b3	"	1.36 ± 0.03	0.47 ± 0.04	g
-3b4	"	1.25 ± 0.03	0.47 ± 0.05	g
-4a	co bl.	1.54 ± 0.07	0.56 ± 0.06	g
-4b	"	1.17 ± 0.07	0.35 ± 0.09	g
-19	"	2.09 ± 0.17	0.80 ± 0.17	g
-1a	"	1.73 ± 0.20	1.17 ± 0.47	g
-1b	"	1.64 ± 0.05	0.54 ± 0.04	g
-1c	"	1.27 ± 0.07	0.55 ± 0.12	g
-1d	"	1.83 ± 0.11	0.70 ± 0.18	g
Mean and RMSD		1.50 ± 0.26	0.56 ± 0.21	g

Table 5c. continued

Sample	Color	Ta	Sb^{d}.
-1a	bl-gr.	0.20 ± 0.02	663.7 ± 26.3
-1b	"	0.13 ± 0.01	227.5 ± 9.1
-1c	"	0.16 ± 0.01	333.8 ± 13.3
-1d	"	0.19 ± 0.01	140.4 ± 5.7
-1e	"	0.19 ± 0.01	210.7 ± 8.5
-1f	"	0.21 ± 0.01	300.2 ± 12.0
-3b1	"	0.19 ± 0.02	534.9 ± 24.1
-3b2	"	0.17 ± 0.01	204.6 ± 9.5
-3b3	"	0.15 ± 0.01	203.0 ± 9.3
-3b4	"	0.18 ± 0.01	405.5 ± 18.4
-4a	"	0.17 ± 0.01	152.0 ± 7.3
-4b	"	0.12 ± 0.01	779.8 ± 36.8
-19	"	0.38 ± 0.03	964.3 ± 43.3
-1a	"	0.57 ± 0.06	6,565.6 ± 981.7
-1b	"	0.22 ± 0.01	67.6 ± 3.1
-1c	"	0.33 ± 0.02	1,701.2 ± 76.0
-1d	"	0.49 ± 0.03	2,350.5 ± 105.1
Mean and RMSD		0.24 ± 0.13	929.7 ± 1,575.0

Table 5c. concluded

Sample	Color	Cr	Th
-1a	bl-gr.	39.3 ± 8.1	4.00 ± 0.38
-1b	"	11.7 ± 4.8	5.09 ± 0.23
-1c	"	21.8 ± 6.2	3.17 ± 0.29
-1d	"	21.8 ± 4.3	2.19 ± 0.20
-1e	"	21.2 ± 5.4	3.35 ± 0.26
-1f	"	25.1 ± 6.0	3.57 ± 0.28
-3b1	"	20.5 ± 6.6	1.40 ± 0.32
-3b2	"	28.8 ± 4.4	1.73 ± 0.22
-3b3	"	19.5 ± 2.7	1.46 ± 0.14
-3b4	"	15.1 ± 3.9	1.45 ± 0.20
-4a	co bl.	11.3 ± 5.1	5.51 ± 0.25
-4b	"	11.3 ± 7.1	3.38 ± 0.34
-19	"	39.1 ± 14.1	2.92 ± 0.69
-1a	"	14.5 ± 34.5	0.89 ± 1.78
-1b	"	17.1 ± 3.2	1.69 ± 0.16
-1c	"	9.0 ± 8.6	1.29 ± 0.42
-1d	"	39.9 ± 13.6	1.91 ± 0.66
Mean and RMSD		21.6 ± 10.0	2.65 ± 1.37

Notes to Table 5

a. All data are given in parts per million unless otherwise indicated.

b. Imprecisely-determined elements are excluded from this Table and from comparisons based upon it. In Series A, elements for which a mean concentration could be determined are, with mean and root mean square deviation: Ca, 4.52 ± 1.87%; Cs, 1.48 ± 1.20 ppm; V, 103.39 ± 41.51 ppm; Sn, 99.1 ± 87.0 ppm; Eu, 0.55 ± 0.21 ppm; Hf, 4.3 ± 2.5 ppm; and Tb, 0.30 ± 0.10 ppm. Approximate upper limits of concentration were estimated for Series A beads for the following elements, with upper limit and representative counting error: Cu in cobalt blue beads, 1500 ± 200 ppm; In, 2 ± 1 ppm; As, 200 ± 120 ppm; Ag, 3 ± 2 ppm; Ir, 0.01 ± 0.02 ppm; Hg, assuming none is lost in the reactor, 1 ± 1 ppm; Mg, 2 ± 3%; W, 3 ± 3 ppm; K, 2 ± 1%; Sr, 600 ± 500 ppm; Ga, 300 ± 150 ppm; and Zn, 170 ± 70 ppm. Pb was determined by X-ray fluorescence analysis on grouped samples from Series A, giving the result ∿ 0.03%.

c. Root Mean Square Deviation (see Chapter 3).

d. Glassmakers' additive, or an element the determination of which is interfered with by a glassmakers' additive. Such elements are used in comparisons where appropriate.

e. Applicable to blue-green beads.

f. Applicable to cobalt blue beads.

g. Elements chosen for Table 5c were those chosen for Table 5b in order to allow comparisons. This procedure has resulted in the inclusion of some elements in Table 5c which are imprecisely determined, according to the standard set forth in note b. No precisely-determined elements were omitted from Table 5c, and, aside from the exceptions indicated above, imprecisely-determined elements were excluded. Elements for which a mean concentration in Series B could be determined are, with mean and root mean square deviation: Ca, 7.94 ± 1.66%; Mg, 0.73 ± 1.90%; Sr, 1,133 ± 416ppm; As, 452.1 ± 458.7 ppm; La, 5.31 ± 4.07 ppm; Lu, 0.16 ± 0.27 ppm; Nd, 2.14 ± 7.84 ppm; Mo, 5.67 ± 7.13 ppm; Hf, 2 ± 2 ppm; Sn, 82.6 ± 69.5 ppm; and Ni, 498 ± 353 ppm. Approximate upper limits of concentration were estimated for the Series B beads for the following elements, given with upper limit and a representative counting error: Cu, in cobalt blue beads, 260 ± 100 ppm; V, 64 ± 40 ppm; K, 4 ± 2%; Ga, 400 ± 90 ppm; In, 7 ± 5 ppm; W, 3 ± 3 ppm; Ag, 3 ± 2 ppm; Ce, 6 ± 2 ppm; Yb, 5.0 ± 0.3 ppm; Cs, 3.7 ± 0.4 ppm; Ir, 0.00 ± 0.01 ppm; Hg, assuming none is lost in the reactor, 1 ± 1 ppm; Eu, 0.9 ± 0.6 ppm; Tb, 0.4 ± 0.1 ppm; and Zn, 100 ± 20 ppm. Pb was determined by X-ray fluorescence on grouped samples, giving a result of ∿ 0.09% for Series B.

h. Not determined for sample labeled MJE-1a.

i. Calculated without MJE-1a.

CHAPTER 7. TRADE WIND BEADS

> "And the manner of their traffic was this: they came in small vessels named zambucos from the kingdoms of Quiloa, Mombaca, and Melynde, bringing many cotton cloths...and many small beads, grey, red, and yellow, which things come to the said kingdoms from the great kingdom of Cambaya in other greater ships....
>
> "The Moors of Çofala kept these wares and sold them afterward to the Heathen of the kingdom of Benemetapa...."
>
> Duarte Barbosa c. 1517-1518[12]
> from Dames (1918:6-8).

Introduction

We come now to a topic encompassing the beads of the Portuguese period which have been mentioned in previous pages. This is the topic of trade wind beads.

The glass beads typically found in East African medieval to recent coastal sites and in Southern African Later Iron Age inland sites have long been recognized to form a series, albeit poorly defined (Beck 1930, 1931; van der Sleen 1958, 1960, 1967; Schofield 1942, 1955, 1958; Robinson 1959; Garlake 1968). Van der Sleen, and to some extent Beck, claimed to recognize the same series in many port towns around the Indian Ocean. Because of its distribution in ports favorably situated to take part in commerce regulated by the monsoon, or trade winds, van der Sleen named the series "trade wind beads" (1956).

The concept, "trade wind beads", has been used vaguely. As presented by van der Sleen (1960, 1967), it covered material spread over two millennia; and the writer has observed that the series, as van der Sleen saw it,

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[12] H. E. J. Stanley, a translator of Barbosa, places the date of this writing c. 1514 (Barbosa, c. 1514).

includes disparate material.[13] The writer observed that the Asian and African glass bead assemblages, as a whole, do not resemble one another visually and typologically, beyond resemblances ascribable to the fact that the material is glass, in its traditional colors. The vast majority of all these beads may be described as monochrome, opaque, and simply constructed. In this report usage of the term "trade wind beads" is hereafter restricted to the assemblage which is found in Africa and which is characterized in this chapter, unless otherwise indicated. A further discussion of the Indian material appears in Part 2 of this Chapter.

Part 1. Trade Wind Beads

Description of Beads

A visually recognizable series of glass beads, the trade wind beads, links many Iron Age archaeological sites of southern and eastern Africa, as discussed below. These beads are usually reheated cane beads, but a small percentage is wound. They occur in the traditional colors of glass: Indian red, blue-green, green, yellow, black, orange (amber), and cobalt blue. They also occur in a greenish-yellow color (also called "pearl"), which might be interpretable as an attempted white. The beads are opaque to translucent, and with slight magnification (72×) bubbles or vacuoles can usually be seen in the glass. In some examples, which contain little to no opacifier, the bubbles alone are apparently sufficient to make the glass translucent to opaque.

The trade wind bead series is shown in Plate IV. This series is visually recognizable, and the author made a special effort to gather

[13] This finding is based on inspection of glass bead assemblages from over thirty Asian sites, mostly Indian, including many named by van der Sleen.

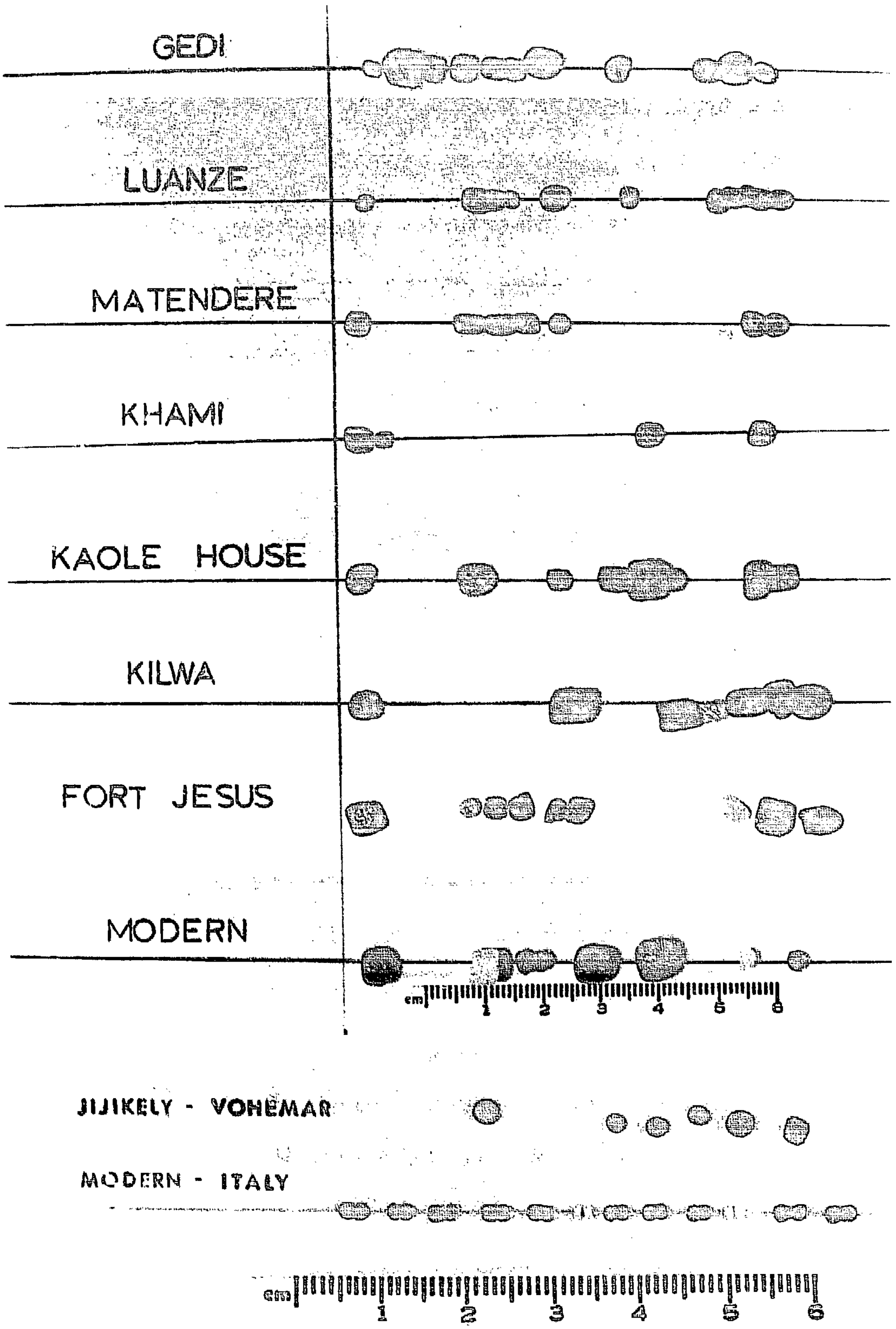

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Plate IV. Trade Wind Beads.

samples from it. The claim that the series is visually recognizable seems substantiated by the fact that of one hundred and fifty four beads analyzed by the author as samples of trade wind beads, one hundred and thirty three fell into a single, though broad, chemical group. The remainder were similar. The series, and the chemical group, include the jijijely of Madagascar (Thierry 1961) and a number of beads from archaeological sites in the Philippine Islands (Fox 1970).

Results and Discussion

One hundred thirty three beads from twenty one sites (Figure 11) were found to fall together in a single chemical group, on the basis of results of neutron activation analysis. This chemical group is entitled the Trade Wind Bead Chemical Group, hereafter abbreviated TWBCG, and it is presented in Table 6.

Most of the beads of the TWBCG are reheated cane beads. The exceptions are: KIL-IR11, a wound biconical bead, KIL-IR14, a wound conical-lenticular bead, and KAB-10, probably a wound bead, oblate in shape, plus a number of beads with smooth, flat ends, which make it difficult to tell if they have been reheated or not. These latter include the beads from Dhlo Dhlo (Chapter 6), which appear to have been barely reheated, as well as the beads from Modjadje's location (Chapter 6) and the beads MJE-5, -3a1, -3a2, and -3a3 from the Mjelele Valley Burial (Chapter 6), which had flat ends as if worn flat. The three beads MAK-1, -2, and LUS-1 also display flat ends.

A distinguishing feature of the TWBCG is its content of the element uranium. The mean uranium concentration in these beads is 112.43 ± 54.91 ppm, an unusually high level for man-made glass (Fleischer and Price 1964).

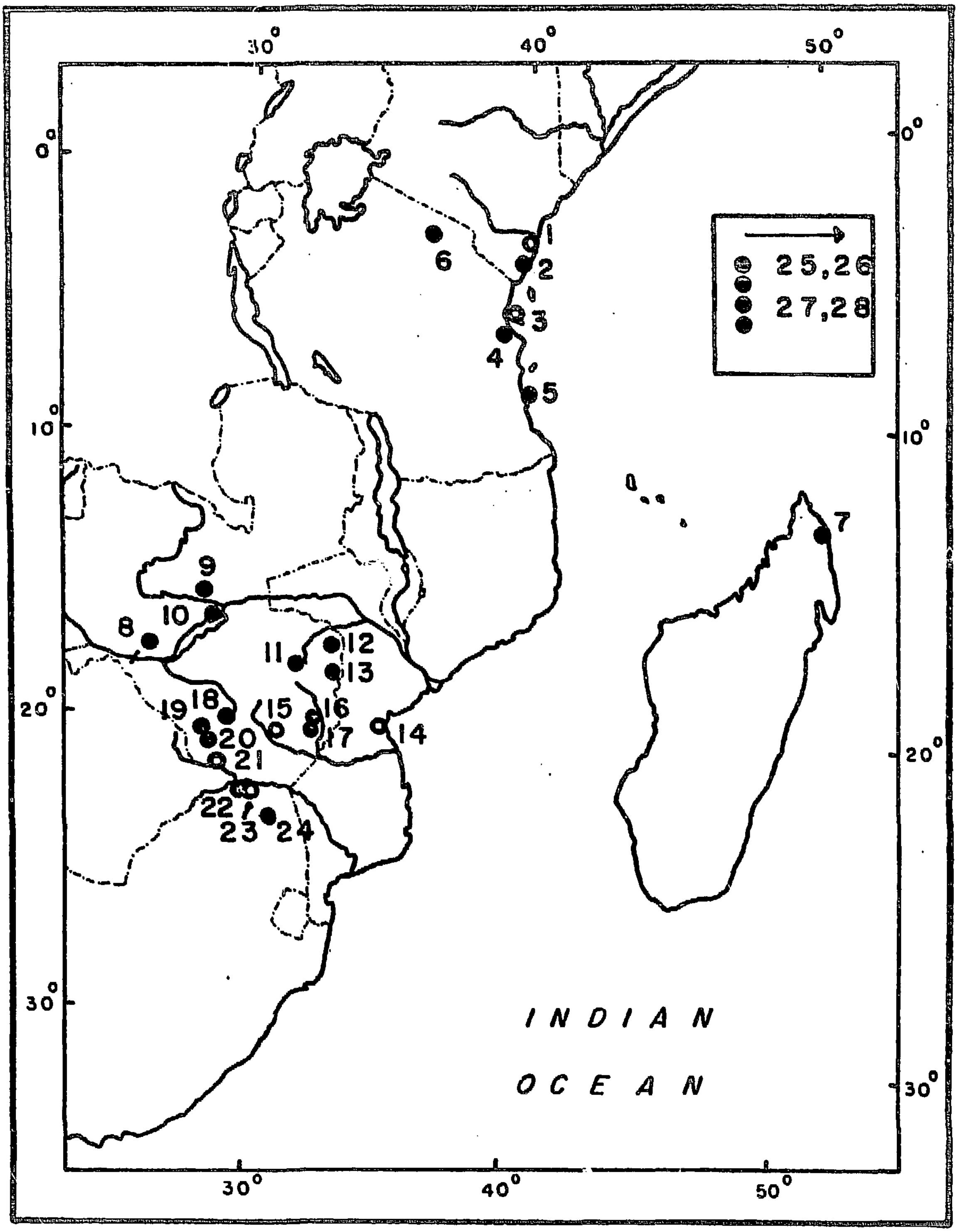

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Figure 11. Distribution of nuclear (●) and peripheral (◎) members of the Trade Wind Bead Chemical Group. The sites are listed in Table 8.

The one hundred thirty three beads in Table 6 may be called the nuclear members of the TWBCG, being characterized by detailed chemical analysis (neutron activation). In addition, seventeen more beads from six more sites (Figure 11, Table 8) are considered to be peripheral members of the TWBCG. These seventeen beads are considered peripheral because they received a less detailed analysis (X-ray fluorescence). These seventeen beads resemble the nuclear members in appearance and in the results of X-ray fluorescence analysis, particularly in the presence of the element uranium, detected by X-ray fluorescence analysis (Table 7). In order to be detected, the uranium must be ∿ 50-70 ppm or more. The peripheral beads do not enter into any means or other calculated parameters representing the nuclear group. They were not given neutron activation analysis, usually because destruction was not desired, or because our samples were too few, or were poorly documented.

The results of X-ray fluorescence analysis of the seventeen peripheral group members are presented in Table 7. In order to facilitate comparison of peripheral with nuclear members of the TWBCG, Tables 9 and 10 present the results of X-ray fluorescence analysis of two typical sets of nuclear trade wind beads, those from Fort Jesus and from Luanze. As the labels indicate, the beads shown in Tables 9 and 10 are the same individual beads are shown in Table 6.

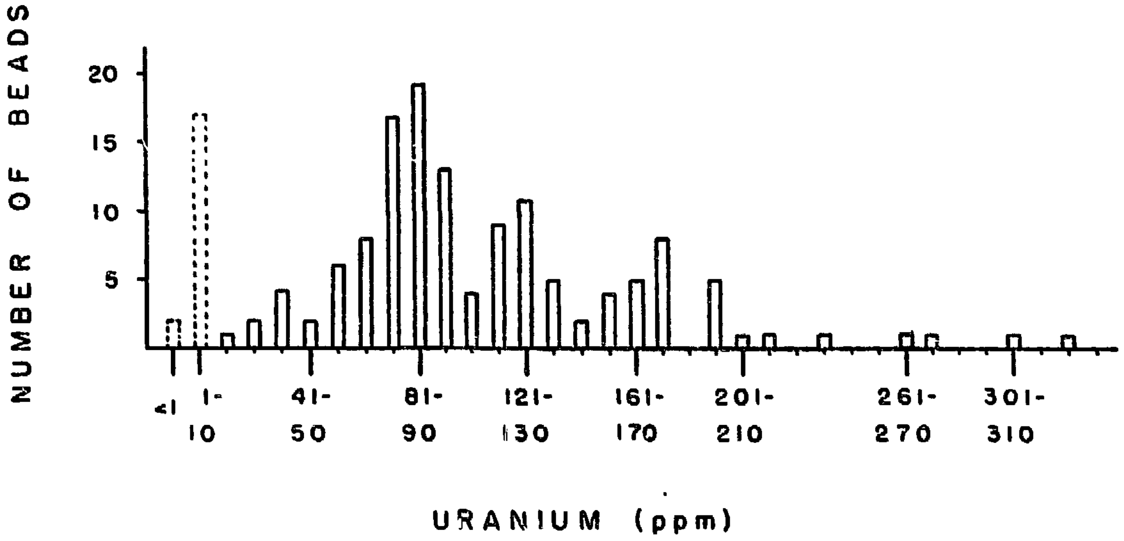
Table 11 contains the results of neutron activation analysis of other beads analyzed as a part of the trade wind bead study. The beads of Table 11a resemble the members of the TWBCG visually, chemically, and in geographical distribution. All are opaque to translucent reheated cane beads, except that BUT-175A and BUT-175B are transparent, KIL-HKCV3 is a wound spheroid, and ING-B8 is unreheated with flat ends.

However, the beads of Table 11a do not show the elevated uranium concentration typical of the TWBCG. When the distribution of uranium concentrations in the TWBCG is plotted as in Figure 12 (solid lines), the concentration ranges < 1 and 1-10 ppm are unpopulated and lie at the extreme tail of the distribution. If the beads of Table 11a are added to the plot (Figure 12, dotted lines), a notable clump is created at the tail of the distribution in the concentration ranges < 1 and 1-10 ppm. This clump contains a larger number of samples than one might expect at the tail of a normal distribution. This clump can be understood and omitted if one maintains that the low-uranium beads do not belong to the distribution.

Table 11b contains the results of analysis of four very transparent, bright green beads. They are cane beads with flat ends, except that MJE-21a appeared reheated. Being bright and transparent, they look very different from the trade wind beads. They also show chemical differences from the TWBCG, particularly in manganese and ytterbium.

The beads of Table 11 are provisionally excluded from the TWBCG as this group is presently understood. However, the resemblance of these beads to the TWBCG is marked. Future research may result in a change in our understanding of the TWBCG and in our disposition of the beads of Table 11.

It should not be considered disturbing to encounter borderline cases as in Table 11, for such cases are inherent in a classificatory approach. The fact that these samples are borderline cases is information in its own right. If our basic assumption is correct, that marked chemical resemblances are due to a commonality of manufacture, then the borderline cases may be regarded as closely related to the TWBCG.



XBL 728-1555

Figure 12. Distribution of uranium concentration in the Trade Wind Bead Chemical Group. The mean is 112.43 ± 54.91 ppm. See text for explanation of dotted bars.

The glass of the TWBCG is a soda-lime glass. The sodium content averages 14.96 ± 1.53% , and the calcium content averages ∿ 5%. The additives in common use were cobalt, zinc, copper, tin, iron and lead (the last by X-ray fluorescence). Manganese was very rarely used. Antimony was not used. The additive tin seems to be sometimes used, and sometimes omitted, in blue-green or green, greenish-yellow (pearl), and Indian red beads. All the yellow and orange beads display sufficient tin to indicate intentional use.

The TWBCG does not fall systematically into meaningful subgroups based on close chemical resemblance. Some small subgroups may be found. For example, the two Indian red beads from Manunggol, MAN-23A1 and MAN-23A2, show about four times the amount of copper colorant usually encountered in copper-colored beads of the TWBCG. The ten beads from the Gereza locality of Kilwa form a rather tight subgroup within the TWBCG. DAM-1a, DAM-1b, and DAM-1c are very much alike, as are MAT-GRY20, MAT-GRY21, and MAT-GRY22. The same may be said for VOH-7 and VOH-8, for KIL-IR12 and KIL-IR17, for KIL-IR15, KIL-IR16, and KIL-IR18, for KIL-MBG and KIL-MBG3, and for KIL-GRY4 and KIL-GRY6. Other small subgroups could be found.

It is not surprising that small clusters of samples like these might occur within the TWBCG. However, there is no clear evidence of a pattern permeating the TWBCG by which it might be broken into mutually exclusive, significant, and interpretable subgroups. For instance, the beads do not fall into subgroups that represent sites or colors, or more properly, groups dictated by the glassmakers' additives.[14] Whether the

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[14] Naturally the beads could be placed into subgroups according to the glassmakers' additives. But we are trying to build a classificatory system

beads are grouped by site or by color, in either case the mean concentrations and root mean square deviations for most elements are very similar (Table 12). Other things being equal, it is possible to take the mean of the root mean square deviations for each grouping as a measure of the heterogeneity in a grouping. When this is done the heterogeneity of color groupings is only slightly greater than that of site groupings on the average (Table 12).

By no means do we wish to leave the impression that all members of the TWBCG were made in the same glass batch. The differences among the group members are sufficiently strong to indicate emphatically that samples from many batches are present. There is a fair consistency in apparent coloring recipe, with occasional marked divergences. For example, in beads colored with copper, the additive is present in the tenths of percent range of concentration, averaging about 0.5%. However, in two copper-colored beads, MAN-23a1 and MAN-23a2, the copper is about four times as high. These two beads show other peculiarities (Table 6).

Another example of a possible divergence from recipe is the apparently rare use of manganese. Leaving out the four exceptional cases, the manganese averages 413 ± 138 ppm. This is less than half of the amount

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[14] (continued) which "sees through" the colors or additives. When looking for chemical subgroups other than (cross-cutting) those of color, we remove the additives from consideration. To say that the beads do not fall into subgroups representing colors means that, when the additives are left out of consideration, it is impossible to tell from the remaining elements what color the beads were. This fact may interest those concerned with cases of correlations between trace elements and glassmakers' additives.

which is found, on the average, in the earth's crust, ∿ 1000 ppm (Mason 1958:44). In other beads that we have analyzed, manganese can clearly be recognized as an additive by its consistently high concentration, in the tenths of percent and percent ranges (Chapters 8 and 9). There is thus little reason to think that manganese was added deliberately to beads of the TWBCG. However, there are four cases in the TWBCG in which manganese lies in the tenths of percent range. These are one black bead (MJE-15b), one yellow (KAB-10), one orange (FJE-A7-1), and one cobalt blue (DHL-1352f). Since there is no color pattern in the occurrence of such high manganese, these instances might be ascribed to factors other than recipe.

In sum, at the present time, it may be convenient to think of the TWBCG as an n-dimensional space in which the bead samples are scattered according to no consistent or far-reaching pattern that we have yet recognized.

Distribution, Dating, and Origin. The sites which yielded beads belonging to the TWBCG are listed in Table 8, and the distribution of these sites is shown in Figure 11. Table 13 gives the dating of the beads, as dated at the sites of occurrence.

The dates range from c. the eleventh century at Bambandyanalo[15] to c. 1700 at such sites as Dhlo Dhlo. The possible nineteenth-century occurrence at the Gereza (Kilwa) is not firmly dated on account of the thinness of later deposits at Kilwa (Chittick 1968). The occurrence

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[15] Engaruka yielded two earlier radiocarbon dates, 330 ± 90 A.D. (GX-348), and 720 ± 120 A.D. (GX-347), but these are regarded with skepticism (Sassoon 1967, Phillipson 1970), and in any case did not come from the same terrace platform (A5) whence came our sample.

c. 1937 as heirlooms in the Transvaal is firmly dated, but is not strictly archaeological. Thus, the entire span over which the TWBCG occurs is approximately nine hundred years, and the main archaeological span is approximately six hundred. Its dating in the Philippines, although unclear, covers similar centuries of the second millennium A.D. (Fox 1970).

If these beads span some six hundred years, it seems inappropriate to think that there was only one agent responsible for their importation, or indeed their manufacture. Six hundred years is longer than the time span of some civilizations, not to mention glass factories. As has been discussed in Chapter 4, if a bead group can span such a long period of time then it would not be as useful an archaeological tool as had previously been envisioned, with respect to dating or elucidating trade routes.

However, before drawing conclusions regarding the utility of chemical groups of glass beads, it is necessary to rule out the possibility that the long time span of the TWBCG may be illusory. Some beads may be mis-dated, through physical displacement by natural agents, on account of inappropriate radiocarbon dates, or by having been kept as heirlooms. If individual beads could be dated, the results may shed light on the question of whether or not the long time span of the bead group is illusory.

Many beads of the TWBCG contain sufficient uranium to make possible dating of individual beads by the fission track method. Such research is now being undertaken. It seems wise to postpone final judgment on the length of time that trade wind beads were being made and exported until this dating research is completed. In the meantime, if we accept the dates which are now given the beads, the following comments are appropriate about the distribution and origin of the trade wind beads.

Because beads of the TWBCG occur at many sites which post-date the arrival of the Portuguese (1498 A.D.), including some sites which witnesses the actual presence of the Portuguese, such as Kilwa (Quiloa), Fort Jesus (Mombaça), and two of the Portuguese fairs in Rhodesia, or Mwene Mutapa (Luanze and Dambarare), it seems likely that they were distributed by the Portuguese in Africa. Indeed, the hypothesis of Portuguese distribution in Rhodesia of the visually recognizable series which our TWBCG represents has already been expressed in the literature (Robinson 1961, Garlake 1968), and in many personal communications.

The occurrence of beads of the TWBCG in pre-Portuguese contexts, such as Period II at Kilwa, beneath the tomb of 1399 A.D. at Gedi, and at Bambandyanalo, would seem to indicate that they were also distributed by the (Arab) precursors of the Portuguese.

This distribution in pre- and post-Portuguese sites is consistent with the distribution which was predicted (Laidler 1934) for the beads which, the Portuguese wrote, came from India. Portuguese records of the sixteenth and seventeenth centuries indicate that beads purchased in India could be readily sold in East Africa (Barbosa c. 1514, in Dames 1918:6-8; a letter of Botelho 1552, in Theal 1964:III, 147; Lavanha 1597, in Theal 1964:II, 303; a letter of the King of Portugal 1635, in Theal 1964:IV, 262). Two of the records, those of 1552 and 1635, indicate that Africans preferred the beads purchased in India to other beads. It has been assumed that this preference of the sixteenth and seventeenth centuries represents the persistence of a fashion which had become established in the days of Arab trade. If this reflects the true age of the preference, then the beads purchased in India could be expected to occur in sites pre-dating and sites post-dating the arrival of the Portuguese. The TWBCG fulfills these distributional expectations, and we are therefore given a clue that the TWBCG may have come from India.

Sic Transit Trade Wind Beads. If these beads might have been purchased in India, one might ask if they were made there. Not necessarily (see Part 2 of this chapter). Prominent among the sources of beads named by the Portuguese are Cambay in India (Barbosa c. 1514, in Dames 1918:7-8; Pires c. 1515:16) and possibly Arabia Felix,or Aden (see Pires c. 1515: 16; Pigafetta c. 1589:576; Chittick 1966). These were among the busiest and most famous entrepôts of the Indian Ocean. Like any modern entrepôt, they handled many goods that did not originate in their own hinterland[16], as is clear from numerous documents and travelers' accounts (especially see Pires c. 1515:7-47). Writing c. 1512-15, only some fifteen years after the first arrival of the Portuguese in the Indian Ocean and contemporaneously with Barbosa, whose description of the trade route from Cambay to Mwene Mutapa is given at the head of this chapter, Tomé Pires gave clear evidence that the entrepôts of the Indian Ocean handled glass beads from the Mediterranean (Pires

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[16] It seems very likely that many stone beads, particularly lathe-turned and/or carnelian beads, originated near Cambay (Arkell 1936; Barbosa c. 1514:66; Pigafetta c. 1589:579; de Brito 1519, in Theal 1964:I, 104; Correa c. 1550, in Theal 1964:II, 26; de Albuquerque 1514, in Theal 1964:III, 146; Pires c. 1515:16, 18, 43, 53). Many stone beads are found in Indian archaeological sites, and some occur in East African coastal sites, such as Kilwa, Period II, and at Vohémar (Thierry 1961). Evidence of the manufacture of stone beads is known from the ancient period in Ujjain (Ghosh 1958). Stone beads have been entirely outside the scope of this investigation.

c. 1515:12, 43). He explained that Venetian galleys brought to Cairo, for trade further east, many Venetian articles including "all sorts of glass beads" (Pires c. 1515:13). He writes (c. 1515:12-13),

> The merchandise which these people[17] take to India comes from Venice in Italy. It comes to Alexandria, and from the Alexandrine warehouses it...is sent to Mecca.... And from there it comes to Jidda and from Jidda it comes to the warehouses they have in Aden and from Aden it is distributed to Cambay, Goa, Malabar, Bengal, Pegu and Siam.

These sites are shown in Figure 13.

Any suggestion of provenience for the TWBCG is inextricably bound up with, and hampered by, its broad dating. The TWBCG is made from soda-lime glass. As is well-known, glass of the ancient world was of the soda-lime type. The conventional historical picture is that the ancient soda-lime tradition passed directly from the ancient to the medieval world in the Near East. However, it is thought that the ancient soda-lime tradition was lost in medieval Europe, where potassium glasses were made, with probable exceptions in Mediterranean Europe, and other parts of Europe which had contact with the Near East. This would include Muslim parts of Europe, and centers of trade, such as Venice. Eventually with the coming of the Renaissance the soda-lime tradition spread from Venice and the other Italian cities to the growing cities of Europe. Thus, the TWBCG, being a soda-lime glass dated so as apparently to span nearly the entire second millennium A.D., might have come from virtually anywhere in the developed world of the second millennium A.D., except northern medieval Europe.

The broad dating of the TWBCG hampers suggestion of a focused origin. Were it only post-Portuguese in date then Europe would be a likely

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[17] Probably Egyptians.

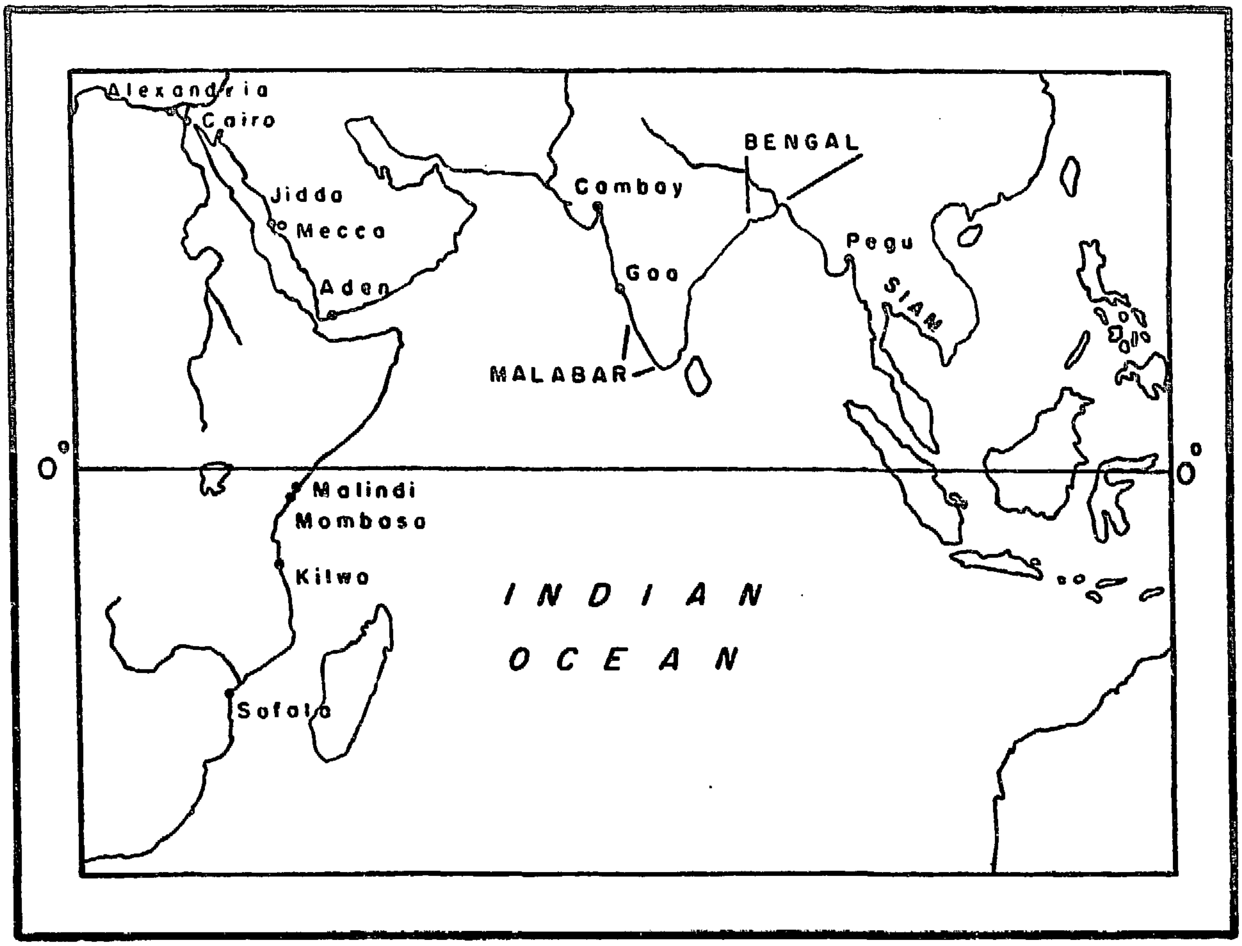

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Figure 13. Some entrepôts named in Portuguese documents.

source, considering its very frequent presence in Portuguese sites, including Portuguese fairs in Rhodesia. Were it only medieval in date, then the medieval Near East, Muslim parts of Europe, or medieval European centers of commerce with the Muslim Near East, such as Venice, might be reasonable suggestions. Pre-Portuguese Arab commerce could well have distributed Venetian beads in the Indian Ocean region; Venice was notorious for her commerce with the "infidel", and documentary evidence of the existence of her bead industry dates back to the end of the thirteenth century (Hetteš 1960:15) and early fourteenth century (Gasparetto 1958:183-4). On the other hand, the medieval Arabs were known for their glass manufacture, and an export commerce in glass trinkets is indicated in medieval sources from the Arab world (see Lamm 1930: exc. 24, 41, 56, 79; Mauny 1961:21-50). However, any attempt at identification of "documentary beads" with "archaeological beads" is fraught with uncertainty because "documentary beads" are never satisfactorily described.

The hypothesis of Indian manufacture of trade wind beads, which we shall discuss in Part 2 of this chapter, has been ill-founded since its inception, and is neither proven nor disproven.

A hypothesis of origins of the TWBCG must rest on firm archaeological data and chemical comparisons. With respect to medieval and post-medieval soda-lime glasses, the conventional glass history rests largely on stylistic and historical study and inference, rather than on chemical data. For example, the best known single work on glass of the medieval Near East is stylistic and historical in nature (Lamm 1930). Published chemical analyses of glass known or even thought to have been manufactured in the medieval Near East are too scant to form the basis of an interpretable comparison between them and our results. We are in very great need of data from factory sites--data that is comparable to the work presented here, in respects of archaeological documentation, analytical precision, analytical accuracy, elements determined, and numbers of samples analyzed.

In the absence of interpretable comparisons and narrow dating, we have no basis to suggest a focused provenience for the TWBCG. We conclude that its source cannot be specified until there may become available a useful number of comparable results of analysis of archaeologically documented samples, from archaeologically documented factory sites.

Part 2. India and the Origin of Trade Wind Beads

As discussed and cited in Part 1, the belief that trade wind beads were made in India originated with Beck. It received elaboration in the writings of Schofield and van der Sleen, and the evidence of Portuguese documents (discussed in Part 1) made the hypothesis seem plausible.

Very little at all is known archaeologically of the medieval to modern period in India, *c.* the tenth to nineteenth centuries A.D. Until recently there has been very little interest in this period, usually called the "Muslim" period, but it hoped that the future will hold some informative excavations of well-preserved "Muslim" sites.

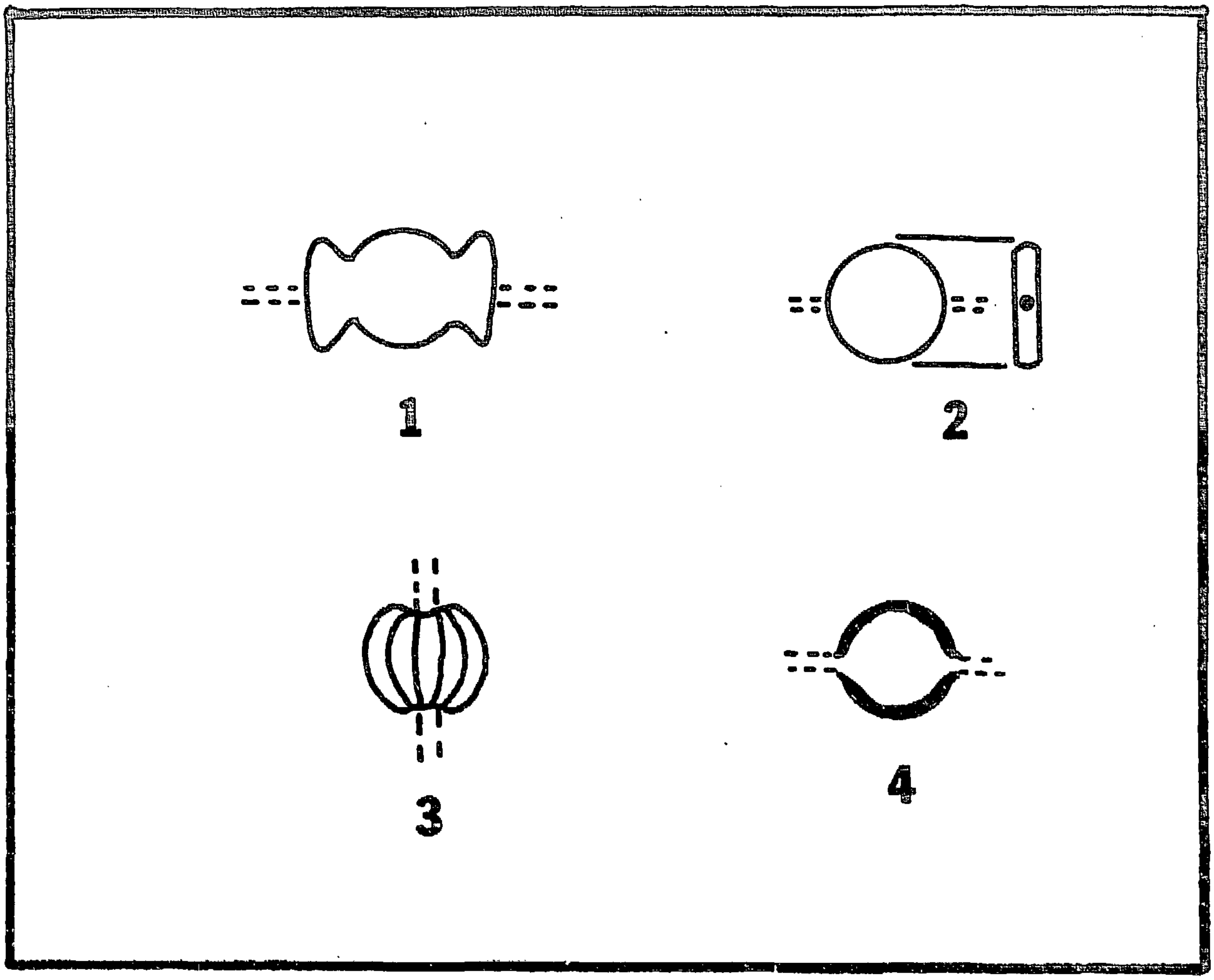
The author examined glass beads and similar glass material from some thirty Indian archaeological sites, mostly ancient, and found that the Indian material as a whole differs from the African. No pattern of visual resemblance of Indian to African glass beads was discovered. Moreover, the results of X-ray fluorescence analysis, presented below, are consistent with this visual impression of unrelatedness.

Most Indian glass bead assemblages of significance are ancient, belonging to the last centuries B.C. and the first centuries A.D., (personal observation; Dikshit 1969) and therefore not comparable to the African assemblages, which are medieval to modern. In view of the chronological disparity, it is not surprising that no pattern of resemblance was found.

Although it is a digression, a brief description of ancient Indian glass beads may be of interest. This period is known in India as the Early Historic Period, and, in a wide sense, dates from c. sixth century B.C. to c. the sixth century A.D. A typical assemblage, which has been published, is that of Nevasa (Sankalia et al. 1960).

The ancient Indian glass bead assemblages show a multiplicity of shapes not found or rare in medieval to modern sites of Africa. For example, collared beads are nearly ubiquitous in India, as are tablet-shaped beads (Figure 14). Also frequent are melon beads, blown beads, beads apparently containing a layer of gold foil, opaque red beads covered with a thin orange nonvitreous crust, polychrome beads, black and white inlaid beads, various faceted beads, and simple reheated and unreheated cane beads (personal observations; Dikshit 1969). In contrast, it is mainly the cane beads which are typical of East African sites. Indian assemblages typically have many stone beads, but these form a small percentage of the East African assemblages.

The ancient Indian glass beads show many interesting typological correspondences among different ancient sites, and seem worthy of considerable further study.

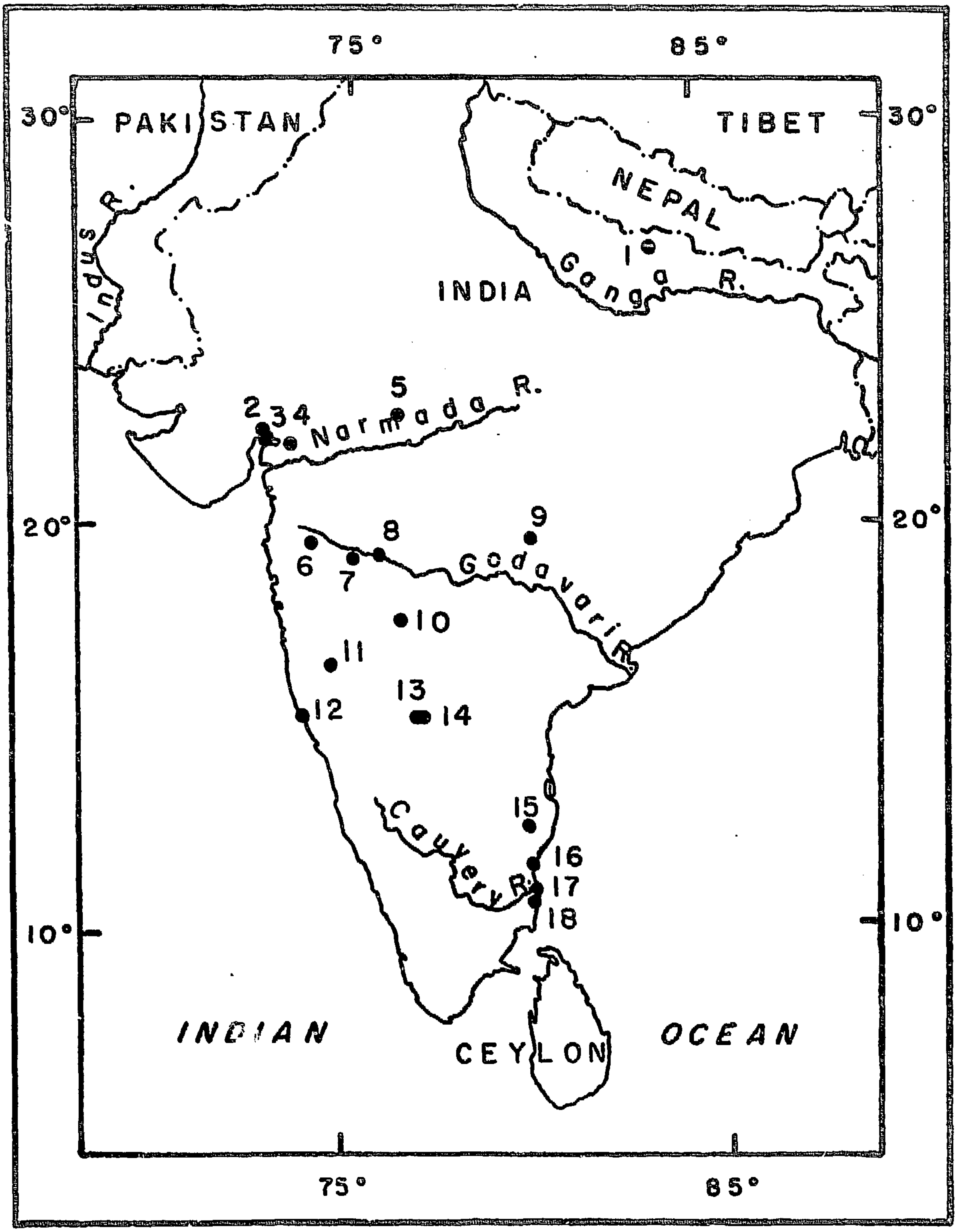


XBL 728-1541

Figure 14. Diagrams of some Indian bead profiles: 1) collared bead, 2) profile and perimeter, tablet bead, 3) melon bead, 4) section, blown bead.

With respect to the medieval period, India has no large, accessible, well-documented glass bead assemblages securely dated to this time, c. 600-1600 A.D. The excavated medieval glass bead material observed by the author in India consisted of samples which are unreliable, either due to their small size or to their incomplete documentation. This material is briefly listed below and the sites may be located in Figure 15. The material consisted of the following: 46 beads from Nagara (cited below) of which the majority may be ancient (the author is unable to relate the detailed labels of the beads to the stratigraphy at the site until the latter may be published); 4 beads, numerous bangle fragments and glass chunks from the incompletely documented site of Maski (Thapar 1957; Dikshit 1969); about 100 glass beads from the unpublished site of Kadkal; some 31 glass beads from medieval Kanchipuram (discussed below); some 43 beads from the medieval locality at Kaveripattinam, Vellaiyam Irippu II (Raman 1968), and some 90 beads from the Muslim-Marathi layers at Nevasa (Sankalia et al. 1960). Other medieval contexts, such as the Medical College Site at Baroda (Subbarao 1953) were examined, but these yielded no beads.

The above medieval glass bead material totals about 300 beads. A detailed typological census was not taken, but much of the material consists of reheated cane beads in the traditional colors of glass. It shows no marked visual resemblances to the African material beyond general likenesses due to the fact that the beads are glass. Where the material is well-documented the author requested samples for analysis, but with negligible response. The author did not see the unpublished material from Kolhapur, but Dikshit (1969) discusses it. He gives little idea as to the extent of the material, but the beads he describes as typical do not occur in African sites as far as the author is aware.



XBL 728-1542

Figure 15. Indian sites mentioned in text. For legend, see Table 14.

The medieval assemblages above seem to contain bead styles that are typically ancient in India. The published census from Nevasa, for example, indicates that the beads of the Muslim-Marathi period are not distinguishable, as a class, from the beads of the much earlier Indo-Roman period at the same site (Sankalia et al. 1960:355ff). This brings us to the subject of bead chronology in India.

The chronology of Indian glass beads is difficult to understand, for many of the same bead types seem to occur over long periods. For example, one easily recognizable style, a reheated cane bead of clear green glass over an opaque yellow core, also known as the "yellow matrix" bead (Sankalia et al. 1960), seems to occur in archaeological sites over a time spread possibly as great as 1800 years. At Nevasa this bead occurs in the Indo-Roman, or Satavahana, and Muslim-Marathi periods, i.e., c. first century B.C. to c. third century A.D., and c. fourteenth to eighteenth centuries A.D., respectively (Sankalia et al. 1960:355; Dikshit 1969; personal observation). It occurs in Satavahana (c. 100 B.C.-c. 200 A.D.) layers at Nasik (Sankalia and Deo 1955; Dikshit 1969; personal observation) and Ter (Dikshit 1969). It occurs among material dated from c. 100-c. 600 A.D. at Akota, ancient Baroda (Subbarao 1953). Here the bead (personal observation) came from a layer (layer 7 in Trench II) which partly underlies a brick structure placed in the third or fourth centuries A.D. (Subbarao 1953).

On the above information alone this bead type might seem to belong to the Satavahana or Indo-Roman period, c. 100 B.C.-c. 200 A.D. But this bead also seems to occur in later contexts. It occurs in the Muslim-Marathi layers at Nevasa (Sankalia et al. 1960). Dr. M. G. Dikshit showed the author one which he said belonged to the Bahmani period at Kolhapur, c. 1435-1518 A.D.

In bangle form this clear green over opaque yellow design was observed by the author in material from Kanchipuram dated to c. 850-1350 A.D. (Raman 1968) and in material from Maski and Kadkal, c. 1512 A.D. (Dikshit 1969).

The beads bearing this design look exceedingly alike, as if they had the same manufacturing origin and not merely the same design. The question thus arises that arose in the African context: whether the long time span of certain artifacts is illusory or not.

The chronological difficulty described above seems typical. The chain link bead, a style which, according to Dikshit (1969), is characteristic of the Bahmani period, 1435-1518 A.D., was observed by the author bearing the label "230 B.C.-285 A.D." among the material from Maski at the Hyderabad Museum. Many other similar examples could be given.

Clearly these are problems for chemical analysis, but it has proven quite difficult to obtain specimens for study outside India. The green over yellow bead from the Bahmani layers at Kolhapur was analyzed by X-ray fluorescence. Tin rather than antimony appears to have been the opacifier in use (Table 16). This is also true of the bangle fragments of Maski and Kadkal (Table 16). If the same is true of the beads from the Satavahana period, then the Satavahana and other ancient occurrences would appear to be quite early examples of the use of tin opacifiers.

The clear green over opaque yellow bead style, so widespread in India, was observed at one site in Africa: Mafia, where five examples occurred in the form of reheated cane beads (Chittick 1967; personal observation). This is the only notable similarity that the author found between assemblages of the two continental regions. To be sure, monochrome reheated cane glass beads found in Indian sites of any period might go unnoticed in a medieval African assemblage--but so would many an undecorated potsherd from many parts of the world, and it is risky to base a hypothesis on such nondescript materials as monochrome cane beads occurring in the basic, traditional, globally-distributed colors of glass.

Although we have no comprehensive archaeological picture of medieval India, or of its glass beads, some fragmentary evidence of glassworking during this period has been revealed. Possible glassworking sites of the medieval period are Maski, Kadkal, Paithan, Sirpur, Nagara, and Kanchipuram (Map, Figure 15).

Maski and Kadkal are eleven miles distant from one another and yield quite similar glass material, including chunks, lumps, bangle fragments, and beads (Dikshit 1969; personal observation). The sites are dated to c. 1518 A.D. on the basis of impressions of Vijayanagar coins said to have been found at Kadkal (Dikshit 1969). Maski has been partially described (Thapar 1957:16), but Kadkal has not.

Paithan (unpublished) yields material similar to that of Maski and Kadkal. Although the site is usually considered ancient, the writer observed sherds of apparent Chinese celadon and blue-and-white wares among the material from that site, and the site figures in medieval histories as a trading center (Sinha 1964).

Sirpur (unpublished) is numismatically dated to c. the thirteenth century A.D. (Dikshit 1969). It yielded crucible sherds lined with glass, as well as glass artifacts of both monochrome and polychrome design.

Nagara is a site two miles north of Cambay in Gujerat. It yielded glass lumps and apparent slag. The site was excavated by Mehta, has been partially described (Ghosh 1966, 1967; Mehta 1962), and is currently under study.

Kanchipuram is a historic South Indian city. Its exact time of origin is unknown, but it has apparently existed continually throughout the two millennia A.D., and it still exists today (Subrahmanyam and Raman 1967). The glass specimens examined by the author were dated c. 850-1350 A.D. (Raman 1968) and would thus belong to the Chola period, c. 850-1300 A.D. (Panikkar 1963; Sinha 1964). This find is interesting in view of Chau Ju Kua's statement that the Chola kingdom exported transparent and opaque glass (Hirth and Rockhill 1912:96). The nature of production at Kanchipuram is unclear, but the artifacts included transparent and opaque glass, as well as two glass-lined crucible sherds (personal observation). The site is currently under study, and glass samples have been promised us.

Results

Tables 15 and 16 present the results of X-ray fluorescence analysis of samples from four of the six possible medieval glassworking sites. Also presented are a few glass samples from the Indian Early Historic Period, as well as samples from the surface at Kaveripattinam, port of the medieval seafaring Chola kingdom (Ghosh 1965), and possibly extant as early as the first century A.D. (Panikkar 1963).

These data may be compared with the results of the same type of analysis of beads of the African TWBCG from Fort Jesus and Luanze, presented in Tables 9 and 10.

Discussion

Certain general similarities are apparent between the Indian samples and beads of the TWBCG. All the specimens are apparently made in a tradition in which tin rather than antimony is the opacifying agent. Lead is used as an additive rather than as a basic ingredient.

However, there are important specific differences between the Indian samples and the TWBCG. In the latter, manganese is rarely used. Black, in the TWBCG, is almost always created by an excessively dark green, an effect due to iron. However, manganese is apparently the agent used to give black in the specimens found at Kaveripattinam. In trade wind beads the zirconium, strontium, and barium consistently run around 0.01-0.03%, 0.02-0.03%, and 0.04-0.08% respectively. The concentrations of these elements in the Indian samples do not follow this pattern, nor do they exhibit a pattern of their own.

In none of the Indian samples was uranium detected, whereas it was usually detected in beads of the TWBCG. In the latter, the average uranium is 112.43 ± 54.91 ppm. This is well above the usual threshold (∿ 50-70 ppm) for detection of uranium by X-ray fluorescence in our experience. If the Indian beads were like the TWBCG, then one might expect a normal distribution of uranium values around the same mean. If the standard deviation were similar, then one might expect over two-thirds of the Indian beads to show detectable uranium on X-ray fluorescence. However, as noted above, this was not the case.

Our particular Indian samples were generally not well-documented. Much of the material is surface or collected material which is not known certainly to have come from excavated contexts, although excavations have been carried out at parts of some of the sites. In some cases, such as Kadkal and Paithan, the sites and excavations have never been published except as mentioned by others (Dikshit 1969). Thus, when X-ray fluorescence of Indian samples did not yield reason to proceed with further analyses, particularly in the absence of satisfactory documentation of the samples and/or the sites, the samples were set aside.

The above X-ray results, representing the majority of known medieval factory sites, do not support the hypothesis of trade wind bead manufacture in India. On the other hand they provide no definitive disproof--our samples are few.

As seen from the above, the hypothesis of trade wind bead manufacture in India rests upon no foundation of chemical data. Moreover, the other evidence originally put forth to support this hypothesis virtually evaporates under close examination in the light of present standards. The vagueness of the term "trade wind beads" has already been discussed. Van der Sleen claimed he "could prove" the Indian manufacture of these beads (1965:394). His proof, as such, was never offered in the literature, and therefore the extent of his evidence is unknown; but he indicated that some, if not all, of his evidence was the finding of 2-5% phosphates in trade wind beads and in Indian beads (1960, 1967). The presence of phosphates, however, is not diagnostic of any particular glass manufacture. They are quite common in many kinds of glass (Turner 1956b:162-164T; 1956c:290T), and 2-5% is a typical amount.

Beck also called attention to similarities between glass beads found in India, Southeast Asia, and East and southern Africa. Beck's bead collection is now preserved in the Museum of Archaeology and Ethnology, Cambridge, and it is possible to view the beads from which he apparently made his judgments. These beads consist mainly of surface collections and other undocumented material, and they appear to be quite mixed. They include beads which would fit into African sites, others which would fit into ancient Indian sites, and others which would fit into nineteenth-century sample sets. A hypothesis based on this undocumented evidence cannot be regarded as firmly grounded.

A pilot's account (Lavanha 1957, <u>in</u> Theal 1964:II, 303) is the main comtemporary report indicating that ceramic beads found in Africa were made, as distinct from purchased, at Negapatam, but it is not clear whether Lavanha was referring to clay or to glass, although glass seems more likely.[18] In any case no archaeological evidence of the manufacture and export of any beads has yet come to light at Negapatam.

In evaluation, present evidence indicates that the hypothesis of manufacture in India of glass beads found in Africa is neither proven, nor disproven, nor well-founded in the first place.

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[18] Clay products are usually brownish or grayish, and Lavanha's mention of beads of clay "of all colors" makes one doubt that they were clay. The reference may have been to trade wind beads, which are easily confused with clay because of their low chroma and their opacity. The writer has observed colleagues make the same mistake when examining trade wind beads for the first time. De Couto, who lived from 1542-1616, may have made the same mistake as well (<u>in</u> Theal 1964:VI, 368).

Table 6. Trade Wind Bead Chemical Groups:
Neutron Activation Analysis[a,b]

Sample	Provenience[c]	Color
FJE-A2-1	Fort Jesus	black
FJE-A2-2	"	"
FJE-A4-1	"	green
FJE-A4-2	"	"
FJE-A4-3	"	"
FJE-A6-1	"	Indian red
FJE-A6-2	"	"
FJE-A8-1	"	greenish-yellow
FJE-A3-1	"	yellow
FJE-A3-2	"	"
FJE-A7-1	"	orange
FJE-X-1	"	pale cobalt blue
FJE-A-1	"	cobalt blue
LUA-1a	Luanze	black
LUA-1c	"	"
LUA-8a	"	blue-green
LUA-7	"	green
LUA-4a	"	Indian red
LUA-3a	"	greenish-yellow
LUA-5b	"	yellow
LUA-9a	"	cobalt blue
LUA-9b	"	"
DAM-4	Dambarare	green
DAM-1a	"	Indian red
DAM-1b	"	"
DAM-1c	"	"
DAM-2a	"	"
DAM-2b	"	"
DAM-3	"	cobalt blue
MAT-3	Matendere	black
MAT-1	"	Indian red
MAT-GRY20	"	greenish-yellow
MAT-GRY21	"	"
MAT-GRY22	"	"
MAT-13	"	yellow
MAT-10	"	cobalt blue
DHL-1353a	Dhlo Dhlo	blue-green
DHL-1353b	"	"
DHL-1353c	"	"
DHL-1353d	"	"
DHL-1353e	"	"
DHL-1353f	"	"

DHL-1352a	Dhlo Dhlo		cobalt blue
DHL-1352b	"		"
DHL-1352c	"		"
DHL-1352d	"		"
DHL-1352e	"		"
DHL-1352f	"		"
VOH-9	Vohémar		green
VOH-3	"		blue-green
VOH-4	"		"
VOH-1	"		Indian red
VOH-2	"		"
VOH-7	"		yellow
VOH-8	"		"
VOH-5	"		cobalt blue
VOH-6	"		"
KIL-IR14	Kilwa,	Period II	Indian red
KIL-IR11	"	"	"
KIL-IR12	"	Period IIIb	"
KIL-GRY12	"	"	greenish-yellow
KIL-GRY8	"	"	"
KIL-LWK1	"	"	blue-green
KIL-LWK2	"	"	"
KIL-GRY11	"	Period IV	greenish-yellow
KIL-GRY10	"	"	"
KIL-GRY1	"	"	"
KIL-MBG	"	"	black
KIL-MBG1	"	"	green
KIL-MBG2	"	"	"
KIL-MBG3	"	"	black
KIL-MBG4	"	"	"
KIL-MBG5	"	"	orange
KIL-IR17	"	"	Indian red
KIL-IR15	"	"	"
KIL-IR16	"	"	"
KIL-IR18	"	"	"
KIL-GRY4	"	"	greenish-yellow
KIL-GRY6	"	"	"
KIL-GRY5	"	"	"
KIL-GRY7	"	"	"
GER-1a	Kilwa (Gereza),	Period V	green
GER-1b	"		"
GER-1d	"		"
GER-1e	"		"
GER-1c	"		"
GER-2a	"		cobalt blue
GER-2b	"		"
GER-2c	"		"
GER-2d	"		"
GER-2e	"		"

BAM-S38a	Bambandyanalo	Indian red
BAM-S38b	"	"
BAM-S38c	"	"
BAM-S38d	"	"
CHI-1	Chibvumani	blue-green
CHI-GRY17	"	greenish-yellow
CHI-GRY18	"	"
CHI-GRY19	"	"
CHI-2	"	Indian red
NYA-GRY16	Nyangwe Fort	greenish-yellow
KHA-4770a	Khami	Indian red
KHA-4770b	"	"
MAK-1	Makoli	orange
MAK-2	"	yellow
LUS-1	Lusaka Cave Site	"
ING-GRY13	Ingombe Ilede	greenish-yellow
ING-GRY14	"	"
ING-GRY2	"	"
ENG-IR10	Engaruka	Indian red
MOD-2a	Modjadje's location	blue-green
MOD-2b	"	"
MOD-2c	"	"
MOD-2d	"	"
MOD-2e	"	"
MOD-2f	"	"
MOD-6	"	yellow
MOD-5a	"	cobalt blue
MOD-5b	"	"
MOD-5c	"	"
MJE-15a	Mjelele Valley Burial	black
MJE-5	"	blue-green
MJE-3a1	"	"
MJE-3a2	"	"
MJE-3a3	"	"
MJE-8a	"	yellow
STA-139a	Santa Ana (Philippine Is.)	black
STA-139b	" "	"
POR-34	Porac "	Indian red
MAN-23a1	Manunggol "	"
MAN-23a2	" "	"
KAB-10	Kab'wan "	yellow
KAB-201	" "	"

Table 6. continued

Sample	Al (%)	Cl (%)	Mn
FJE-A2-1	3.03 ± 0.06	1.01 ± 0.12	684 ± 17
FJE-A2-2	3.60 ± 0.30	1.06 ± 0.14	340 ± 23
FJE-A4-1	2.98 ± 0.24	1.67 ± 0.13	519 ± 22
FJE-A4-2	3.47 ± 0.07	1.27 ± 0.14	408 ± 19
FJE-A4-3	3.50 ± 0.10	1.34 ± 0.15	679 ± 34
FJE-A6-1	3.64 ± 0.13	1.80 ± 0.15	704 ± 17
FJE-A6-2	3.55 ± 0.09	1.22 ± 0.14	512 ± 14
FJE-A8-1	3.99 ± 0.18	1.17 ± 0.09	407 ± 18
FJE-A3-1	3.46 ± 0.36	1.70 ± 0.20	516 ± 30
FJE-A3-2	3.56 ± 0.08	1.12 ± 0.14	486 ± 26
FJE-A7-1	2.69 ± 0.10	1.32 ± 0.12	1,041 ± 27
FJE-X-1	2.95 ± 0.13	1.57 ± 0.14	872 ± 29
FJE-A-1	3.91 ± 0.08	1.55 ± 0.15	655 ± 32
LUA-1a	3.64 ± 0.11	1.86 ± 0.20	328 ± 13
LUA-1c	4.38 ± 0.08	1.52 ± 0.21	562 ± 18
LUA-8a	3.06 ± 0.13	1.29 ± 0.20	309 ± 13
LUA-7	4.38 ± 0.13	1.21 ± 0.18	425 ± 13
LUA-4a	3.88 ± 0.27	1.42 ± 0.25	510 ± 21
LUA-3a	3.92 ± 0.24	1.93 ± 0.21	334 ± 14
LUA-5b	3.98 ± 0.19	1.62 ± 0.21	306 ± 13
LUA-9a	5.01 ± 0.37	1.11 ± 0.38	431 ± 22
LUA-9b	3.91 ± 0.34	1.52 ± 0.20	302 ± 14
DAM-4	4.22 ± 0.25	1.79 ± 0.25	462 ± 18
DAM-1a	3.72 ± 0.46	1.51 ± 0.25	766 ± 25
DAM-1b	3.55 ± 0.28	1.02 ± 0.31	534 ± 19
DAM-1c	3.12 ± 0.21	1.73 ± 0.26	555 ± 21
DAM-2a	3.70 ± 0.09	1.03 ± 0.18	517 ± 13
DAM-2b	4.16 ± 0.11	1.39 ± 0.19	539 ± 15
DAM-3	3.30 ± 0.15	1.18 ± 0.20	322 ± 14
MAT-3	4.69 ± 0.22	1.44 ± 0.25	394 ± 22
MAT-1	4.40 ± 0.29	1.61 ± 0.21	312 ± 28
MAT-GRY20	3.86 ± 0.08	1.69 ± 0.15	373 ± 18
MAT-GRY21	4.04 ± 0.12	1.91 ± 0.16	384 ± 21
MAT-GRY22	3.71 ± 0.15	1.72 ± 0.15	367 ± 22
MAT-13	3.67 ± 0.26	1.25 ± 0.22	331 ± 23
MAT-10	4.05 ± 0.24	1.23 ± 0.23	868 ± 35
DHL-1353a	4.55 ± 0.15	1.84 ± 0.23	351 ± 25
DHL-1353b	2.77 ± 0.21	1.41 ± 0.27	286 ± 30
DHL-1353c	3.91 ± 0.17	1.26 ± 0.17	280 ± 21
DHL-1353d	2.99 ± 0.30	1.98 ± 0.21	376 ± 27
DHL-1353e	2.06 ± 0.12	1.40 ± 0.19	172 ± 19
DHL-1353f	3.18 ± 0.13	1.55 ± 0.17	253 ± 21

DHL-1352a	3.30 ± 0.19	2.00 ± 0.31	262 ± 30
DHL-1352b	3.56 ± 0.20	1.70 ± 0.25	299 ± 25
DHL-1352c	4.37 ± 0.46	1.23 ± 0.35	308 ± 36
DHL-1352d	4.42 ± 0.49	1.91 ± 0.29	311 ± 30
DHL-1352e	2.95 ± 1.03	1.52 ± 0.38	367 ± 41
DHL-1352f	4.53 ± 0.18	2.06 ± 0.33	1,128 ± 42
VOH-9	5.82 ± 0.59	1.38 ± 0.28	475 ± 24
VOH-3	3.42 ± 0.17	1.11 ± 0.25	296 ± 17
VOH-4	3.35 ± 0.21	1.48 ± 0.25	296 ± 18
VOH-1	4.28 ± 0.13	0.56 ± 0.21	429 ± 15
VOH-2	4.19 ± 0.16	0.61 ± 0.21	436 ± 17
VOH-7	3.27 ± 0.18	1.08 ± 0.23	321 ± 31
VOH-8	4.19 ± 0.35	1.41 ± 0.25	330 ± 19
VOH-5	3.64 ± 0.41	1.81 ± 0.29	401 ± 18
VOH-6	4.27 ± 0.27	1.52 ± 0.25	399 ± 19
KIL-IR14	4.58 ± 0.12	1.16 ± 0.13	267 ± 14
KIL-IR11	3.62 ± 0.31	1.12 ± 0.12	404 ± 13
KIL-IR12	4.74 ± 0.08	1.53 ± 0.15	582 ± 16
KIL-GRY12	4.28 ± 1.06	1.58 ± 0.12	288 ± 43
KIL-GRY8	4.09 ± 0.21	1.49 ± 0.11	452 ± 38
KIL-IWK1	3.71 ± 0.09	1.23 ± 0.20	371 ± 16
KIL-IWK2	3.58 ± 0.10	1.88 ± 0.19	420 ± 16
KIL-GRY11	4.99 ± 0.53	1.55 ± 0.12	466 ± 44
KIL-GRY10	4.47 ± 0.28	1.81 ± 0.11	450 ± 37
KIL-GRY1	–[d]	–[d]	488 ± 19
KIL-MBG	–[d]	–[d]	337 ± 37
KIL-MBG1	4.02 ± 0.07	1.29 ± 0.20	353 ± 15
KIL-MBG2	4.77 ± 0.21	1.77 ± 0.21	421 ± 19
KIL-MBG3	3.12 ± 0.14	1.26 ± 0.20	386 ± 14
KIL-MBG4	4.62 ± 0.20	1.27 ± 0.18	680 ± 16
KIL-MBG5	3.22 ± 0.23	1.58 ± 0.17	316 ± 12
KIL-IR17	4.27 ± 0.06	1.12 ± 0.14	513 ± 11
KIL-IR15	3.26 ± 0.15	1.47 ± 0.14	346 ± 16
KIL-IR16	3.22 ± 0.23	1.58 ± 0.14	352 ± 17
KIL-IR18	3.32 ± 0.07	1.40 ± 0.14	506 ± 12
KIL-GRY4	5.03 ± 1.01	1.54 ± 0.11	451 ± 32
KIL-GRY6	4.57 ± 0.14	1.30 ± 0.14	453 ± 22
KIL-GRY5	5.32 ± 0.23	1.40 ± 0.10	546 ± 35
KIL-GRY7	4.91 ± 0.22	1.37 ± 0.11	523 ± 36
GER-1a	4.21 ± 0.16	1.60 ± 0.19	342 ± 13
GER-1b	3.86 ± 0.18	1.35 ± 0.18	343 ± 13
GER-1d	3.82 ± 0.39	1.42 ± 0.19	388 ± 15
GER-1e	4.62 ± 0.65	1.25 ± 0.21	349 ± 19
GER-1c	4.08 ± 0.25	1.46 ± 0.18	382 ± 14
GER-2a	3.81 ± 0.13	1.57 ± 0.19	304 ± 16
GER-2b	3.64 ± 0.17	1.76 ± 0.20	296 ± 18
GER-2c	3.72 ± 0.22	1.57 ± 0.19	294 ± 18
GER-2d	3.24 ± 0.31	1.80 ± 0.20	287 ± 19
GER-2e	2.83 ± 0.54	1.68 ± 0.22	292 ± 22

BAM-S38a	4.47 ± 1.42	1.14 ± 0.24	597 ± 27
BAM-S38b	4.42 ± 0.13	1.26 ± 0.23	387 ± 27
BAM-S38c	4.86 ± 0.52	0.68 ± 0.22	532 ± 17
BAM-S38d	4.44 ± 0.17	1.03 ± 0.25	405 ± 32
CHI-1	3.10 ± 0.08	1.49 ± 0.19	267 ± 14
CHI-GRY17	3.45 ± 0.09	1.78 ± 0.14	404 ± 21
CHI-GRY18	2.15 ± 0.16	0.80 ± 0.11	240 ± 19
CHI-GRY19	5.21 ± 0.28	1.71 ± 0.19	517 ± 28
CHI-2	4.05 ± 0.18	1.56 ± 0.19	311 ± 14
NYA-GRY16	4.09 ± 0.25	1.48 ± 0.16	442 ± 27
KHA-4770a	3.27 ± 0.39	1.30 ± 0.25	540 ± 29
KHA-4770b	4.48 ± 0.33	1.43 ± 0.29	543 ± 18
MAK-1	3.69 ± 0.16	1.11 ± 0.12	437 ± 11
MAK-2	2.50 ± 0.10	1.24 ± 0.13	660 ± 12
LUS-1	3.42 ± 0.46	1.17 ± 0.17	379 ± 10
ING-GRY13	3.54 ± 0.08	1.33 ± 0.14	505 ± 17
ING-GRY14	3.50 ± 0.37	1.57 ± 0.16	352 ± 24
ING-GRY2	-^{d}	-^{d}	380 ± 16
ENG-IR10	-^{d}	-^{d}	502 ± 24
MOD-2a	3.57 ± 0.16	1.06 ± 0.14	299 ± 20
MOD-2b	3.73 ± 0.28	1.42 ± 0.17	286 ± 25
MOD-2c	2.21 ± 0.62	1.17 ± 0.23	306 ± 35
MOD-2d	3.30 ± 0.13	1.31 ± 0.19	322 ± 29
MOD-2e	3.47 ± 0.18	1.70 ± 0.21	299 ± 33
MOD-2f	3.13 ± 0.27	1.91 ± 0.25	259 ± 38
MOD-6	2.71 ± 0.21	1.34 ± 0.23	229 ± 17
MOD-5a	3.84 ± 0.16	1.60 ± 0.19	365 ± 24
MOD-5b	3.45 ± 0.24	1.44 ± 0.21	368 ± 29
MOD-5c	3.71 ± 0.53	2.69 ± 0.32	272 ± 47
MJE-15a	3.36 ± 0.16	1.46 ± 0.28	2,720 ± 46
MJE-5	3.17 ± 0.24	1.37 ± 0.24	247 ± 13
MJE-3a1	3.17 ± 0.19	1.40 ± 0.18	236 ± 10
MJE-3a2	2.78 ± 0.33	1.89 ± 0.22	272 ± 13
MJE-3a3	3.08 ± 0.58	1.45 ± 0.27	267 ± 19
MJE-8a	4.61 ± 0.47	1.01 ± 0.15	528 ± 12
STA-139a	5.10 ± 0.30	2.12 ± 0.24	368 ± 18
STA-139b	4.35 ± 0.41	2.20 ± 0.23	311 ± 18
POR-34	5.09 ± 0.23	1.00 ± 0.16	-^{d}
MAN-23a1	3.97 ± 0.10	0.48 ± 0.14	818 ± 23
MAN-23a2	3.86 ± 0.08	0.50 ± 0.16	817 ± 22
KAB-10	3.70 ± 0.13	1.42 ± 0.15	1,487 ± 30
KAB-201	4.40 ± 0.37	1.30 ± 0.36	384 ± 19

Table 6. continued

Sample	Na (%)	Cu^e	U
FJE-A2-1	13.09 ± 0.14	-^{e}	78.48 ± 0.42
FJE-A2-2	14.19 ± 0.12	-^{e}	111.51 ± 0.63
FJE-A4-1	14.88 ± 0.16	6,852 ± 129	123.91 ± 0.65
FJE-A4-2	15.34 ± 0.18	3,162 ± 121	86.12 ± 0.46
FJE-A4-3	15.11 ± 0.14	4,409 ± 122	137.44 ± 0.74
FJE-A6-1	16.88 ± 0.22	6,557 ± 133	157.65 ± 0.61
FJE-A6-2	16.40 ± 0.21	3,991 ± 113	136.16 ± 0.53
FJE-A8-1	15.36 ± 0.13	-^{e}	55.86 ± 0.26
FJE-A3-1	15.84 ± 0.15	-^{e}	81.05 ± 0.47
FJE-A3-2	14.98 ± 0.13	-^{e}	122.54 ± 0.65
FJE-A7-1	14.14 ± 0.15	-^{e}	125.11 ± 0.66
FJE-X-1	14.71 ± 0.14	-^{e}	65.83 ± 0.37
FJE-A-1	15.22 ± 0.14	-^{e}	84.47 ± 0.47
LUA-1a	15.37 ± 0.17	-^{e}	192.50 ± 1.07
LUA-1c	14.45 ± 0.25	-^{e}	165.66 ± 0.96
LUA-8a	15.76 ± 0.17	4,507 ± 145	90.40 ± 0.53
LUA-7	15.40 ± 0.17	4,763 ± 129	71.18 ± 0.40
LUA-4a	14.14 ± 0.15	4,250 ± 172	69.89 ± 0.46
LUA-3a	15.71 ± 0.17	-^{e}	64.66 ± 0.37
LUA-5b	15.75 ± 0.17	-^{e}	93.96 ± 0.54
LUA-9a	14.38 ± 0.19	1,912 ± 267	82.24 ± 0.56
LUA-9b	14.49 ± 0.16	-^{e}	173.21 ± 0.96
DAM-4	15.50 ± 0.20	8,464 ± 203	208.11 ± 1.12
DAM-1a	16.16 ± 0.17	5,443 ± 173	131.64 ± 0.76
DAM-1b	16.34 ± 0.19	5,002 ± 225	138.07 ± 0.75
DAM-1c	15.77 ± 0.16	4,846 ± 178	140.38 ± 0.82
DAM-2a	13.75 ± 0.18	6,407 ± 155	98.00 ± 0.54
DAM-2b	14.97 ± 0.19	5,163 ± 150	89.50 ± 0.50
DAM-3	15.30 ± 0.20	-^{e}	124.94 ± 0.68
MAT-3	15.29 ± 0.21	-^{e}	95.94 ± 0.51
MAT-1	14.06 ± 0.20	5,347 ± 169	99.27 ± 0.52
MAT-GRY20	15.72 ± 0.13	-^{e}	117.07 ± 0.65
MAT-GRY21	15.82 ± 0.14	-^{e}	117.52 ± 0.66
MAT-GRY22	15.34 ± 0.13	-^{e}	114.08 ± 0.64
MAT-13	12.88 ± 0.18	-^{e}	125.00 ± 0.64
MAT-10	14.53 ± 0.21	-^{e}	59.50 ± 0.33
DHL-1353a	14.93 ± 0.19	5,192 ± 194	87.16 ± 0.43
DHL-1353b	15.22 ± 0.20	4,537 ± 217	117.40 ± 0.58
DHL-1353c	14.69 ± 0.18	4,977 ± 152	19.58 ± 0.12
DHL-1353d	16.89 ± 0.21	5,272 ± 180	31.90 ± 0.18
DHL-1353e	14.02 ± 0.13	3,487 ± 150	38.30 ± 0.24
DHL-1353f	15.83 ± 0.14	5,132 ± 139	87.07 ± 0.21

DHL-1352a	14.42 ± 0.21	-^{e}	80.33 ± 0.45
DHL-1352b	15.29 ± 0.20	1,519 ± 180	41.83 ± 0.23
DHL-1352c	15.67 ± 0.23	-^{e}	64.17 ± 0.38
DHL-1352d	16.10 ± 0.22	-^{e}	91.20 ± 0.46
DHL-1352e	15.34 ± 0.22	-^{e}	40.62 ± 0.27
DHL-1352f	16.54 ± 0.23	-^{e}	196.15 ± 0.96
VOH-9	14.50 ± 0.17	5,503 ± 200	168.83 ± 0.89
VOH-3	15.15 ± 0.17	4,726 ± 176	95.23 ± 0.53
VOH-4	14.98 ± 0.17	4,888 ± 182	92.39 ± 0.52
VOH-1	12.76 ± 0.18	6,312 ± 178	87.81 ± 0.47
VOH-2	12.89 ± 0.18	6,470 ± 184	89.25 ± 0.48
VOH-7	13.42 ± 0.20	-^{e}	78.06 ± 0.43
VOH-8	13.57 ± 0.16	-^{e}	79.14 ± 0.45
VOH-5	14.93 ± 0.17	-^{e}	74.56 ± 0.46
VOH-6	14.64 ± 0.17	-^{e}	153.64 ± 0.81
KIL-IR14	13.82 ± 0.18	2,585 ± 98	84.70 ± 0.33
KIL-IR11	13.04 ± 0.16	5,542 ± 108	69.73 ± 0.28
KIL-IR12	16.84 ± 0.21	1,740 ± 100	175.53 ± 0.67
KIL-GRY12	15.50 ± 0.16	-^{e}	102.14 ± 0.43
KIL-GRY8	17.54 ± 0.18	-^{e}	81.01 ± 0.34
KIL-LWK1	15.98 ± 0.27	5,640 ± 175	152.30 ± 0.83
KIL-LWK2	15.32 ± 0.25	5,449 ± 164	126.44 ± 0.69
KIL-GRY11	16.74 ± 0.18	-^{e}	147.37 ± 0.74
KIL-GRY10	15.28 ± 0.16	-^{e}	238.38 ± 0.92
KIL-GRY1	14.26 ± 0.14	-^{e}	172.16 ± 3.91
KIL-MBG	15.02 ± 0.25	-^{e}	180.31 ± 3.33
KIL-MBG1	16.82 ± 0.28	3,043 ± 149	178.57 ± 0.97
KIL-MBG2	17.27 ± 0.29	2,568 ± 150	261.15 ± 1.41
KIL-MBG3	15.78 ± 0.19	-^{e}	180.04 ± 0.99
KIL-MBG4	14.99 ± 0.18	-^{e}	123.76 ± 0.69
KIL-MBG5	13.35 ± 0.17	-^{e}	213.45 ± 1.13
KIL-IR17	14.47 ± 0.19	1,339 ± 89	191.30 ± 0.74
KIL-IR15	16.69 ± 0.21	2,227 ± 96	121.95 ± 0.47
KIL-IR16	16.79 ± 0.21	2,210 ± 100	120.26 ± 0.46
KIL-IR18	16.84 ± 0.21	1,440 ± 93	113.60 ± 0.44
KIL-GRY4	15.46 ± 0.16	-^{e}	180.28 ± 0.72
KIL-GRY6	15.67 ± 0.18	-^{e}	190.57 ± 1.00
KIL-GRY5	15.18 ± 0.16	-^{e}	178.92 ± 0.69
KIL-GRY7	16.64 ± 0.18	-^{e}	-^{d}
GER-1a	15.30 ± 0.15	5,931 ± 136	86.54 ± 0.52
GER-1b	15.15 ± 0.15	5,910 ± 131	84.29 ± 0.51
GER-1d	15.38 ± 0.15	5,705 ± 129	86.06 ± 0.51
GER-1e	15.43 ± 0.15	6,069 ± 144	88.58 ± 0.53
GER-1c	15.10 ± 0.15	6,184 ± 127	123.90 ± 0.72
GER-2a	16.27 ± 0.16	-^{e}	79.14 ± 0.48
GER-2b	15.85 ± 0.16	-^{e}	74.93 ± 0.46
GER-2c	16.04 ± 0.16	-^{e}	77.17 ± 0.47
GER-2d	16.19 ± 0.16	-^{e}	77.54 ± 0.47
GER-2e	16.05 ± 0.16	-^{e}	76.68 ± 0.48

BAM-S38a	13.12 ± 0.12	6,173 ± 160	83.98 ± 0.48
BAM-S38b	12.96 ± 0.19	3,749 ± 180	169.52 ± 0.87
BAM-S38c	9.73 ± 0.1[illegible]	4,107 ± 166	72.30 ± 0.42
BAM-S38d	12.33 ± 0.19	4,383 ± 202	98.16 ± 0.53
CHI-1	16.23 ± 0.28	6,765 ± 178	121.58 ± 0.71
CHI-GRY17	17.18 ± 0.20	–[e]	89.48 ± 0.48
CHI-GRY18	9.60 ± 0.11	–[e]	60.48 ± 0.33
CHI-GRY19	14.69 ± 0.13	–[e]	307.58 ± 1.68
CHI-2	17.49 ± 0.19	3,734 ± 127	190.56 ± 1.02
NYA-GRY16	17.24 ± 0.16	–[e]	277.64 ± 1.47
KHA-4770a	14.60 ± 0.20	4,873 ± 184	141.90 ± 0.73
KHA-4770b	16.18 ± 0.19	7,624 ± 217	27.76 ± 0.22
MAK-1	15.05 ± 0.12	–[e]	179.12 ± 0.70
MAK-2	15.08 ± 0.12	–[e]	113.92 ± 0.46
LUS-1	14.25 ± 0.11	–[e]	111.79 ± 0.44
ING-GRY13	16.57 ± 0.18	–[e]	127.71 ± 0.67
ING-GRY14	14.70 ± 0.14	–[e]	325.57 ± 1.72
ING-GRY2	13.91 ± 0.14	–[e]	100.45 ± 7.47
ENG-IR10	13.20 ± 0.21	5,275 ± 203	151.51 ± 1.21
MOD-2a	14.93 ± 0.13	5,725 ± 125	102.66 ± 0.48
MOD-2b	15.45 ± 0.14	5,205 ± 138	58.15 ± 0.30
MOD-2c	14.42 ± 0.14	5,447 ± 182	93.82 ± 0.51
MOD-2d	14.06 ± 0.14	4,217 ± 157	30.22 ± 0.21
MOD-2e	15.11 ± 0.15	5,358 ± 174	76.22 ± 0.42
MOD-2f	16.32 ± 0.16	4,354 ± 186	31.11 ± 0.23
MOD-6	14.72 ± 0.13	–[e]	99.20 ± 0.55
MOD-5a	14.94 ± 0.14	–[e]	79.00 ± 0.47
MOD-5b	15.05 ± 0.14	–[e]	98.45 ± 0.58
MOD-5c	15.28 ± 0.16	–[e]	79.69 ± 0.58
MJE-15a	15.57 ± 0.20	–[e]	167.29 ± 0.96
MJE-5	14.29 ± 0.13	3,940 ± 152	106.31 ± 0.59
MJE-3a1	14.56 ± 0.12	4,841 ± 115	53.48 ± 0.31
MJE-3a2	14.75 ± 0.13	4,045 ± 134	74.13 ± 0.42
JE-3a3	15.42 ± 0.14	6,207 ± 173	66.72 ± 0.42
MJE-8a	12.68 ± 0.11	–[e]	86.21 ± 0.[illegible]4
STA-139a	16.98 ± 0.22	–[e]	63.89 ± 0.39
STA-139b	15.16 ± 0.20	–[e]	101.96 ± 0.59
POR-34	–[d]	–[e]	54.53 ± 0.32
MAN-23a1	8.75 ± 0.12	22,632 ± 320	89.32 ± 0.52
MAN-23a2	8.64 ± 0.14	25,381 ± 411	87.28 ± 0.50
KAB-10	15.16 ± 0.19	–[e]	93.21 ± 0.53
KAB-201	11.87 ± 0.20	–[e]	64.35 ± 0.40

Table 6. continued

Sample	Sm	Co[f]	Sc
FJE-A2-1	2.66 ± 0.12	14.28 ± 0.22	5.49 ± 0.03
FJE-A2-2	3.50 ± 0.19	12.87 ± 0.28	5.78 ± 0.04
FJE-A4-1	3.74 ± 0.18	11.58 ± 0.20	7.41 ± 0.03
FJE-A4-2	2.10 ± 0.13	13.13 ± 0.23	3.11 ± 0.02
FJE-A4-3	3.83 ± 0.22	182.71 ± 1.86	6.50 ± 0.05
FJE-A6-1	4.28 ± 0.22	33.56 ± 0.38	7.08 ± 0.03
FJE-A6-2	2.27 ± 0.18	51.08 ± 0.56	2.97 ± 0.02
FJE-A8-1	2.33 ± 0.09	8.08 ± 0.25	3.60 ± 0.04
FJE-A3-1	1.67 ± 0.14	5.68 ± 0.35	2.23 ± 0.04
FJE-A3-2	2.11 ± 0.20	8.33 ± 0.21	2.62 ± 0.03
FJE-A7-1	2.62 ± 0.18	7.72 ± 0.24	3.63 ± 0.03
FJE-X-1	2.56 ± 0.11	229.64 ± 2.29	4.20 ± 0.04
FJE-A-1	2.32 ± 0.14	758.04 ± 7.25	3.64 ± 0.08
LUA-1a	6.28 ± 0.14	16.76 ± 0.32	6.10 ± 0.04
LUA-1c	4.66 ± 0.22	34.70 ± 0.45	7.10 ± 0.04
LUA-8a	3.23 ± 0.12	183.98 ± 2.08	5.58 ± 0.05
LUA-7	3.95 ± 0.09	64.01 ± 0.67	7.71 ± 0.04
LUA-4a	5.13 ± 0.10	9.90 ± 0.42	6.16 ± 0.07
LUA-3a	3.79 ± 0.10	6.48 ± 0.22	4.59 ± 0.04
LUA-5b	3.69 ± 0.12	12.88 ± 0.32	6.09 ± 0.04
LUA-9a	3.18 ± 0.13	1,006.00 ± 9.78	5.56 ± 0.18
LUA-9b	3.93 ± 0.21	482.38 ± 4.97	6.26 ± 0.07
DAM-4	5.71 ± 0.25	38.22 ± 0.56	7.16 ± 0.05
DAM-1a	3.74 ± 0.18	30.86 ± 0.56	5.20 ± 0.05
DAM-1b	3.16 ± 0.20	26.95 ± 0.63	5.45 ± 0.06
DAM-1c	3.90 ± 0.19	27.59 ± 0.64	5.52 ± 0.06
DAM-2a	4.85 ± 0.11	17.05 ± 0.32	5.91 ± 0.04
DAM-2b	4.04 ± 0.09	34.56 ± 0.47	8.84 ± 0.04
DAM-3	3.76 ± 0.15	323.32 ± 2.98	3.53 ± 0.05
MAT-3	3.72 ± 0.14	46.98 ± 0.64	6.77 ± 0.05
MAT-1	4.06 ± 0.14	11.59 ± 0.28	7.47 ± 0.04
MAT-GRY20	4.94 ± 0.19	10.31 ± 0.26	6.21 ± 0.04
MAT-GRY21	4.93 ± 0.19	10.11 ± 0.27	6.22 ± 0.05
MAT-GRY22	4.89 ± 0.19	10.06 ± 0.26	6.22 ± 0.05
MAT-13	5.24 ± 0.17	9.77 ± 0.26	6.46 ± 0.04
MAT-10	3.84 ± 0.09	809.27 ± 6.93	5.03 ± 0.09
DHL-1353a	3.50 ± 0.14	14.45 ± 0.35	5.23 ± 0.04
DHL-1353b	2.85 ± 0.18	138.23 ± 1.54	4.00 ± 0.05
DHL-1353c	2.12 ± 0.03	47.95 ± 0.55	2.52 ± 0.03
DHL-1353d	1.93 ± 0.05	48.18 ± 0.63	2.56 ± 0.03
DHL-1353e	1.34 ± 0.07	76.90 ± 1.10	2.03 ± 0.04
DHL-1353f	1.74 ± 0.06	28.12 ± 0.47	2.77 ± 0.03

DHL-1352a	4.55 ± 0.13	929.32 ± 8.17	4.83 ± 0.14
DHL-1352b	2.26 ± 0.07	879.42 ± 7.47	3.24 ± 0.10
DHL-1352c	3.24 ± 0.11	968.27 ± 8.56	5.04 ± 0.15
DHL-1352d	3.68 ± 0.14	1,418.20 ± 11.88	5.69 ± 0.16
DHL-1352e	2.05 ± 0.07	730.42 ± 7.14	4.26 ± 0.14
DHL-1352f	4.80 ± 0.30	1,762.50 ± 14.95	6.26 ± 0.21
VOH-9	4.72 ± 0.24	160.25 ± 1.86	7.13 ± 0.08
VOH-3	3.23 ± 0.14	142.62 ± 1.66	5.48 ± 0.06
VOH-4	3.29 ± 0.14	128.31 ± 1.46	5.58 ± 0.06
VOH-1	4.96 ± 0.12	29.21 ± 0.50	8.01 ± 0.05
VOH-2	5.01 ± 0.13	28.05 ± 0.48	7.94 ± 0.05
VOH-7	3.14 ± 0.11	11.52 ± 0.44	5.95 ± 0.05
VOH-8	3.29 ± 0.12	13.64 ± 0.55	6.10 ± 0.06
VOH-5	4.53 ± 0.11	1,613.20 ± 14.37	6.21 ± 0.18
VOH-6	4.40 ± 0.21	1,694.60 ± 14.83	6.77 ± 0.17
KIL-IR14	2.73 ± 0.12	5.78 ± 0.14	5.65 ± 0.03
KIL-IR11	4.54 ± 0.10	18.06 ± 0.28	10.66 ± 0.04
KIL-IR12	6.37 ± 0.23	17.13 ± 0.26	8.76 ± 0.03
KIL-GRY12	3.56 ± 0.16	7.26 ± 0.22	6.22 ± 0.04
KIL-GRY8	5.00 ± 0.12	13.34 ± 0.26	7.77 ± 0.04
KIL-LWK1	4.03 ± 0.17	74.12 ± 0.85	5.48 ± 0.03
KIL-LWK2	3.45 ± 0.14	47.64 ± 0.59	4.93 ± 0.03
KIL-GRY11	6.12 ± 0.24	11.50 ± 0.52	8.86 ± 0.10
KIL-GRY10	6.20 ± 0.34	12.61 ± 0.28	8.00 ± 0.04
KIL-GRY1	7.19 ± 1.01	10.51 ± 1.15	7.80 ± 0.14
KIL-MBG	7.33 ± 1.47	24.11 ± 0.24	5.97 ± 0.02
KIL-MBG1	5.60 ± 0.18	13.27 ± 0.26	6.47 ± 0.03
KIL-MBG2	6.96 ± 0.28	11.87 ± 0.24	7.24 ± 0.03
KIL-MBG3	4.46 ± 0.21	20.64 ± 0.38	6.11 ± 0.04
KIL-MBG4	5.48 ± 0.14	23.00 ± 0.38	8.19 ± 0.04
KIL-MBG5	3.98 ± 0.25	14.91 ± 0.26	4.74 ± 0.03
KIL-IR17	5.90 ± 0.27	17.36 ± 0.28	7.77 ± 0.03
KIL-IR15	3.73 ± 0.17	21.74 ± 0.28	6.97 ± 0.03
KIL-IR16	3.80 ± 0.16	21.71 ± 0.28	6.92 ± 0.03
KIL-IR18	3.79 ± 0.15	14.31 ± 0.22	7.40 ± 0.03
KIL-GRY4	7.03 ± 0.26	8.67 ± 0.27	7.72 ± 0.05
KIL-GRY6	7.08 ± 0.29	8.57 ± 0.18	7.72 ± 0.04
KIL-GRY5	6.54 ± 0.26	15.47 ± 0.26	9.70 ± 0.04
KIL-GRY7	–[d]	–[d]	–[d]
GER-1a	3.65 ± 0.12	64.71 ± 0.87	7.48 ± 0.06
GER-1b	3.53 ± 0.11	64.37 ± 0.85	7.24 ± 0.05
GER-1d	3.62 ± 0.12	68.39 ± 0.80	7.59 ± 0.05
GER-1e	3.72 ± 0.11	66.11 ± 0.83	7.63 ± 0.05
GER-1c	4.27 ± 0.16	61.47 ± 0.77	7.55 ± 0.05
GER-2a	3.47 ± 0.11	1,339.20 ± 11.93	5.33 ± 0.13
GER-2b	3.29 ± 0.10	1.274.40 ± 11.38	5.22 ± 0.13
GER-2c	3.37 ± 0.11	1,334.40 ± 11.89	5.14 ± 0.13
GER-2d	3.40 ± 0.11	1,344.90 ± 11.87	5.03 ± 0.12
GER-2e	3.38 ± 0.11	1,316.70 ± 11.82	4.97 ± 0.14

BAM-S38a	6.01 ± 0.13	12.11 ± 0.43	7.97 ± 0.06
BAM-S38b	4.65 ± 0.24	7.53 ± 0.26	5.80 ± 0.04
BAM-S38c	5.54 ± 0.11	7.29 ± 0.38	6.72 ± 0.06
BAM-S38d	3.73 ± 0.14	8.89 ± 0.29	6.83 ± 0.04
CHI-1	2.39 ± 0.16	17.75 ± 0.28	4.14 ± 0.03
CHI-GRY17	4.00 ± 0.14	9.13 ± 0.18	5.67 ± 0.03
CHI-GRY18	2.72 ± 0.10	5.52 ± 0.14	4.54 ± 0.03
CHI-GRY19	8.14 ± 0.50	13.12 ± 0.43	9.97 ± 0.08
CHI-2	5.50 ± 0.21	11.89 ± 0.27	6.91 ± 0.04
NYA-GRY16	6.41 ± 0.43	15.68 ± 0.30	8.29 ± 0.05
KHA-4770a	3.47 ± 0.20	23.25 ± 0.39	8.18 ± 0.05
KHA-4770b	4.64 ± 0.05	44.47 ± 0.81	8.64 ± 0.08
MAK-1	2.78 ± 0.26	9.99 ± 0.31	3.17 ± 0.03
MAK-2	2.45 ± 0.17	11.60 ± 0.24	3.77 ± 0.03
LUS-1	1.98 ± 0.16	7.93 ± 0.18	2.66 ± 0.02
ING-GRY13	5.94 ± 0.19	11.64 ± 0.21	7.89 ± 0.04
ING-GRY14	4.39 ± 0.50	10.25 ± 0.25	5.20 ± 0.04
ING-GRY2	6.03 ± 0.59	8.60 ± 1.04	8.06 ± 0.19
ENG-IR10	8.91 ± 1.16	22.59 ± 0.22	8.70 ± 0.02
MOD-2a	3.58 ± 0.16	48.43 ± 0.63	4.82 ± 0.04
MOD-2b	2.98 ± 0.10	71.02 ± 0.85	5.05 ± 0.04
MOD-2c	3.14 ± 0.16	42.72 ± 0.80	4.46 ± 0.06
MOD-2d	1.49 ± 0.06	63.98 ± 0.83	2.70 ± 0.03
MOD-2e	2.75 ± 0.13	136.32 ± 1.75	4.31 ± 0.07
MOD-2f	3.05 ± 0.06	51.23 ± 0.85	5.00 ± 0.06
MOD-6	2.46 ± 0.13	11.25 ± 0.37	3.82 ± 0.04
MOD-5a	4.17 ± 0.13	1,709.00 ± 14.71	6.01 ± 0.20
MOD-5b	3.36 ± 0.16	1,400.60 ± 12.45	4.93 ± 0.20
MOD-5c	3.45 ± 0.15	1,064.60 ± 10.33	5.44 ± 0.22
MJE-15a	3.29 ± 0.22	18.97 ± 0.53	4.72 ± 0.05
MJE-5	2.71 ± 0.14	188.24 ± 2.34	4.57 ± 0.08
MJE-3a1	2.67 ± 0.07	38.31 ± 0.64	4.69 ± 0.05
MJE-3a2	2.96 ± 0.10	92.95 ± 1.28	4.27 ± 0.06
MJE-3a3	3.37 ± 0.09	62.54 ± 1.14	4.81 ± 0.07
MJE-8a	4.22 ± 0.10	9.80 ± 0.24	6.93 ± 0.04
STA-139a	4.30 ± 0.10	23.81 ± 0.46	7.24 ± 0.05
STA-139b	4.04 ± 0.15	10.85 ± 0.25	6.26 ± 0.04
POR-34	4.00 ± 0.08	5.97 ± 0.18	6.75 ± 0.04
MAN-23a1	4.72 ± 0.13	26.15 ± 0.43	7.16 ± 0.04
MAN-23a2	4.64 ± 0.12	63.12 ± 0.73	7.15 ± 0.03
KAB-10	3.01 ± 0.13	6.97 ± 0.20	4.91 ± 0.03
KAB-201	5.76 ± 0.10	7.25 ± 0.20	6.30 ± 0.04

Table 6. continued

Sample	Fe (%)	Yb	Ta
FJE-A2-1	1.52 ± 0.03	1.21 ± 0.06	0.53 ± 0.00
FJE-A2-2	1.23 ± 0.03	1.33 ± 0.08	0.56 ± 0.01
FJE-A4-1	1.74 ± 0.03	1.84 ± 0.07	0.55 ± 0.01
FJE-A4-2	1.11 ± 0.02	0.83 ± 0.06	0.42 ± 0.01
FJE-A4-3	2.66 ± 0.05	1.39 ± 0.10	0.54 ± 0.01
FJE-A6-1	2.82 ± 0.04	1.53 ± 0.05	0.54 ± 0.01
FJE-A6-2	1.47 ± 0.02	0.69 ± 0.04	0.45 ± 0.00
FJE-A8-1	1.11 ± 0.03	1.03 ± 0.08	0.57 ± 0.01
FJE-A3-1	0.68 ± 0.04	0.57 ± 0.11	0.37 ± 0.01
FJE-A3-2	0.78 ± 0.02	0.66 ± 0.07	0.47 ± 0.01
FJE-A7-1	1.04 ± 0.03	0.98 ± 0.08	0.35 ± 0.01
FJE-A-1	1.32 ± 0.03	1.09 ± 0.08	0.33 ± 0.01
FJE-A-1	1.29 ± 0.06	0.74 ± 0.14	0.50 ± 0.01
LUA-1a	1.41 ± 0.03	1.36 ± 0.08	0.57 ± 0.01
LUA-1c	2.67 ± 0.04	1.78 ± 0.08	0.63 ± 0.01
LUA-8a	1.54 ± 0.04	1.23 ± 0.11	0.50 ± 0.01
LUA-7	2.64 ± 0.04	1.49 ± 0.07	0.66 ± 0.01
LUA-4a	2.66 ± 0.07	1.62 ± 0.16	0.65 ± 0.02
LUA-3a	1.21 ± 0.03	1.63 ± 0.08	0.57 ± 0.01
LUA-5b	1.67 ± 0.04	1.49 ± 0.09	0.56 ± 0.01
LUA-9a	2.25 ± 0.12	0.90 ± 0.35	0.52 ± 0.03
LUA-9b	1.78 ± 0.05	1.23 ± 0.13	0.51 ± 0.01
DAM-4	2.37 ± 0.04	1.69 ± 0.10	0.86 ± 0.01
DAM-1a	2.66 ± 0.05	1.28 ± 0.10	0.48 ± 0.01
DAM-1b	2.47 ± 0.06	1.04 ± 0.13	0.44 ± 0.01
DAM-1c	2.69 ± 0.06	1.48 ± 0.13	0.45 ± 0.01
DAM-2a	2.57 ± 0.04	1.86 ± 0.09	0.73 ± 0.01
DAM-2b	3.80 ± 0.05	1.35 ± 0.08	0.50 ± 0.01
DAM-3	1.35 ± 0.04	0.82 ± 0.10	0.36 ± 0.01
MAT-3	2.67 ± 0.05	1.37 ± 0.09	0.58 ± 0.01
MAT-1	3.75 ± 0.05	1.41 ± 0.09	0.54 ± 0.01
MAT-GRY20	1.67 ± 0.04	1.73 ± 0.10	0.71 ± 0.01
MAT-GRY21	1.70 ± 0.04	1.60 ± 0.10	0.68 ± 0.01
MAT-GRY22	1.67 ± 0.04	1.60 ± 0.10	0.67 ± 0.01
MAT-13	1.86 ± 0.04	1.61 ± 0.09	0.63 ± 0.01
MAT-10	1.41 ± 0.05	1.66 ± 0.15	0.60 ± 0.01
DHL-1353a	1.45 ± 0.03	1.26 ± 0.08	0.48 ± 0.01
DHL-1353b	1.06 ± 0.04	0.89 ± 0.11	0.46 ± 0.01
DHL-1353c	0.69 ± 0.02	0.84 ± 0.05	0.32 ± 0.01
DHL-1353d	0.79 ± 0.02	0.69 ± 0.06	0.31 ± 0.01
DHL-1353e	0.62 ± 0.03	0.51 ± 0.09	0.38 ± 0.01
DHL-1353f	0.80 ± 0.02	0.63 ± 0.06	0.34 ± 0.01

DHL-1352a	1.40 ± 0.08	1.32 ± 0.24	0.72 ± 0.02
DHL-1352b	1.04 ± 0.06	0.81 ± 0.17	0.41 ± 0.01
DHL-1352c	1.34 ± 0.09	1.36 ± 0.26	0.60 ± 0.02
DHL-1352d	1.70 ± 0.09	0.61 ± 0.24	0.57 ± 0.02
DHL-1352e	1.21 ± 0.08	0.42 ± 0.24	0.45 ± 0.02
DHL-1352f	2.09 ± 0.13	1.11 ± 0.34	0.57 ± 0.03
VOH-9	2.74 ± 0.07	1.63 ± 0.17	0.71 ± 0.01
VOH-3	1.55 ± 0.05	1.04 ± 0.12	0.51 ± 0.01
VOH-4	1.66 ± 0.04	1.17 ± 0.11	0.50 ± 0.01
VOH-1	3.21 ± 0.05	2.01 ± 0.11	0.65 ± 0.01
VOH-2	3.13 ± 0.05	2.02 ± 0.10	0.63 ± 0.01
VOH-7	1.76 ± 0.05	1.23 ± 0.12	0.48 ± 0.01
VOH-8	1.74 ± 0.06	1.34 ± 0.14	0.53 ± 0.01
VOH-5	2.07 ± 0.11	0.85 ± 0.30	0.55 ± 0.03
VOH-6	1.83 ± 0.10	0.97 ± 0.25	0.74 ± 0.02
KIL-IR14	2.73 ± 0.04	1.51 ± 0.05	1.37 ± 0.01
KIL-IR11	4.20 ± 0.05	3.61 ± 0.09	1.93 ± 0.01
KIL-IR12	2.41 ± 0.03	2.26 ± 0.07	1.11 ± 0.01
KIL-GRY12	2.31 ± 0.04	1.06 ± 0.09	0.55 ± 0.01
KIL-GRY8	2.14 ± 0.04	1.87 ± 0.08	0.94 ± 0.01
KIL-LWK1	1.57 ± 0.03	1.30 ± 0.07	0.58 ± 0.01
KIL-LWK2	1.59 ± 0.03	1.02 ± 0.06	0.53 ± 0.01
KIL-GRY11	2.20 ± 0.07	2.13 ± 0.20	1.15 ± 0.02
KIL-GRY10	2.17 ± 0.04	2.09 ± 0.09	1.36 ± 0.01
KIL-GRY1	1.95 ± 0.11	1.88 ± 0.30	1.31 ± 0.04
KIL-MBG	1.60 ± 0.02	1.45 ± 0.04	1.12 ± 0.01
KIL-MBG1	1.77 ± 0.03	1.65 ± 0.07	0.81 ± 0.01
KIL-MBG2	2.00 ± 0.03	1.87 ± 0.07	0.92 ± 0.01
KIL-MBG3	1.73 ± 0.03	1.30 ± 0.08	0.67 ± 0.01
KIL-MBG4	2.29 ± 0.04	1.84 ± 0.08	0.93 ± 0.01
KIL-MBG5	1.29 ± 0.02	1.02 ± 0.07	0.54 ± 0.01
KIL-IR17	2.36 ± 0.03	1.93 ± 0.07	0.90 ± 0.01
KIL-IR15	2.83 ± 0.04	1.14 ± 0.05	0.63 ± 0.01
KIL-IR16	2.81 ± 0.04	1.08 ± 0.05	0.51 ± 0.00
KIL-IR18	3.02 ± 0.04	1.08 ± 0.05	0.51 ± 0.01
KIL-GRY4	1.74 ± 0.04	2.42 ± 0.11	1.27 ± 0.01
KIL-GRY6	1.85 ± 0.03	2.53 ± 0.09	1.37 ± 0.01
KIL-GRY5	2.82 ± 0.04	2.42 ± 0.09	1.36 ± 0.01
KIL-GRY7	-[d]	-[d]	-[d]
GER-1a	2.92 ± 0.05	1.10 ± 0.10	0.53 ± 0.01
GER-1b	2.86 ± 0.05	1.27 ± 0.10	0.50 ± 0.01
GER-1d	3.01 ± 0.05	1.10 ± 0.08	0.52 ± 0.01
GER-1e	2.96 ± 0.05	1.35 ± 0.09	0.55 ± 0.01
GER-1c	2.93 ± 0.05	1.56 ± 0.09	0.53 ± 0.01
GER-2a	1.63 ± 0.08	0.54 ± 0.20	0.48 ± 0.02
GER-2b	1.50 ± 0.08	0.80 ± 0.20	0.45 ± 0.02
GER-2c	1.70 ± 0.08	0.69 ± 0.20	0.49 ± 0.02
GER-2d	1.53 ± 0.07	0.77 ± 0.17	0.49 ± 0.02
GER-2e	1.58 ± 0.08	0.76 ± 0.22	0.51 ± 0.02

BAM-S38a	3.82 ± 0.07	2.55 ± 0.15	1.12 ± 0.01
BAM-S38b	2.60 ± 0.04	2.19 ± 0.10	0.80 ± 0.01
BAM-S38c	2.41 ± 0.06	2.92 ± 0.15	1.55 ± 0.02
BAM-S38d	2.76 ± 0.05	2.14 ± 0.10	0.80 ± 0.01
CHI-1	1.25 ± 0.02	0.98 ± 0.06	0.54 ± 0.01
CHI-GRY17	1.79 ± 0.03	1.11 ± 0.06	0.50 ± 0.01
CHI-GRY18	1.39 ± 0.03	0.98 ± 0.06	0.41 ± 0.00
CHI-GRY19	2.40 ± 0.06	2.51 ± 0.17	1.47 ± 0.01
CHI-2	2.20 ± 0.04	1.64 ± 0.08	0.82 ± [illegible]
NYA-GRY16	2.65 ± 0.05	2.31 ± 0.10	0.91 ± 0.01
KHA-4770a	3.38 ± 0.05	1.37 ± 0.09	0.59 ± 0.01
KHA-4770b	3.66 ± 0.07	1.80 ± 0.14	0.57 ± 0.01
MAK-1	0.83 ± 0.03	1.06 ± 0.10	0.46 ± 0.01
MAK-2	0.97 ± 0.03	1.14 ± 0.07	0.51 ± 0.01
LUS-1	0.82 ± 0.02	0.66 ± 0.06	0.43 ± 0.01
ING-GRY13	2.04 ± 0.03	2.08 ± 0.08	1.01 ± 0.01
ING-GRY14	1.52 ± 0.03	1.28 ± 0.08	0.66 ± 0.01
ING-GRY2	2.37 ± 0.16	1.51 ± 0.45	0.89 ± 0.05
ENG-IR10	3.04 ± 0.03	2.29 ± 0.06	0.93 ± 0.01
MOD-2a	1.30 ± 0.03	1.30 ± 0.08	0.57 ± 0.01
MOD-2b	1.38 ± 0.03	1.18 ± 0.08	0.55 ± 0.01
MOD-2c	1.30 ± 0.04	0.89 ± 0.11	0.42 ± 0.01
MOD-2d	0.78 ± 0.03	0.61 ± 0.07	0.31 ± 0.01
MOD-2e	1.22 ± 0.05	1.04 ± 0.14	0.47 ± 0.01
MOD-2f	1.36 ± 0.04	0.88 ± 0.11	0.99 ± 0.01
MOD-6	0.98 ± 0.03	1.03 ± 0.10	0.39 ± 0.01
MOD-5a	1.60 ± 0.12	1.12 ± 0.34	0.58 ± 0.03
MOD-5b	1.59 ± 0.13	0.82 ± 0.37	0.88 ± 0.27
MOD-5c	1.40 ± 0.14	0.52 ± 0.44	0.62 ± 0.03
MJE-15a	1.37 ± 0.04	0.96 ± 0.11	0.46 ± 0.01
MJE-5	1.28 ± 0.06	0.56 ± 0.16	0.46 ± 0.02
MJE-3a1	1.27 ± 0.04	1.09 ± 0.09	0.62 ± 0.01
MJE-3a2	1.14 ± 0.04	1.01 ± 0.12	0.48 ± 0.01
MJE-3a3	1.27 ± 0.05	1.27 ± 0.15	0.54 ± 0.02
MJE-8a	1.85 ± 0.03	1.63 ± 0.08	0.70 ± 0.01
STA-139a	2.28 ± 0.05	1.37 ± 0.10	0.65 ± 0.01
STA-139b	1.80 ± 0.04	1.67 ± 0.08	1.04 ± 0.01
POR-34	3.84 ± 0.06	1.86 ± 0.09	0.81 ± 0.01
MAN-23a1	1.92 ± 0.04	2.16 ± 0.09	1.00 ± 0.01
MAN-23a2	1.91 ± 0.03	2.18 ± 0.07	0.81 ± 0.01
KAB-10	1.10 ± 0.03	1.92 ± 0.09	0.86 ± 0.01
KAB-201	1.51 ± 0.03	2.11 ± 0.09	0.98 ± 0.01

Table 6. continued

Sample	Sb	Sn[g]	Th
FJE-A2-1	0.9 ± 0.1	-[g]	11.33 ± 0.11
FJE-A2-2	1.0 ± 0.1	-[g]	17.84 ± 0.19
FJE-A4-1	5.0 ± 0.3	4,560 ± 14	14.49 ± 0.13
FJE-A4-2	6.1 ± 0.3	4,567 ± 14	11.55 ± 0.12
FJE-A4-3	5.4 ± 0.4	1,285 ± 15	22.56 ± 0.22
FJE-A6-1	5.1 ± 0.3	659 ± 5	23.66 ± 0.13
FJE-A6-2	3.8 ± 0.2	323 ± 5	9.89 ± 0.08
FJE-A8-1	1.1 ± 0.2	-[g]	13.51 ± 0.16
FJE-A3-1	26.4 ± 1.2	4,577 ± 23	11.05 ± 0.19
FJE-A3-2	3.3 ± 0.2	7,292 ± 20	11.60 ± 0.13
FJE-A7-1	89.5 ± 4.2	12,419 ± 28	18.47 ± 0.18
FJE-X-1	1.0 ± 0.2	-[g]	14.11 ± 0.18
FJE-A-1	2.7 ± 0.4	-[g]	10.93 ± 0.31
LUA-1a	0.7 ± 0.1	-[g]	17.93 ± 0.14
LUA-1c	0.7 ± 0.1	-[g]	28.04 ± 0.20
LUA-8a	6.4 ± 0.4	-[g]	17.59 ± 0.20
LUA-7	3.0 ± 0.2	-[g]	22.36 ± 0.15
LUA-4a	5.0 ± 0.4	852 ± 20	79.24 + 0.56
LUA-3a	0.4 ± 0.1	-[g]	27.98 ± 0.21
LUA-5b	5.3 ± 0.3	3,994 ± 15	19.79 ± 0.18
LUA-9a	3.5 ± 0.9	866 ± 35	21.16 ± 0.55
LUA-9b	0.6 ± 0.2	-[g]	14.96 ± 0.23
DAM-4	11.2 ± 0.6	3,153 ± 13	30.30 ± 0.21
DAM-1a	4.8 ± 0.3	1,003 ± 12	27.82 ± 0.23
DAM-1b	4.8 ± 0.4	963 ± 15	23.55 ± 0.24
DAM-1c	5.0 ± 0.4	868 ± 15	25.72 ± 0.26
DAM-2a	7.6 ± 0.4	990 ± 9	62.67 ± 0.34
DAM-2b	3.1 ± 0.2	-[g]	17.90 ± 0.15
DAM-3	0.8 ± 0.2	-[g]	20.49 ± 0.20
MAT-3	1.9 ± 0.2	579 ± 10	21.71 ± 0.18
MAT-1	14.8 ± 0.7	-[g]	28.13 ± 0.20
MAT-GRY20	0.7 ± 0.1	-[g]	28.78 ± 0.26
MAT-GRY21	1.1 ± 0.2	-[g]	30.74 ± 0.28
MAT-GRY22	0.9 ± 0.2	-[g]	29.48 ± 0.27
MAT-13	1.3 ± 0.2	4,072 ± 14	24.41 ± 0.18
MAT-10	0.9 ± 0.3	-[g]	29.77 ± 0.31
DHL-1353a	9.1 ± 0.6	-[g]	21.16 ± 0.17
DHL-1353b	11.8 ± 0.7	-[g]	18.18 ± 0.20
DHL-1353c	2.7 ± 0.2	-[g]	17.56 ± 0.12
DHL-1353d	3.5 ± 0.3	-[g]	12.77 ± 0.12
DHL-1353e	7.5 ± 0.6	-[g]	10.84 ± 0.16
DHL-1353f	2.8 ± 0.2	-[g]	9.95 ± 0.11

DHL-1352a	3.7 ± 0.7	-[g]	18.24 ± 0.40
DHL-1352b	2.0 ± 0.5	-[g]	14.06 ± 0.31
DHL-1352c	3.1 ± 0.7	-[g]	24.07 ± 0.44
DHL-1352d	4.0 ± 0.7	-[g]	21.08 ± 0.46
DHL-1352e	3.2 ± 0.7	-[g]	14.38 ± 0.39
DHL-1352f	6.7 ± 1.1	308 ± 38	32.23 ± 0.63
VOH-9	70.3 ± 3.4	3,567 ± 21	24.21 ± 0.28
VOH-3	0.7 ± 0.3	-[g]	16.75 ± 0.21
VOH-4	0.9 ± 0.2	-[g]	17.15 ± 0.19
VOH-1	19.9 ± 1.0	235 ± 11	20.33 ± 0.19
VOH-2	20.9 ± 1.0	286 ± 10	20.11 ± 0.18
VOH-7	105.2 ± 4.5	4,550 ± 17	14.58 ± 0.18
VOH-8	128.8 ± 6.0	4,978 ± 20	15.04 ± 0.22
VOH-5	3.0 ± 0.8	-[g]	21.96 ± 0.54
VOH-6	3.5 ± 0.7	328 ± 31	29.49 ± 0.51
KIL-IR14	7.3 ± 0.4	-[g]	24.70 ± 0.14
KIL-IR11	33.5 ± 1.5	2,665 ± 9	40.36 ± 0.23
KIL-IR12	4.0 ± 0.2	281 ± 6	32.81 ± 0.18
KIL-GRY12	3.8 ± 0.3	1,441 ± 12	17.54 ± 0.17
KIL-GRY8	2.0 ± 0.2	270 ± 10	29.53 ± 0.21
KIL-LWK1	15.1 ± 0.8	1,112 ± 7	15.06 ± 0.13
KIL-LWK2	14.9 ± 0.8	1,073 ± 7	12.69 ± 0.12
KIL-GRY11	4.4 ± 0.5	550 ± 26	47.79 ± 0.46
KIL-GRY10	0.7 ± 0.1	-[g]	35.60 ± 0.25
KIL-GRY1	58.5 ± 5.4	-[g]	34.20 ± 0.56
KIL-MBG	0.9 ± 0.1	-[g]	12.96 ± 0.07
KIL-MBG1	8.1 ± 0.5	492 ± 7	28.90 ± 0.20
KIL-MBG2	8.2 ± 0.4	558 ± 8	38.08 ± 0.24
KIL-MBG3	0.5 ± 0.1	-[g]	12.65 ± 0.13
KIL-MBG4	1.8 ± 0.2	-[g]	27.93 ± 0.20
KIL-MBG5	9.6 ± 0.5	7,140 ± 15	14.30 ± 0.12
KIL-IR17	3.7 ± 0.2	344 ± 6	32.22 ± 0.18
KIL-IR15	7.2 ± 0.4	296 ± 5	18.07 ± 0.11
KIL-IR16	7.2 ± 0.4	311 ± 5	17.91 ± 0.11
KIL-IR18	7.6 ± 0.4	299 ± 5	17.36 ± 0.11
KIL-GRY4	2.0 ± 0.2	602 ± 14	42.55 ± 0.30
KIL-GRY6	1.8 ± 0.1	821 ± 11	42.38 ± 0.30
KIL-GRY5	1.2 ± 0.1	1,415 ± 10	37.90 ± 0.25
KIL-GRY7	-[d]	-[d]	-[d]
GER-1a	8.5 ± 0.5	-[g]	18.38 ± 0.20
GER-1b	7.9 ± 0.5	-[g]	18.28 ± 0.19
GER-1d	8.5 ± 0.5	-[g]	18.59 ± 0.17
GER-1e	9.2 ± 0.5	-[g]	18.60 ± 0.18
GER-1c	10.0 ± 0.6	-[g]	21.42 ± 0.19
GER-2a	2.2 ± 0.5	-[g]	18.96 ± 0.41
GER-2b	1.2 ± 0.5	-[g]	18.75 ± 0.40
GER-2c	1.3 ± 0.5	-[g]	18.64 ± 0.41
GER-2d	0.9 ± 0.4	-[g]	18.74 ± 0.38
GER-2e	1.8 ± 0.6	-[g]	18.62 ± 0.44

BAM-S38a	38.7 ± 1.9	546 ± 15	29.36 ± 0.28
BAM-S38b	19.3 ± 0.9	261 ± 11	69.92 ± 0.38
BAM-S38c	22.9 ± 1.3	394 ± 15	25.29 ± 0.26
BAM-S38d	31.0 ± 1.4	214 ± 11	32.18 ± 0.22
CHI-1	24.6 ± 1.2	1,355 ± 8	10.30 ± 0.10
CHI-GRY17	3.8 ± 0.2	922 ± 10	28.63 ± 0.21
CHI-GRY18	0.7 ± 0.1	1,104 ± 9	11.41 ± 0.12
CHI-GRY19	3.5 ± 0.4	1,643 ± 27	30.87 ± 0.35
CHI-2	12.0 ± 0.6	888 ± 9	29.74 ± 0.19
NYA-GRY16	1.7 ± 0.2	1,698 ± 15	26.02 ± 0.24
KHA-4770a	13.2 ± 0.7	177 ± 9	15.36 ± 0.15
KHA-4770b	10.0 ± 0.7	321 ± 14	19.98 ± 0.24
MAK-1	138.0 ± 6.8	9,010 ± 21	11.24 ± 0.15
MAK-2	36.0 ± 1.8	7,432 ± 18	10.88 ± 0.12
LUS-1	19.8 ± 1.0	7,176 ± 17	8.70 ± 0.10
ING-GRY13	0.4 ± 0.1	1,974 ± 11	22.00 ± 0.18
ING-GRY14	1.4 ± 0.2	2,269 ± 15	18.67 ± 0.19
ING-GRY2	16.1 ± 2.1	2,052 ± 96	20.96 ± 0.68
ENG-IR10	27.6 ± 0.9	–[g]	25.51 ± 0.11
MOD-2a	4.9 ± 0.3	–[g]	23.49 ± 0.17
MOD-2b	4.9 ± 0.3	–[g]	18.01 ± 0.16
MOD-2c	6.8 ± 0.6	–[g]	19.56 ± 0.22
MOD-2d	2.7 ± 0.3	–[g]	7.84 ± 0.11
MOD-2e	11.7 ± 0.8	–[g]	15.08 ± 0.23
MOD-2f	5.3 ± 0.4	–[g]	16.91 ± 0.20
MOD-6	20.9 ± 1.1	4,667 ± 16	11.00 ± 0.16
MOD-5a	2.9 ± 0.7	–[g]	25.07 ± 0.66
MOD-5b	2.8 ± 0.7	–[g]	20.93 ± 0.66
MOD-5c	8.2 ± 1.0	–[g]	36.72 ± 0.78
MJE-15a	16.0 ± 1.0	–[g]	12.06 ± 0.19
MJE-5	6.9 ± 0.6	–[g]	11.71 ± 0.25
MJE-3a1	19.2 ± 1.0	–[g]	14.95 ± 0.17
MJE-3a2	16.5 ± 1.0	–[g]	15.85 ± 0.21
MJE-3a3	8.2 ± 0.7	–[g]	22.80 ± 0.27
MJE-6a	3.7 ± 0.3	5,256 ± 14	25.63 ± 0.18
STA-139a	1.1 ± 0.2	–[g]	23.04 ± 0.23
STA-139b	0.3 ± 0.1	–[g]	11.90 ± 0.14
POR-34	4.8 ± 0.3	–[g]	21.52 ± 0.20
MAN-23a1	8.1 ± 0.6	–[g]	12.98 ± 0.15
MAN-23a2	4.8 ± 0.4	–[g]	12.68 ± 0.12
KAB-10	14.6 ± 0.9	6,509 ± 20	17.25 ± 0.18
KAB-201	6.0 ± 0.4	1,448 ± 11	23.25 ± 0.18

Table 6. concluded

Sample	Hf	Zn^{f,h}
FJE-A2-1	5.48 ± 0.22	82 ± 4
FJE-A2-2	4.87 ± 0.29	20 ± 6
FJE-A4-1	9.92 ± 0.33	33 ± 4
FJE-A4-2	2.92 ± 0.17	233 ± 5
FJE-A4-3	4.85 ± 0.35	304 ±13
FJE-A6-1	5.58 ± 0.20	178 ± 5
FJE-A6-2	1.70 ± 0.15	113 ± 6
FJE-A8-1	2.44 ± 0.24	53 ± 6
FJE-A3-1	1.49 ± 0.30	438 ±13
FJE-A3-2	2.20 ± 0.19	941 ±10
FJE-A7-1	5.03 ± 0.25	3,080 ±14
FJE-X-1	6.40 ± 0.37	-^{h}
FJE-A-1	2.49 ± 0.65	-^{h}
LUA-1a	5.66 ± 0.28	38 ± 6
LUA-1c	7.77 ± 0.29	96 ± 6
LUA-8a	4.22 ± 0.37	59 ±15
LUA-7	5.74 ± 0.26	56 ± 7
LUA-4a	14.74 ± 0.61	208 ±13
LUA-3a	8.34 ± 0.32	48 ± 5
LUA-5b	6.08 ± 0.32	523 ±10
LUA-9a	4.00 ± 1.26	-^{h}
LUA-9b	3.30 ± 0.50	-^{h}
DAM-4	5.29 ± 0.34	501 ±11
DAM-1a	5.64 ± 0.34	182 ±10
DAM-1b	5.08 ± 0.40	153 ±12
DAM-1c	6.65 ± 0.44	134 ±12
DAM-2a	12.72 ± 0.41	151 ± 7
DAM-2b	5.32 ± 0.30	86 ± 7
DAM-3	3.41 ± 0.40	-^{h}
MAT-3	4.83 ± 0.29	186 ±10
MAT-1	6.96 ± 0.30	39 ± 7
MAT-GRY20	6.15 ± 0.33	50 ± 6
MAT-GRY21	5.04 ± 0.33	51 ± 6
MAT-GRY22	5.60 ± 0.33	44 ± 6
MAT-13	3.68 ± 0.25	617 ±10
MAT-10	11.75 ± 0.64	-^{h}
DHL-1353a	5.06 ± 0.29	47 ± 7
DHL-1353b	2.41 ± 0.36	47 ±16
DHL-1353c	4.25 ± 0.19	27 ± 6
DHL-1353d	2.00 ± 0.20	41 ± 8
DHL-1353e	1.46 ± 0.28	25 ±13
DHL-1353f	1.97 ± 0.19	20 ± 6

DHL-1352a	2.77 ± 0.93	–[h]
DHL-1352b	2.86 ± 0.73	–[h]
DHL-1352c	12.83 ± 1.05	–[h]
DHL-1352d	4.80 ± 1.07	–[h]
DHL-1352e	3.13 ± 0.93	–[h]
DHL-1352f	8.08 ± 1.47	–[h]
VOH-9	5.66 ± 0.52	218 ± 21
VOH-3	3.26 ± 0.40	33 ± 17
VOH-4	2.89 ± 0.36	49 ± 15
VOH-1	7.46 ± 0.35	426 ± 11
VOH-2	5.31 ± 0.31	411 ± 11
VOH-7	3.36 ± 0.31	400 ± 12
VOH-8	3.84 ± 0.40	386 ± 15
VOH-5	5.67 ± 1.27	–[h]
VOH-6	5.84 ± 1.16	–[h]
KIL-IR14	11.82 ± 0.33	37 ± 4
KIL-IR11	43.22 ± 1.10	239 ± 7
KIL-IR12	6.56 ± 0.25	293 ± 6
KIL-GRY12	3.82 ± 0.27	20 ± 6
KIL-GRY8	4.70 ± 0.26	64 ± 6
KIL-LWK1	3.91 ± 0.23	292 ± 8
KIL-LWK2	3.20 ± 0.21	457 ± 8
KIL-GRY11	7.08 ± 0.59	78 ± 13
KIL-GRY10	5.57 ± 0.30	48 ± 6
KIL-GRY1	5.79 ± 0.74	26 ± 27
KIL-MBG	3.31 ± 0.13	87 ± 4
KIL-MBG1	4.12 ± 0.24	481 ± 7
KIL-MBG2	6.55 ± 0.27	242 ± 6
KIL-MBG3	3.43 ± 0.26	63 ± 7
KIL-MBG4	5.25 ± 0.29	52 ± 7
KIL-MBG5	2.90 ± 0.22	2,383 ± 13
KIL-IR17	6.02 ± 0.23	91 ± 5
KIL-IR15	2.89 ± 0.17	154 ± 5
KIL-IR16	2.94 ± 0.17	147 ± 5
KIL-IR18	2.38 ± 0.17	52 ± 5
KIL-GRY4	6.56 ± 0.35	38 ± 7
KIL-GRY6	6.67 ± 0.28	34 ± 4
KIL-GRY5	5.92 ± 0.27	42 ± 6
KIL-GRY7	–[d]	–[d]
GER-1a	4.01 ± 0.35	72 ± 11
GER-1b	3.75 ± 0.33	57 ± 11
GER-1d	3.50 ± 0.28	48 ± 9
GER-1e	5.39 ± 0.32	87 ± 10
GER-1c	3.40 ± 0.30	70 ± 10
GER-2a	3.61 ± 0.90	–[h]
GER-2b	3.14 ± 0.88	–[h]
GER-2c	3.48 ± 0.91	–[h]
GER-2d	4.10 ± 0.82	–[h]
GER-2e	4.18 ± 0.96	–[h]

BAM-S38a	18.15 ± 0.64	308 ± 13
BAM-S38b	15.66 ± 0.44	168 ± 7
BAM-S38c	33.08 ± 0.93	164 ± 12
BAM-S38d	18.75 ± 0.51	155 ± 8
CHI-1	2.31 ± 0.17	242 ± 6
CHI-GRY17	2.86 ± 0.18	50 ± 4
CHI-GRY18	2.85 ± 0.18	32 ± 4
CHI-GRY19	6.42 ± 0.53	87 ± 11
CHI-2	4.44 ± 0.28	180 ± 7
NYA-GRY16	4.96 ± 0.32	126 ± 7
KHA-4770a	3.51 ± 0.26	86 ± 8
KHA-4770b	7.14 ± 0.47	96 ± 14
MAK-1	3.30 ± 0.25	2,231 ± 14
MAK-2	5.53 ± 0.24	50 ± 5
LUS-1	2.29 ± 0.16	942 ± 8
ING-GRY13	4.82 ± 0.24	32 ± 5
ING-GRY14	4.38 ± 0.28	45 ± 5
ING-GRY2	6.81 ± 1.08	93 ± 32
ENG-IR10	5.24 ± 0.16	74 ± 4
MOD-2a	7.04 ± 0.29	49 ± 8
MOD-2b	4.21 ± 0.26	41 ± 9
MOD-2c	3.31 ± 0.34	60 ± 12
MOD-2d	1.73 ± 0.22	28 ± 9
MOD-2e	3.36 ± 0.43	71 ± 19
MOD-2f	3.30 ± 0.34	42 ± 11
MOD-6	2.20 ± 0.28	686 ± 13
MOD-5a	7.40 ± 1.41	-[h]
MOD-5b	5.48 ± 1.42	-[h]
MOD-5c	4.15 ± 1.56	-[h]
MJE-15a	3.88 ± 0.37	74 ± 10
MJE-5	3.11 ± 0.53	1 ± 24
MJE-3a1	3.40 ± 0.29	46 ± 9
MJE-3a2	3.29 ± 0.38	56 ± 15
MJE-3a3	5.80 ± 0.47	70 ± 16
MJE-8a	5.27 ± 0.26	667 ± 10
STA-139a	4.92 ± 0.34	53 ± 8
STA-139b	3.13 ± 0.25	53 ± 6
POR-34	14.68 ± 0.54	36 ± 6
MAN-23a1	4.79 ± 0.29	130 ± 7
MAN-23a2	4.98 ± 0.23	130 ± 6
KAB-10	19.65 ± 0.74	19 ± 5
KAB-201	20.43 ± 0.63	29 ± 5

Notes to Table 6.

a. All data are given in parts per million unless otherwise indicated. See Table 12 for averages of this data.

b. Imprecisely-determined elements have been omitted from this Table. Those for which a mean concentration could be determined for the Group are (with mean and root mean square deviation): Ca, 4.42 ± 1.90%; V, 130 ± 229 ppm; Dy, 6.2 ± 2.0 ppm; K, 2.3 ± 1.4%; Cs, 1.3 ± 0.8 ppm; Eu, 0.8 ± 0.3 ppm; Tb, 0.4 ± 0.2 ppm. For GER-2a, GER-2b, GER-2c, GER-2d and GER-2e, As averages 278 ± 15 ppm; for the following individual specimens As is: LUA-8a, 149.7 ± 5.9 ppm; LUA-9a, 547.8 ± 17.8 ppm; LUA-9b, 525.9 ±13.8 ppm; DAM-3, 248.4 ± 7.4 ppm; MAT-10, 279.0 ± 8.8 ppm; VOH-5, 2,949.5 ± 71.1 ppm; VOH-6, 2,437.4 ±58.9 ppm; and MAN-23a2, 196.6 ± 7.6 ppm. For the remainder of the Group the mean As is 78 ± 137 ppm. The following upper limits of concentration for the Group could be determined (with estimated representative counting error): Mg, 5 ± 3%, Sr, 2000 ± 1000 ppm; Ga, 300 ± 200 ppm; In, 20 ± 10 ppm; W, 76 ± 4 ppm; Ag, 60 ± 4 ppm; Ir, 0.02 ± 0.02 ppm; Hg, assuming none is lost in the reactor, 23 ± 1 ppm; and Cr, 66 ± 10 ppm.

c. For further details of provenience, see Appendix 1.

d. Element not determined in this sample.

e. Glassmaker's additive. Not determined when below the limit of reliable detection, approximately 500 ppm.

f. Glassmaker's additive.

g. Glassmaker's additive. Not determined when below the limit of reliable detection, approximately 200 ppm.

h. Glassmaker's additive. Not determined when Co concentration exceeds approximately 200 ppm.

Table 7a. X-ray Fluorescence Analysis of Trade Wind Beads from Gedi[a]

Sample	Color	Fe	Cu	Zn	As	Sr
GED-2a	Indian red	2.3 ± 0.4	0.27 ± 0.05	0.02	<0.03	0.02
GED-2b	" "	2.9 ± 0.4	0.18 ± 0.04	0.03	<0.03	0.02
GED-4[c]	Green	2.9 ± 0.4	0.29 ± 0.06	0.03	<0.03	0.02
GED-9	"	0.8 ± 0.2	0.40 ± 0.07	0.03	–[b]	0.04 ± 0.01
GED-6a	Blue-green	0.7 ± 0.2	0.24 ± 0.04	<0.02	<0.03	0.01
GED-6b	"	0.8 ± 0.2	0.21 ± 0.04	<0.02	0.02	0.01
GED-3[c]	Yellow	1.7 ± 0.3	0.02	0.01	–[b]	0.02
GED-7	Cobalt Blue	1.9 ± 0.3	0.03	0.02	0.05 ± 0.02	0.02
GED-10	Pale " "	1.1 ± 0.2	0.01	0.01	0.03	0.02
GED-1	Black	1.4 ± 0.2	0.02	0.02	<0.03	0.02

[a] All data are given in percent. Specimen -1 contained ∿ 0.06% Mn. Otherwise Mn was not detected, the lower limit of detection being 0.1%. Specimen -7 contained 0.08 ± 0.02% Co, and specimen -10 contained 0.04% Co. Otherwise this element was below the limit of detection of ∿ 0.05%. In some cases Rb could not be determined due to high Pb content. Otherwise it was not detected, the limit of detection being ∿ 0.02%. Sb was not detected; the limit was ∿ 0.005%. Specimen -6b contained 0.03% Bi.

[b] Not determined due to high Pb content.

[c] Sample consisted of more than one bead.

Table 7a. concluded

Sample	Zr	Sn	Ba	Pb	U
GED-2a	0.02	∿ 0.008	0.04 ± 0.01	0.04	+
GED-2b	0.02	∿ 0.008	0.04 ± 0.01	0.05	+
GED-4	0.01	0.022 ± 0.005	0.04 ± 0.01	0.09	+
GED-9	0.01	0.5 ± 0.1	0.06 ± 0.01	0.8 ± 0.2	
GED-6a	0.01	∿ 0.004	0.03	0.02	+
GED-6b	0.01	∿ 0.005	0.03	0.03	+
GED-3	0.02	0.28 ± 0.04	0.05 ± 0.01	1.7 ± 0.3	+
GED-7	0.01	0.031 ± 0.005	0.05 ± 0.01	0.11 ± 0.03	
GED-10	0.01	< 0.005	0.04 ± 0.01	0.02	
GED-1	0.02	0.021 ± 0.004	0.07 ± 0.02	0.06	+

Table 7b. X-ray Fluorescence Analysis of Miscellaneous Trade Wind Beads[a]

Sample	Color	Fe	Cu	Zn	Sr
KAO-183J	Black	1.0 ± 0.2	<0.02	0.01	0.02
ZAN-1064	Indian red	2.4 ± 0.4	0.28 ± 0.05	0.08 ± 0.02	0.02
SOF-1	" "	3.4 ± 0.5	0.31 ± 0.07	0.02	0.02
SOF-2	" "	2.0 ± 0.3	0.24 ± 0.06	0.02	0.02
REN-23[b]	" "	1.8 ± 0.3	0.15 ± 0.03	0.02	0.03
MPL-4[b]	Black	1.1 ± 0.2	0.02	0.01	0.02
MAP-093[b]	"	1.4 ± 0.2	0.02	<0.02	0.03 ± 0.01
MST-77a[b]	Indian red	2.5 ± 0.4	0.14 ± 0.03	<0.02	0.02
MST-103b[b]	" "	1.6 ± 0.3	0.5 ± 0.1	<0.02	0.03 ± 0.01
MST-76c[b]	Black	1.5 ± 0.2	0.02	<0.02	0.03 ± 0.01

[a] All data are given in percent. Mn was not detected and therefore lies below the lower limit of detection of ∿ 0.1%. Co was not detected; the lower limit of detection was ∿ 0.05%. As lies below the limit of detection of 0.05%, and Rb below the limit of 0.02%. Specimen SOF-2 contained ∿ 0.005% Sb. Otherwise this element was not detected; the lower limit of detection was ∿ 0.005%, except for REN-23 and MPL-4, where it was ∿ 0.01%.

[b] Sample consisted of more than one bead.

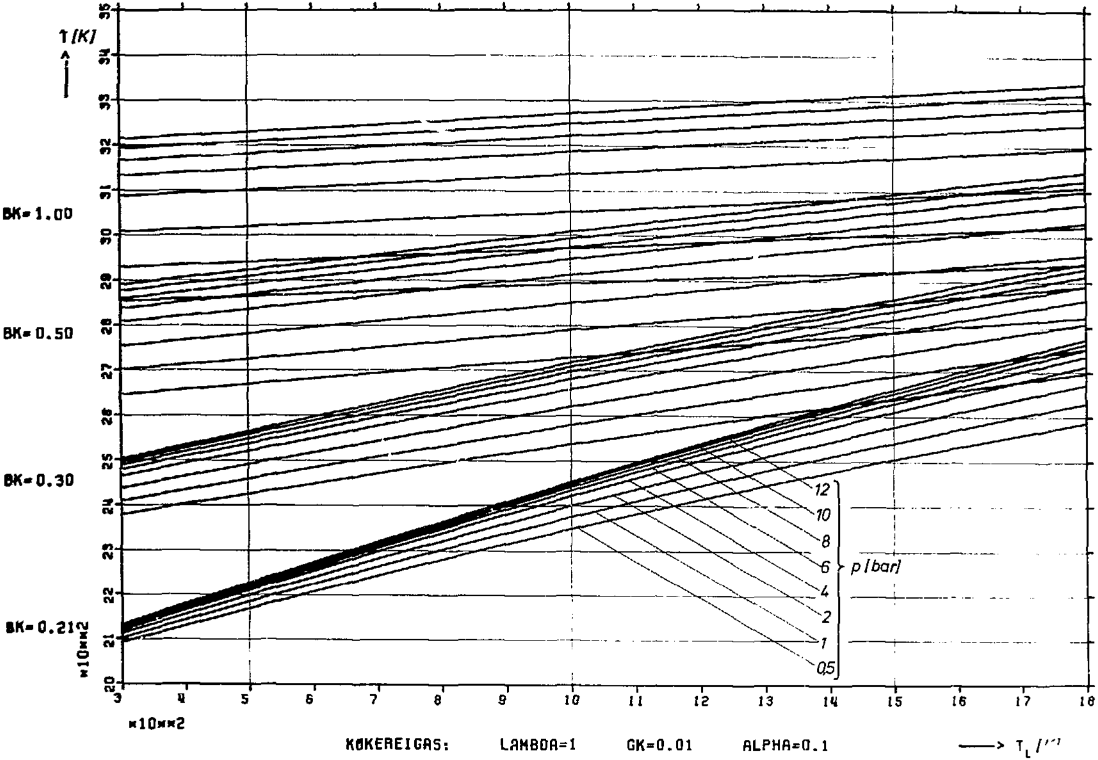

Abb. 29 Flammentemperatur in Abhängigkeit der Vorwärmtemperatur T_L bei verschiedenen Anreicherungsgraden und Drücken

Table 7b. concluded

Sample	Provenience
KAO-183J	Kaole House, Tanzania, 2C, SW room, below possible floor, wound lenticular bead.
ZAN-1064	Zanzibar, beach, wound lenticular bead.
SOF-1	Sofala, Portuguese East Africa, surface, reheated cane bead.
SOF-2	" " " " " " " "
REN-23	Renders Ruins, Rhodesia, from excavations of E. Goodall in 1944, reheated cane beads.
MPL-4	Mapela, site of a Portuguese fair in Rhodesia, reheated cane beads.
MAP-093	Mapungubwe, Skeleton 10, reheated cane beads.
MST-77a	Mapungubwe, Southern Terrace, B3M, 24-30", reheated cane beads.
MST-103b	" " " C3M, 18-24" " " "
MST-76c	" " " B3R, 24-30" " " "

Table 8. Sites Yielding Members of the Trade Wind Bead Chemical Group[a]

Map No.	Site	Chief Reference
1.	Gedi, below floor of tomb	Kirkman 1960
2.	Fort Jesus	Kirkman in preparation
3.	Zanzibar, beach	van der Sleen 1967, Tornati and van der Sleen 1960
4.	Kaole House, below floor	Chittick 1959
5.	Kilwa	Chittick 1966, Chittick in preparation
6.	Engaruka, terrace A5U4	Sassoon 1967
7.	Vohémar, jijikely	Thierry 1961
8.	Makoli	Inskeep, letters to van Riet Lowe
9.	Lusaka Cave Site	<u>ibid</u>.
10.	Ingombe Ilede, Burial 8	Fagan 1972
11.	Dambarare	Garlake 1968
12.	Luanze	Garlake 1966
13.	Nyangwe Fort (Inyanga)	Summers 1958
14.	Sofala, surface	van der Sleen 1967
15.	Renders Ruins (at Zimbabwe)	Schofield 1958
16.	Matendere, midden	Caton-Thompson 1931
17.	Chibvumani (Hubvumi), South Passage	<u>ibid</u>.
18.	Dhlo Dhlo	<u>ibid</u>.
19.	Khami, on Floor IV	Robinson 1959
20.	Mjelele Valley Burial	National Museum of Rhodesia collections
21.	Mapela	Garlake 1971
22.	Bambandyanalo, Skeleton 38	Gardner 1963
23.	Mapungubwe	Fouché 1937, Gardner 1963, Eloff 1969
24.	Modjadje's location	van Riet Lowe 1937, Krige and Krige 1943
25.	Kab'wan (Philippines)	Fox 1970
26.	Manunggol (")	<u>ibid</u>.
27.	Santa Ana (")	<u>ibid</u>.
28.	Porac (")	<u>ibid</u>.

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[a] For dates, see Table 13.

Table 9. X-ray Fluorescence Analysis of Trade Wind Beads from Fort Jesus[a]

Sample	Color	Fe	Cu	Zn	Sr	Zr
FJE-A6-1	Indian red	2.4 ± 0.4	0.33 ± 0.08	0.02	0.03	0.03
FJE-A6-2	" "	1.2 ± 0.2	0.24 ± 0.04	0.02	0.02	0.01
FJE-A4-3	Green	2.2 ± 0.4	0.34 ± 0.07	0.03	0.02	0.03
FJE-A4-1	"	1.5 ± 0.3	0.5 ± 0.1	<0.02	-[b]	-[b]
FJE-A4-2	Yellow-green	0.9 ± 0.2	0.24 ± 0.05	0.04	-[b]	-[b]
FJE-A3-1	Yellow	0.6 ± 0.2	0.02	0.07 ± 0.02	-[b]	-[b]
FJE-A3-2	"	0.7 ± 0.2	0.02	0.10 ± 0.02	-[b]	-[b]
FJE-A3-3	"	0.5 ± 0.1	0.02	0.05 ± 0.02	-[b]	-[b]
FJE-A7-1	Orange	1.1 ± 0.2	<0.02	0.23 ± 0.05	-[b]	-[b]
FJE-A8-1	Pearl	0.8 ± 0.2	<0.02	0.01	0.02	0.01
FJE-A1-1	Cobalt Blue	0.9 ± 0.2	0.01	<0.01	0.02	0.01
FJE-X1	Pale " "	1.1 ± 0.2	0.04	0.01	0.02	0.03
FJE-A2-1	Black	1.2 ± 0.2	0.02	0.01	0.03	0.02

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[a] All samples were single reheated cane beads. All data are given in percent. Sample A1-1 contained 0.04% Mn and 0.08% Co. Otherwise these elements were not detected in the samples. The lower limits of detection were 0.1% for Mn and 0.05% for Co. As was not detected, the lower limit being 0.03%. Rb could not be determined due to interference from Pb and from U. Specimens A2-1, A3-1 and A7-1 contained 0.01% Sb. This element was not detected in the remainder of the samples; the lower limit of detection was 0.005%.

Table 9. concluded

Sample	Sn	Ba	Pb	U
A6-1	0.07 ± 0.02	0.07 ± 0.02	0.25 ± 0.05	+
A6-2	0.034 ± 0.007	0.05 ± 0.01	0.12 ± 0.03	+
A4-3	0.14 ± 0.03	0.06 ± 0.01	0.6 ± 0.2	+
A4-1	0.4 ± 0.1	0.04 ± 0.01	2.1 ± 0.4	-[b]
A4-2	0.4 ± 0.1	0.05 ± 0.01	2.4 ± 0.5	-[b]
A3-1	0.6 ± 0.1	0.06 ± 0.02	3.2 ± 0.6	-[b]
A3-2	0.7 ± 0.1	0.06 ± 0.02	3.5 ± 0.6	-[b]
A3-3	0.5 ± 0.1	0.05 ± 0.01	3.1 ± 0.6	-[b]
A7-1	1.1 ± 0.2	0.05 ± 0.01	7.3 ± 1.0	-[b]
A8-1	0.002	0.05 ± 0.01	0.02	+
A1-1	0.004	0.06 ± 0.01	0.02	+
X1	0.004	0.06 ± 0.01	0.02	+
A2-1	0.005	0.04 ± 0.01	<0.02	+

[b] Unable to determine due to high Pb content.

Table 10. X-ray Fluorescence Analysis of Trade Wind Beads from Luanze[a]

Sample	Color	Fe	Cu	Zn	Rb	Sr	Zr
LUA-4[c]	Indian red	2.0 ± 0.4	0.27 ± 0.05	0.02	<0.02	0.03	0.03
LUA-6	Green	2.2 ± 0.4	0.32 ± 0.05	0.03	–[b]	–[b]	–[b]
LUA-7	"	2.3 ± 0.4	0.36 ± 0.06	<0.01	0.01	0.02	0.02
LUA-8a	Blue-green	1.1 ± 0.2	0.28 ± 0.04	0.02	<0.02	0.02	0.01
LUA-8b	"	1.1 ± 0.2	0.27 ± 0.04	<0.01	<0.02	0.02	0.02
LUA-5[c]	Yellow	1.2 ± 0.2	0.01	0.04 ± 0.01	–[b]	–[b]	–[b]
LUA-3[c]	Pearl	1.0 ± 0.2	0.02	0.01	0.01	0.02	0.02
LUA-9[c]	Pale Cobalt Blue	1.4 ± 0.2	0.05 ± 0.01	<0.01	<0.02	0.02	0.01
LUA-1[c]	Black	1.8 ± 0.3	0.02	<0.01	0.01	0.02	0.02

[a] All are reheated cane beads. All data are given in percent. Specimen LUA-9 contained 0.05 ± 0.02% Co and 0.02% As. Otherwise these elements were not detected. The limit of detection for Co was 0.05%, for As 0.03%. In addition, Mn and Sb were not detected, the lower limits being 0.1% and 0.005% respectively.

[b] Not determined due to high Pb content.

[c] Sample consisted of more than one bead.

Table 10. concluded

Sample	Sn	Ba	Pb	U
LUA-4	0.08 ± 0.02	0.06 ± 0.01	0.32 ± 0.05	+
LUA-6	0.25 ± 0.04	0.03	1.0 ± 0.2	–[b]
LUA-7	∿ 0.008	0.05 ± 0.01	0.04	
LUA-8a	∿ 0.008	0.04 ± 0.01	0.03	
LUA-8b	0.010± 0.002	0.08 ± 0.02	0.03	+
LUA-5	0.42 ± 0.05	0.05 ± 0.01	2.3 ± 0.4	+
LUA-3	∿ 0.008	0.07 ± 0.01	<0.02	
LUA-9	0.028± 0.005	0.04 ± 0.01	0.08 ± 0.02	+
LUA-1	0.012± 0.003	0.06 ± 0.01	0.04	

Table 11a. Glass Beads Resembling the TWBCG: Neutron Activation Analysis[a,b]

Sample	Provenience	Color
KIL-HKCV3	Kilwa, Period IIIa	Blue[c]
KIL-GM2	" Period IIIa-b	Gray-green
KIL-GRY9	" "	Greenish-yellow
KIL-GM1	" "	Blue-green
KIL-IR13	" "	Indian red
KAO-183H	Kaole House, below floor	"
KAO-183G	" "	"
KAO-172A	" "	"
ING-B8	Ingombe Ilede, Burial 8	Blue
SIR-3295	Siraf (Iran)	Green
BUT-174A	Butong (Philippines)	"
BUT-174B	" "	"
BUT-175B	" "	Blue-green[d]
BUT-175A	" "	" [d]
BUT-102A1	" "	Indian red
BUT-102A2	" "	"
CAL-102B1	Calatagan "	Indian red, green[e]
CAL-102B2	" "	Ind. red over green
MJE-15B	Mjelele Valley Burial	Black

Table 11a. continued

Sample	Color	Al (%)	Cl (%)	Mn
-HKCV3	blue	n.d.[f]	n.d.	1,322 ± 36
-GM2	gy-gr.	3.61 ± 0.29	1.48 ± 0.19	331 ± 14
-GRY9	gr-yel.	3.53 ± 0.18	1.15 ± 0.14	313 ± 14
-GM1	bl-gr.	2.99 ± 0.11	0.99 ± 0.16	427 ± 16
-IR13	IR	2.59 ± 0.07	0.89 ± 0.12	422 ± 14
-183H	"	2.78 ± 0.07	0.67 ± 0.13	441 ± 13
-183G	"	2.88 ± 0.11	0.71 ± 0.15	433 ± 16
-172A	"	2.78 ± 0.11	1.08 ± 0.13	423 ± 14
-B8	blue	n.d.	n.d.	484 ± 40
-3295	grn.	4.29 ± 0.09	0.63 ± 0.18	661 ± 19
-174A	"	3.90 ± 0.17	0.25 ± 0.16	574 ± 15
-174B	"	4.39 ± 0.11	0.88 ± 0.25	534 ± 15
-175B	bl-gr.	4.84 ± 0.28	0.13 ± 0.29	743 ± 22
-175A	"	5.06 ± 0.19	0.28 ± 0.23	760 ± 20
-102A1	IR	4.79 ± 0.11	0.95 ± 0.18	449 ± 20
-102A2	"	4.94 ± 0.14	0.89 ± 0.19	443 ± 12
-102B1	IR, grn.	6.94 ± 0.16	0.83 ± 0.21	499 ± 13
-102B2	IR/grn.	6.15 ± 0.31	1.37 ± 0.24	350 ± 14
-15B	black	3.13 ± 0.16	0.81 ± 0.22	610 ± 18

Table 11a. continued

Sample	Color	Na (%)	Cu	U
-HKCV3	blue	10.26 ± 0.17	b	1.31 ± 0.21
-GM2	gy-gr.	15.68 ± 0.19	b	9.06 ± 0.10
-GRY9	gr-yel.	15.73 ± 0.19	b	6.02 ± 0.05
-GM1	bl-gr.	12.98 ± 0.22	6,269 ± 164	0.59 ± 0.05
-IR13	IR	13.50 ± 0.17	10,743 ± 165	0.45 ± 0.03
-183H	"	13.03 ± 0.16	10,386 ± 163	0.97 ± 0.04
-183G	"	13.34 ± 0.17	12,042 ± 201	0.52 ± 0.04
-172A	"	14.19 ± 0.17	10,377 ± 159	0.61 ± 0.04
-B8	blue	13.64 ± 0.23	6,325 ± 241	-0.13 ± 0.13
-3295	grn.	12.30 ± 0.21	4,323 ± 166	7.76 ± 0.07
-174A	"	13.10 ± 0.17	5,566 ± 146	8.53 ± 0.08
-174B	"	13.32 ± 0.22	4,818 ± 154	8.34 ± 0.07
-175B	bl-gr.	14.57 ± 0.23	7,086 ± 230	5.27 ± 0.08
-175A	"	14.37 ± 0.19	6.952 ± 204	5.44 ± 0.09
-102A1	IR	11.24 ± 0.18	18,420 ± 311	7.01 ± 0.06
-102A2	"	10.92 ± 0.17	22,375 ± 368	7.26 ± 0.07
-102B1	IR,grn.	9.31 ± 0.15	7,776 ± 168	5.71 ± 0.06
-102B2	IR/grn.	11.88 ± 0.19	7,275 ± 181	8.62 ± 0.08
-15B	black	12.06 ± 0.15	b	1.19 ± 0.09

Table 11a. continued

Sample	Color	Sm	Co	Sc
-HKCV3	blue	1.35 ± 0.04	392.26 ± 2.52	3.11 ± 0.03
-GM2	gy-gr.	3.42 ± 0.02	6.76 ± 0.17	3.92 ± 0.03
-GRY9	gr-yel.	3.91 ± 0.02	6.86 ± 0.12	4.04 ± 0.02
-GM1	bl-gr.	1.10 ± 0.01	6.97 ± 0.13	2.63 ± 0.01
-IR13	IR	1.03 ± 0.01	10.01 ± 0.17	2.44 ± 0.02
-133H	"	1.38 ± 0.01	9.79 ± 0.34	3.31 ± 0.03
-183G	"	1.36 ± 0.01	8.15 ± 0.25	3.28 ± 0.03
-172A	"	1.13 ± 0.01	5.30 ± 0.24	2.91 ± 0.02
-B8	blue	0.93 ± 0.02	3.84 ± 0.09	1.91 ± 0.01
-3295	grn.	3.28 ± 0.02	13.54 ± 0.24	4.81 ± 0.03
-174A	"	3.33 ± 0.02	17.14 ± 0.33	4.16 ± 0.03
-174B	"	3.27 ± 0.02	15.67 ± 0.29	4.07 ± 0.03
-175B	bl-gr.	2.70 ± 0.02	8.45 ± 0.30	3.49 ± 0.04
-175A	"	2.76 ± 0.02	8.65 ± 0.27	3.69 ± 0.04
-102A1	IR	3.63 ± 0.02	11.02 ± 0.25	4.35 ± 0.03
-102A2	"	3.72 ± 0.02	11.57 ± 0.25	4.35 ± 0.03
-102B1	IR,grn.	4.70 ± 0.02	26.72 ± 0.40	9.30 ± 0.05
-102B2	IR/grn.	3.80 ± 0.02	8.03 ± 0.25	6.66 ± 0.05
-15B	black	1.46 ± 0.02	8.59 ± 0.30	3.48 ± 0.04

Table 11a. continued

Sample	Color	Fe (%)	Yb	Ta
-HKCV3	blue	1.59 ± 0.02	0.64 ± 0.05	0.31 ± 0.01
-GM2	gy-gr.	3.31 ± 0.05	1.15 ± 0.06	0.64 ± 0.01
-GRY9	gr-yel.	1.39 ± 0.02	1.52 ± 0.04	0.71 ± 0.00
-GM1	bl-gr.	0.77 ± 0.01	0.52 ± 0.03	0.25 ± 0.00
-IR13	IR	2.06 ± 0.03	0.48 ± 0.03	0.27 ± 0.00
-183H	"	1.93 ± 0.04	0.62 ± 0.08	0.33 ± 0.01
-183G	"	1.96 ± 0.03	0.54 ± 0.06	0.39 ± 0.01
-172A	"	1.76 ± 0.03	0.57 ± 0.06	0.30 ± 0.00
-B8	blue	0.54 ± 0.01	0.34 ± 0.03	0.23 ± 0.00
-3295	grn.	1.17 ± 0.02	2.00 ± 0.07	0.52 ± 0.01
-174A	"	1.19 ± 0.03	2.00 ± 0.09	0.53 ± 0.01
-174B	"	1.12 ± 0.03	1.92 ± 0.08	0.53 ± 0.01
-175B	bl-gr.	0.93 ± 0.03	1.74 ± 0.10	0.50 ± 0.01
-175A	"	0.86 ± 0.03	1.58 ± 0.09	0.50 ± 0.01
-102A1	IR	1.32 ± 0.03	1.87 ± 0.08	0.62 ± 0.01
-102A2	"	1.26 ± 0.03	1.69 ± 0.08	0.64 ± 0.01
-102B1	IR,grn.	2.42 ± 0.04	1.65 ± 0.09	0.56 ± 0.01
-102B2	IR/grn.	1.54 ± 0.04	1.20 ± 0.09	0.40 ± 0.01
-15B	black	1.01 ± 0.03	0.71 ± 0.08	0.36 ± 0.01

Table 11a. continued

Sample	Color	Sb	Sn	Th
-HKCV3	blue	1.5 ± 0.1	b	1.70 ± 1.37
-GM2	gy-gr.	2.9 ± 0.2	b	13.94 ± 0.12
-GRY9	gr-yel.	1.9 ± 0.1	1,424 ± 5	12.87 ± 0.08
-GM1	bl-gr.	14.1 ± 0.7	1,767 ± 5	2.09 ± 0.04
-IR13	IR	22.0 ± 1.0	b	1.58 ± 0.04
-183H	"	162.2 ± 7.3	b	2.01 ± 0.10
-183G	"	35.8 ± 1.7	b	0.67 ± 0.10
-172A	"	114.6 ± 5.2	b	1.45 ± 0.08
-B8	blue	13.9 ± 0.5	2,373 ± 12	0.89 ± 0.03
-3295	grn.	1.9 ± 0.2	1,820 ± 9	8.01 ± 0.10
-174A	"	9.3 ± 0.7	2,414 ± 12	8.23 ± 0.13
-174B	"	4.7 ± 0.3	2,368 ± 11	7.86 ± 0.11
-175B	bl-gr.	11.1 ± 0.9	b	7.29 ± 0.15
-175A	"	10.6 ± 0.8	b	7.10 ± 0.13
-102A1	IR	10.1 ± 0.8	b	10.08 ± 0.13
-102A2	"	8.1 ± 0.6	b	10.41 ± 0.13
-102B1	IR,grn.	3.8 ± 0.3	b	9.30 ± 0.14
-102B2	IR/grn.	11.2 ± 0.9	b	9.28 ± 0.15
-15B	black	7.1 ± 0.5	b	1.92 ± 0.10

Table 11a. concluded

Sample	Color	Hf	Zn
-HKCV3	blue	2.52 ± 0.24	$\overset{\sim}{<} 1$
-GM2	gy-gr.	19.84 ± 0.61	59 ± 5
-GRY9	gr-yel.	24.16 ± 0.62	27 ± 3
-GM1	bl-gr.	1.88 ± 0.10	68 ± 3
-IR13	IR	1.76 ± 0.11	54 ± 3
-183H	"	2.28 ± 0.22	84 ± 8
-183G	"	2.28 ± 0.20	54 ± 6
-172A	"	1.96 ± 0.17	31 ± 6
-B8	blue	1.48 ± 0.07	72 ± 2
-3295	grn.	15.04 ± 0.43	28 ± 4
-174A	"	15.78 ± 0.54	59 ± 6
-174B	"	18.29 ± 0.57	63 ± 5
-175B	bl-gr.	15.59 ± 0.57	30 ± 7
-175A	"	14.56 ± 0.52	33 ± 6
-102A1	IR	16.45 ± 0.55	41 ± 5
-102A2	"	17.77 ± 0.59	41 ± 5
-102B1	IR,grn.	14.17 ± 0.50	69 ± 7
-102B2	IR/grn.	11.24 ± 0.45	44 ± 6
-15B	black	2.40 ± 0.25	58 ± 7

Table 11b. Transparent Green Beads from the Mjelele Valley Burial: Neutron Activation Analysis

Sample	Al (%)	Cl (%)	Mn
MJE-20	4.19 ± 0.32	0.30 ± 0.22	323 ± 20
MJE-21A	4.25 ± 0.30	0.24 ± 0.19	344 ± 16
MJE-21B	4.02 ± 0.72	2.01 ± 0.29	1,714 ± 33
MJE-22	2.45 ± 1.08	1.41 ± 0.35	3,204 ± 58

Sample	Na (%)	Cu	U
MJE-20	13.37 ± 0.14	10,451 ± 192	177.37 ± 1.01
MJE-21A	13.29 ± 0.15	7,883 ± 167	352.22 ± 1.87
MJE-21B	18.61 ± 0.20	13,438 ± 264	181.21 ± 1.03
MJE-22	13.77 ± 0.16	27,764 ± 425	169.71 ± 1.04

Sample	Sm	Co	Sc
MJE-20	7.00 ± 0.23	7.38 ± 0.32	7.76 ± 0.06
MJE-21A	8.12 ± 0.42	5.73 ± 0.26	6.92 ± 0.04
MJE-21B	3.10 ± 0.24	11.25 ± 0.44	4.09 ± 0.05
MJE-22	3.30 ± 0.24	35.64 ± 0.94	5.48 ± 0.08

Table 11b. concluded

Sample	Fe (%)	Yb	Ta
-20	1.64 ± 0.04	3.08 ± 0.13	0.99 ± 0.01
-21A	1.38 ± 0.03	3.22 ± 0.11	0.99 ± 0.01
-21B	1.44 ± 0.05	0.66 ± 0.12	0.34 ± 0.01
-22	1.52 ± 0.07	1.01 ± 0.19	0.53 ± 0.02

Sample	Sb	Sn	Th
-20	2.3 ± 0.3	g	17.49 ± 0.21
-21A	3.2 ± 0.3	g	18.00 ± 0.17
-21B	7.3 ± 0.5	g	9.99 ± 0.19
-22	42.5 ± 2.2	1,889 ± 23	15.02 ± 0.29

Sample	Hf	Zn
-20	8.57 ± 0.44	52 ± 8
-21A	7.60 ± 0.37	257 ± 8
-21B	2.62 ± 0.36	165 ± 11
-22	4.49 ± 0.55	663 ± 22

Notes to Table 11

a. All data are given in parts per million unless otherwise indicated.

b. Elements imprecisely determined for the TWBCG are excluded from this Table. For samples in this Table, the upper limits of concentration, with representative counting errors, are: Mg, 4 ± 2%; Ca, 9 ± 2%; V, 160 ± 30 ppm; Dy, 8 ± 1 ppm; Cu, where not used as an additive, 700 ± 200 ppm; K, 6 ± 1%; Sr, 0.2 ± 0.1%; Ga, 600 ± 250 ppm; In, 10 ± 7 ppm; As, in KIL-HKCV3 (colored by Co) is 442.3 ± 6.6 ppm; otherwise the upper limit is 160 ± 7 ppm; W, 3.5 ± 1.0 ppm; Sn, where not used as an additive, 480 ± 10 ppm; Cs, 1.2 ± 0.3 ppm; Ag, 29 ± 1 ppm; Ir, 0.040 ± 0.005 ppm; Hg, assuming none is lost in the reactor, 0.5 ± 0.3 ppm; Eu, 1.5 ± 0.2 ppm; and Tb, 0.58 ± 0.05 ppm.

c. The surface is decayed to a greenish-black. The decayed surface was not analyzed.

d. Transparent.

e. Streaked.

f. Not determined.

g. Elements imprecisely determined for the TWBCG are excluded from this Table. For samples in this Table, the upper limits of concentration, with representative counting errors, are: Mg, 4 ± 4%; Ca, 9 ± 4%; V, 250 ± 125 ppm; Dy, 9 ± 2 ppm; K, 4 ± 2%; Sr, 0.09 ± 0.07%; Ga, 200 ± 200 ppm; In, 20 ± 13 ppm; As, 95 ± 9 ppm; W, 14 ± 5 ppm; Ag, 15 ± 2 ppm; Cs, 5.7 ± 0.3 ppm; Sn, where not used as an additive, 550 ± 50 ppm; Ir, 0.006 ± 0.006 ppm; Hg, assuming none is lost in the reactor, 2.5 ± 0.5 ppm; Eu, 1.2 ± 0.2 ppm; and Tb, 0.86 ± 0.08 ppm.

Table 12. Averaged data of the TWBCG[a]

Grouping	Al (%)	Cl (%)
A. By Site		
Fort Jesus	3.41 ± 0.39	1.37 ± 0.26
Luanze	4.02 ± 0.54	1.50 ± 0.28
Dambarare	3.68 ± 0.41	1.38 ± 0.32
Matendere	4.06 ± 0.37	1.55 ± 0.26
Dhlo Dhlo	3.55 ± 0.81	1.65 ± 0.30
Vohémar	4.05 ± 0.79	1.22 ± 0.42
Kilwa, Period IIIb	4.08 ± 0.46	1.54 ± 0.23
Kilwa, Period IV	4.21 ± 0.78	1.45 ± 0.19
Gereza (Kilwa, Period V)	3.78 ± 0.50	1.55 ± 0.18
Bambandyanalo	4.55 ± 0.21	1.03 ± 0.25
Chibvumani	3.59 ± 1.14	1.47 ± 0.39
Ingombe Ilede	3.52 ± 0.28	1.45 ± 0.17
Modjadje's location	3.31 ± 0.51	1.57 ± 0.47
Mjelele Valley Burial	3.36 ± 0.64	1.43 ± 0.28
B. By Color and Additives		
black	3.99 ± 0.73	1.52 ± 0.41
blue-green, high Sn[b]	3.80 ± 0.90	1.51 ± 0.25
blue-green, low Sn	3.51 ± 0.69	1.46 ± 0.25
Indian red, high Sn	3.66 ± 0.29	1.34 ± 0.28
Indian red, low Sn	4.12 ± 0.56	1.16 ± 0.39
greenish-yellow, high Sn	4.01 ± 0.99	1.44 ± 0.29
greenish-yellow, low Sn	4.30 ± 0.51	1.62 ± 0.24
yellow	3.62 ± 0.63	1.30 ± 0.21
orange	3.20 ± 0.50	1.34 ± 0.24
cobalt blue	3.75 ± 0.55	1.64 ± 0.34
C. For the TWBCG	3.81 ± 0.69	1.44 ± 0.34

Table 12. continued

Grouping	Mn	Na (%)
A. By Site		
FJE	602 ± 198	15.09 ± 0.98
LUA	390 ± 97	15.05 ± 0.67
DAM	528 ± 132	15.40 ± 0.87
MAT	433 ± 194	14.81 ± 1.06
DHL	366 ± 246	15.41 ± 0.85
VOH	376 ± 66	14.09 ± 0.94
KIL-IIIb	423 ± 108	16.23 ± 0.94
KIL-IV	446 ± 94	15.72 ± 1.11
GER	328 ± 38	15.68 ± 0.45
BAM	480 ± 101	12.03 ± 1.58
CHI	348 ± 113	15.04 ± 3.23
ING	412 ± 81	15.06 ± 1.37
MOD	301 ± 44	15.03 ± 0.61
MJE	712 ± 990	14.54 ± 1.04
B. By Color		
black	646 ± 701	15.08 ± 0.98
bl-gr., high Sn	450 ± 120	15.36 ± 0.56
bl-gr., low Sn	312 ± 58	15.28 ± 0.81
IR, high Sn	514 ± 141	15.24 ± 1.62
IR, low Sn	507 ± 147	13.95 ± 2.59
gr-y., high Sn	413 ± 100	15.02 ± 2.20
gr-y., low Sn	427 ± 58	15.81 ± 0.88
yellow	496 ± 334	14.18 ± 1.28
orange	598 ± 388	14.18 ± 0.85
co bl.	427 ± 235	15.33 ± 0.67
C. For the TWBCG	450 ± 271	14.96 ± 1.53

Table 12. continued

Grouping	Cu	U
A. By Site		
FJE	n.a.[c]	105.09 ± 31.51
LUA	n.a.	111.52 ± 50.58
DAM	n.a.	132.95 ± 38.53
MAT	n.a.	104.05 ± 22.23
DHL	n.a.	70.48 ± 49.34
VOH	n.a.	102.10 ± 34.43
KIL-IIIb	n.a.	127.48 ± 37.84
KIL-IV	n.a.	174.50 ± 42.04
GER	n.a.	85.48 ± 14.34
BAM	n.a.	105.99 ± 43.65
CHI	n.a.	153.94 ± 98.59
ING	n.a.	184.58 ± 122.86
MOD	n.a.	74.85 ± 26.89
MJE	n.a.	92.36 ± 40.86
B. By Color		
black	d	132.85 ± 45.68
bl-gr., high Sn	5,781 ± 1;615	140.59 ± 36.47
bl-gr., low Sn	4,897 ± 933	84.54 ± 49.35
IR, high Sn	5,032 ± 880	119.75 ± 43.55
IR, low Sn	6,170 ± 6,221	110.06 ± 41.12
gr-y., high Sn	d	176.05 ± 96.93
gr-y., low Sn	d	128.84 ± 56.85
yellow	d	95.70 ± 19.22
orange	d	172.56 ± 44.53
co bl.	d	89.79 ± 39.02
C. For the TWBCG	5,449 ± 3,683[e]	112.43 ± 54.91

Table 12. continued

Grouping	Sm	Co
A. By Site		
FJE	2.77 ± 0.80	n.a.
LUA	4.20 ± 1.00	n.a.
DAM	4.17 ± 0.85	n.a.
MAT	4.52 ± 0.62	n.a.
DHL	2.84 ± 1.12	n.a.
VOH	4.06 ± 0.81	n.a.
KIL-IIIb	4.48 ± 1.22	n.a.
KIL-IV	5.70 ± 1.34	n.a.
GER	3.57 ± 0.28	n.a.
BAM	4.98 ± 1.01	n.a.
CHI	4.55 ± 2.35	n.a.
ING	5.45 ± 0.93	n.a.
MOD	3.04 ± 0.72	n.a.
MJE	3.20 ± 0.58	n.a.
B. By Color		
black	4.52 ± 1.37	22.45 ± 10.48
bl-gr., high Sn	3.75 ± 1.17	68.18 ± 67.32
bl-gr., low Sn	3.23 ± 1.16	74.77 ± 48.00
IR, high Sn	4.40 ± 0.84	20.33 ± 8.20
IR, low Sn	4.60 ± 1.39	23.07 ± 15.19
gr-y., high Sn	5.48 ± 1.73	10.53 ± 3.40
gr-y., low Sn	5.24 ± 1.48	10.17 ± 2.06
yellow	3.25 ± 1.28	9.72 ± 2.52
orange	3.12 ± 0.75	10.87 ± 3.68
co bl.	3.50 ± 0.75	1,110.84 ± 437.32
C. For the TWBCG	4.03 ± 1.43	1,110.84 ± 437.32[e]
		34.70 ± 40.37[f]

Table 12. continued

Grouping	Sc	Fe (%)
A. By Site		
FJE	4.48 ± 1.76	1.45 ± 0.64
LUA	6.13 ± 0.90	1.98 ± 0.58
DAM	5.95 ± 1.67	2.56 ± 0.72
MAT	6.34 ± 0.74	2.10 ± 0.83
DHL	4.04 ± 1.40	1.18 ± 0.44
VOH	6.57 ± 0.95	2.19 ± 0.66
KIL-IIIb	6.63 ± 1.60	2.00 ± 0.40
KIL-IV	7.35 ± 1.18	2.15 ± 0.51
GER	6.32 ± 1.25	2.26 ± 0.71
BAM	6.83 ± 0.89	2.90 ± 0.63
CHI	6.24 ± 2.34	1.81 ± 0.50
ING	7.05 ± 1.61	1.98 ± 0.43
MOD	4.65 ± 0.92	1.29 ± 0.25
MJE	5.00 ± 0.97	1.37 ± 0.25
B. By Color		
black	6.34 ± 0.94	1.87 ± 0.52
bl-gr., high Sn	5.73 ± 1.58	1.88 ± 0.63
bl-gr., low Sn	5.16 ± 1.75	1.61 ± 0.77
IR, high Sn	6.54 ± 1.90	2.78 ± 0.65
IR, low Sn	7.26 ± 1.30	2.90 ± 0.66
gr-y., high Sn	7.33 ± 1.85	2.11 ± 0.48
gr-y., low Sn	6.70 ± 1.65	1.76 ± 0.38
yellow	4.82 ± 1.71	1.31 ± 0.46
orange	3.85 ± 0.81	1.05 ± 0.23
co bl.	5.12 ± 0.93	1.57 ± 0.30
C. For the TWBSC	5.93 ± 1.74	1.93 ± 0.78

Table 12. continued

Grouping	Yb	Ta
A. By Site		
FJE	1.07 ± 0.38	0.47 ± 0.08
LUA	1.42 ± 0.27	0.57 ± 0.06
DAM	1.36 ± 0.36	0.55 ± 0.18
MAT	1.57 ± 0.13	0.63 ± 0.06
DHL	0.87 ± 0.32	0.47 ± 0.13
VOH	1.36 ± 0.43	0.59 ± 0.10
KIL-IIIb	1.50 ± 0.54	0.74 ± 0.27
KIL-IV	1.74 ± 0.51	0.96 ± 0.32
GER	0.99 ± 0.33	0.50 ± 0.03
BAM	2.45 ± 0.37	1.06 ± 0.36
CHI	1.44 ± 0.66	0.75 ± 0.43
ING	1.62 ± 0.41	0.86 ± 0.18
MOD	0.94 ± 0.24	0.58 ± 0.21
MJE	1.09 ± 0.35	0.54 ± 0.10
B. By Color		
black	1.42 ± 0.26	0.70 ± 0.22
bl-gr., high Sn	1.33 ± 0.37	0.59 ± 0.14
bl-gr., low Sn	1.09 ± 0.34	0.53 ± 0.16
IR, high Sn	1.79 ± 0.85	0.79 ± 0.53
IR, low Sn	1.79 ± 0.55	0.79 ± 0.30
gr-y., high Sn	1.78 ± 0.65	0.91 ± 0.39
gr-y., low Sn	1.80 ± 0.38	0.92 ± 0.32
yellow	1.28 ± 0.50	0.58 ± 0.19
orange	1.02 ± 0.04	0.45 ± 0.10
co bl.	0.91 ± 0.30	0.54 ± 0.13
C. For the TWBCG	1.38 ± 0.56	0.67 ± 0.29

Table 12. continued

Grouping	Sb	Sn
A. By Site		
FJE	11.63 ± 24.33	n.a.
LUA	2.85 ± 2.34	n.a.
DAM	5.32 ± 3.31	n.a.
MAT	3.07 ± 5.17	n.a.
DHL	5.00 ± 3.06	n.a.
VOH	39.25 ± 49.49	n.a.
KIL-IIIb	7.94 ± 6.47	n.a.
KIL-IV	7.71 ± 13.91	n.a.
GER	5.16 ± 3.92	n.a.
BAM	27.98 ± 8.67	n.a.
CHI	8.92 ± 9.72	n.a.
ING	5.99 ± 8.79	n.a.
MOD	7.12 ± 5.59	n.a.
MJE	11.75 ± 6.30	n.a.
B. By Color		
black	2.34 ± 4.56	d
bl-gr., high Sn	19.07 ± 21.73	2,584 ± 1,548
bl-gr., low Sn	7.26 ± 4.31	d
IR, high Sn	10.39 ± 10.51	1,176 ± 659
IR, low Sn	12.94 ± 10.14	d
gr-y., high Sn	3.45 ± 4.63	1,534 ± 487
gr-y., low Sn	7.18 ± 18.07	d
yellow	30.94 ± 41.88	5,163 ± 1,730
orange	79.05 ± 64.85	9,523 ± 2,677
co bl.	2.73 ± 1.88	d
C. For the TWBCG	11.41 ± 21.47	3,369 ± 2,742[e]

Table 12. continued

Grouping	Th	Hf
A. By Site		
FJE	14.69 ± 4.56	4.26 ± 2.38
LUA	27.67 ±19.84	6.65 ± 3.46
DAM	29.78 ±15.10	6.30 ± 2.99
MAT	27.57 ± 3.28	6.29 ± 2.62
DHL	17.88 ± 6.26	4.30 ± 3.25
VOH	19.96 ± 4.80	4.81 ± 1.54
KIL-IIIb	21.53 ± 9.04	4.44 ± 1.30
KIL-IV	28.80 ±11.77	4.84 ± 1.64
GER	18.90 ± 0.91	3.86 ± 0.63
BAM	39.19 ±20.68	21.41 ± 7.90
CHI	22.19 ±10.38	3.78 ± 1.68
ING	20.54 ± 1.70	5.34 ± 1.29
MOD	19.46 ± 8.04	4.22 ± 1.90
MJE	17.17 ± 5.76	4.13 ± 1.13
B. By Color		
black	17.95 ± 6.40	4.78 ± 1.34
bl-gr., high Sn	17.65 ± 7.17	4.76 ± 2.40
bl-gr., low Sn	18.25 ± 5.98	3.80 ± 1.41
IR, high Sn	41.30 ±21.49	13.21 ±13.82
IR, low Sn	24.00 ±12.15	8.68 ± 7.41
gr-y., high Sn	25.64 ± 9.54	4.95 ± 1.49
gr-y., low Sn	32.02 ± 9.20	5.73 ± 1.56
yellow	16.10 ± 5.90	6.34 ± 6.56
orange	14.67 ± 3.63	3.75 ± 1.13
co bl.	21.06 ± 6.40	5.13 ± 2.77
C. For the TMCG	22.16 ±10.90	5.94 ± 5.40

Table 12. concluded

Grouping	Zn	Mean RMSD[g] (%)
A. By Site		
FJE	n.a.	43.1
LUA	n.a.	31.5
DAM	n.a.	n.a.
MAT	n.a.	n.a.
DHL	n.a.	40.9
VOH	n.a.	31.3
KIL-IIIb	n.a.	n.a.
KIL-IV	n.a.	35.8
GER	n.a.	19.3
BAM	n.a.	n.a.
CHI	n.a.	n.a.
ING	n.a.	n.a.
MOD	n.a.	30.0
MJE	n.a.	n.a.
B. By Color		
black	73.14 ± 43.46	44.3
bl-gr., high Sn	285.10 ± 146.10	34.3
bl-gr., low Sn	71.34 ± 91.77	32.9
IR, high Sn	178.24 ± 36.43	n.a.
IR, low Sn	153.30 ± 111.63	37.4
gr-y., high Sn	56.25 ± 34.22	38.4
gr-y., low Sn	50.00 ± 13.96	40.6
yellow	474.87 ± 322.25	45.2
orange	2,564.90 ± 452.82	n.a.
co bl.	≲ 200.	31.3
C. For the TWBCG	2,564.7 ± 452.7[e]	33.1 by site[h]
	153.2 ± 185.5[f]	38.1 by color

Notes to Table 12

a. Mean and root mean square deviation (see Chapter 3) are given, in parts per million unless otherwise indicated. Only groupings having three or more members appear here. Where no determination was made for an element, the sample is omitted from the average of that element. Pb was estimated on grouped samples by X-ray fluorescence analysis. The results are: for black, $\sim$ 0.02 - 0.2%; blue-green with high Sn, $\sim$ 0.1 - 3.%; blue-green with low Sn, $\lesssim$ 0.1%; Indian red with high Sn, $\sim$ 0.3%; Indian red with low Sn, $\lesssim$ 0.3%; greenish-yellow with high Sn, $\sim$ 0.02 - 2.%; greenish-yellow with low Sn, $\sim$ 0.02%; yellow, $\sim$ 3.%; orange, $\sim$ 6.%; cobalt blue, $< 0.1\%$.

b. High Sn is $\geq$ 800 ppm, low Sn is $\leq$ 700 ppm.

c. Not applicable.

d. Imprecisely determined due to concentration at or near the lower limit of quantification.

e. Applies to cases where the additive was apparently used.

f. Applies to cases where the additive was apparently not used.

g. Root mean square deviation. Calculated only for groupings containing eight samples or more, using only the 13 elements consistently determined.

h. If GER is omitted, the mean RMSD is 35.4%.

Table 13. Dating of the Trade Wind Bead Chemical Group in Africa and Madagascar

Site	A. D. Date	Major Bases of Date	References
Bambandyanalo	1050 ± 65	C^{14}, Y-135-17	Fagan 1965
Mapungubwe	1380 ± 60	C^{14}, Y-135-14	"
	1420 ± 60	C^{14}, Y-135-9	"
Mapela	1280 ± 95	C^{14}, SR-115	Fagan 1967
Kilwa, Period II	*c.* 1150-1300	ceramic/numismatic/	Chittick 1966,
	1160 ± 110	C^{14}, N-256	Fagan 1967
Period IIIb	*c.* 15th century	historic/architectural/ ceramic/numismatic	Chittick 1966
Periods IV, V	*c.* 16th through 19th centuries	dating not firm (poor preservation in late parts of site)	Chittick 1966, Chittick 1969
Gereza (Period V)	*c.* 19th century	estimate	" ,
	1775 ± 90	C^{14}, SR-155	Phillipson 1970
Gedi	pre-1399	inscription/stratigraphic	Kirkman 1960
Kaole House	pre-15th century	ceramic/stratigraphic	Chittick 1959
Ingombe Ilede	1340 ± 85	C^{14}, GX-1368	Phillipson 1970,
	1445 ± 85	C^{14}, GX-1369	Phillipson and Fagan 1969
Engaruka	*c.* 15th to 18th centuries	best estimate	Phillipson 1970, Sassoon 1967
	1445 ± 85	C^{14}, GX-900	
	1460 ± 90	C^{14}, GX-247	
	1480 ± 110	C^{14}, N-1892	
	1650 ± 100	C^{14}, N-1893	
	1750 ± 100	C^{14}, N-1894	

Table 13. continued

Site	A. D. Date	Major Bases of Date	References
Vohémar	1550-1750		Verin 1970
Luanze	1580-1680	historic/ceramic	Garlake 1968
Dambarare	1570-1750	historic/ceramic	"
Nyangwe Fort (Inyanga)	*c.* 16th-19th centuries	estimate (ceramic/bead)	Summers 1967
Khami	*c.* 17th-18th centuries	ceramic	Robinson 1959, Garlake 1968,
	post-1450 ± 95	C^{14}, SR-94	Fagan 1966
Dhlo Dhlo	*c.* 1700	ceramic	Caton-Thompson 1931, Garlake 1968
Fort Jesus	*c.* 17th-18th centuries	ceramic/stratigraphic/ historic (Fort constructed in 1593)	Kirkman 1969
Modjadje's location	*c.* 1937	ethnographic	van Riet Lowe 1937

Table 14. Sites in Figure 14

Map No.	Site and Abbreviation	Chief References
1.	Kopia (KOP)	Dikshit 1969
2.	Nagara (NAG)	Ghosh 1966, 1967
3.	Cambay	---
4.	Akota (Baroda)	Subbarao 1953
5.	Ujjain	Ghosh 1958
6.	Nasik	Sankalia and Deo 1955
7.	Nevasa	Sankalia *et al.* 1960
8.	Paithan (PAI)	Dikshit 1969
9.	Sirpur	*ibid.*
10.	Ter (TER)	*ibid.*
11.	Kilhapur (KOL)	*ibid.*
12.	Goa	---
13.	Maski (MAS)	Dikshit 1969, Thapar 1957
14.	Kadkal (KAD)	Dikshit 1969
15.	Kanchipuram	Subrahmanyam and Raman 1967, Ghosh 1965
16.	Arikamedu (ARI)	Wheeler 1946
17.	Kaveripattinam (KAV)	Ghosh 1965
18.	Negapatam	Lavanha 1597

Table 15a. X-ray Fluorescence Analysis of Glass Samples of the Early Historic Period in India[a]

Sample	Color	Mn	Fe	Co	Cu	Zn	Rb
KOL-1	cobalt blue, white	0.7 ± 0.2	0.45 ± 0.08	0.05	0.015	∿ 0.005	<0.01
TER-1	pale blue-green	<0.1	0.30 ± 0.06	<0.05	∿ 0.006	∿ 0.003	0.01
KOP-1	pale blue-green	<0.1	0.7 ± 0.2	<0.05	∿ 0.005	0.01	0.01
ARI-1	Indian red	0.2 ± 0.1	1.2 ± 0.2	<0.1	1.2 ± 0.2	<0.05	0.005
ARI-2	green	<0.1	1.6 ± 0.3	<0.1	1.2 ± 0.2	<0.05	b

Sample	Sr	Zr	Sn	Sb	Ba	Pb	U
KOL-1	0.07 ± 0.01	0.02	1.4 ± 0.2	<0.01	0.30 ± 0.04	<0.03	b
TER-1	∿ 0.008	∿ 0.004	<0.02	<0.005	0.02	<0.02	b
KOP-1	0.02	0.01	<0.005	<0.005	0.05 ± 0.01	<0.03	b
ARI-1	0.04 ± 0.01	0.02	<0.005	<0.005	0.09 ± 0.02	<0.05	b
ARI-2	c	c	0.7 ± 0.1	<0.005	0.07 ± 0.02	6.3 ± 0.8	b

[a] All data are given in percent. In all specimens the upper limit for As is 0.04 %. Specimens TER-1 and KOP-1 both contained ∿ 0.002% Mo. Specimen KOL-1 contained 0.01% Ni.

[b] Not detected. The threshold of U detection depends on several factors, but this threshold is usually around 50 ppm.

[c] High lead content prevents determination of these elements.

Table 15b. Identification of Samples

Sample	Site	Culture	Description
KOL-1	Kolhapur	Deccan, Satavahana dynasty (c. 100 B.C.-200 A.D.)(Dikshit 1969)	Cobalt blue transparent tetragonal bead with double opaque white disc inside, transecting axis, forming double white stripe on perimeter.
TER-1	Ter	"	Pale blue-green transparent hexagonal biconical bead.
KOP-1	Kopia	Mound, with glass-working debris and artifacts of c. 2nd-3rd century A.D. Uttar Pradesh. (Dikshit 1969)	Pale blue-green transparent chunk.
ARI-1	Arikamedu	Glassworking site, Indo-Roman, SE coast. (1st century A.D., Wheeler 1946)	Opaque Indian red chunk.
ARI-2	"	"	Opaque green reheated cane bead, perforation incomplete, color incompletely mixed, giving streaks of opaque green and opaque yellow.

Table 16. X-ray Fluorescence Analysis of Glass from Sites of the Medieval Period in India. Part 1a. Non-factory Sites[a]

Sample	Color	Mn	Fe	Cu	Zn	Rb
KOL-2	green (over yellow)	<0.1	1.4 ± 0.3	0.5 ± 0.1	<0.03	<0.01
KOL-3	blue-green	<0.1	0.8 ± 0.2	0.4 ± 0.1	<0.03	0.01
KAV-6	yellow	<0.1	1.0 ± 0.2	0.05 ± 0.01	0.01	b
KAV-7	yellow	<0.1	1.0 ± 0.2	0.04 ± 0.01	0.03	b
KAV-2	yellow-green	<0.1	0.7 ± 0.2	0.7 ± 0.2	0.02	b
KAV-1	green	<0.1	0.7 ± 0.2	0.32 ± 0.05	<0.01	b
KAV-8	blue-green	<0.1	1.0 ± 0.2	0.8 ± 0.2	<0.01	<0.01
KAV-10	Indian red	<0.1	1.6 ± 0.3	1.4 ± 0.2	<0.01	<0.01
KAV-9	Indian red	0.21 ± 0.07	1.1 ± 0.2	1.3 ± 0.2	<0.01	0.01
KAV-3	black	0.5 ± 0.1	0.4 ± 0.1	0.02	0.03	0.02
KAV-4	black	0.5 ± 0.1	0.4 ± 0.1	0.01	0.03	0.02
KAV-5	black, white	0.4 ± 0.1	1.0 ± 0.2	0.05 ± 0.01	0.02	<0.01

Table 16. Part 1a. concluded

Sample	Sr	Zr	Sn	Ba	Pb	U
KOL-2	0.05 ± 0.01	0.11 ± 0.02	0.25 ± 0.04	0.10 ± 0.02	0.4 ± 0.1	c
KOL-3	0.03	0.03	0.03 ± 0.01	0.08 ± 0.02	0.20 ± 0.05	c
KAV-6	0.06 ± 0.02	0.05 ± 0.01	0.37 ± 0.06	0.10 ± 0.02	2.8 ± 0.4	b
KAV-7	b	b	1.2 ± 0.2	0.06 ± 0.02	11. ± 2.	b
KAV-2	0.07 ± 0.02	0.04 ± 0.01	0.5 ± 0.1	0.07 ± 0.02	4.5 ± 0.5	b
KAV-1	0.03	0.09 ± 0.02	0.35 ± 0.06	0.15 ± 0.03	1.6 ± 0.2	b
KAV-8	0.03	0.05 ± 0.01	0.13 ± 0.02	0.11 ± 0.02	0.09 ± 0.03	c
KAV-10	0.02	0.09 ± 0.02	0.25 ± 0.04	0.06 ± 0.01	0.6 ± 0.1	c
KAV-9	0.04 ± 0.01	0.03	<0.005	0.08 ± 0.02	<0.03	c
KAV-3	0.02	0.02	<0.005	0.14 ± 0.03	<0.03	c
KAV-4	0.03	0.02	<0.005	0.16 ± 0.03	<0.03	c
KAV-5	0.04 ± 0.01	0.03	∿ 0.006	0.22 ± 0.04	<0.03	c

[a] All data are given in percent. In all specimens, the upper limit for As was 0.04% except that in specimens KAV-1, -2, -6, and -7 this is uncertain due to the interference from Pb. In all specimens the upper limit for Co was 0.05%, and for Sb, 0.01%.

[b] High Pb content interferes with determination of this element.

[c] Not detected. The threshold of U detection depends on several factors, but this threshold is usually around 50 ppm.

Table 16. Part 1b. Identification of Samples

Sample	Site	Culture	Description
KOL-2	Kolhapur	Deccan, Bahmani dynasty (1435-1518 A.D.)(Dikshit 1969)	Green transparent over yellow opaque core, reheated cane bead.
KOL-3	"	"	Blue-green transparent reheated cane bead.
KAV-6	Kaveripattinam	Seaport of the Chola kingdom, c. 850-1300 A.D. (Panikkar 1963)(Sinha 1964)	Yellow opaque to translucent reheated cane bead.
KAV-7	"	"	" " " " " " "
KAV-2	"	"	Yellow green opaque to translucent reheated cane bead.
KAV-1	"	"	Green opaque to translucent reheated cane bead.
KAV-8	"	"	Blue-green translucent reheated cane bead.
KAV-10	"	"	Indian red opaque reheated cane bead.
KAV-9	"	"	" " " " " "
KAV-3	"	"	Black opaque reheated cane bead.
KAV-4	"	"	" " " " "
KAV-5	"	"	Black opaque bicone, with white stripe marvered in around perimeter.

Table 16. X-ray Fluorescence Analysis of Glass from Sites of the Medieval Period in India. Part 2a. Possible Factory Sites in the Deccan[a]

Sample	Color	Fe	Cu	Zn	Rb	Sr
MAS-5	cobalt blue	0.36 ± 0.07	0.04 ± 0.01	0.04 ± 0.01	b	b
MAS-2	black	5.9 ± 1.2	∿ 0.01	∿ 0.01	∿ 0.01	∿ 0.02
MAS-8	yellow-green	2.1 ± 0.4	<0.02	0.01	0.02	0.02
MAS-10b	yellow	1.8 ± 0.3	0.01	0.01	b	0.04 ± 0.01
MAS-10a	blue-green	1.3 ± 0.2	0.8 ± 0.2	<0.03	<0.01	0.03
MAS-6	green (over yellow)	1.7 ± 0.3	0.4 ± 0.1	<0.03	<0.01	0.04 ± 0.01
MAS-9	blue-green	1.0 ± 0.2	0.5 ± 0.1	<0.03	0.01	0.02
MAS-1	green	1.5 ± 0.3	0.6 ± 0.1	<0.03	<0.01	0.06 ± 0.01
MAS-3	Indian red	1.6 ± 0.3	1.9 ± 0.3	<0.03	<0.01	0.03
MAS-4	Indian red	0.9 ± 0.2	0.7 ± 0.1	<0.03	<0.01	0.04 ± 0.01
MAS-7	yellow-green	1.1 ± 0.2	0.24 ± 0.05	0.06 ± 0.02	b	0.02
KAD-1b	yellow	1.7 ± 0.3	0.04 ± 0.01	0.01	b	0.06 ± 0.02
KAD-1a	green	1.8 ± 0.3	0.40 ± 0.06	<0.03	<0.01	0.05 ± 0.01
PAI-1	green	1.6 ± 0.3	0.7 ± 0.2	0.06 ± 0.02	b	b
PAI-2	blue-green	0.8 ± 0.2	0.8 ± 0.2	<0.03	0.02	0.02
PAI-3	blue-green	0.8 ± 0.2	0.30 ± 0.05	<0.03	0.01	0.03

Table 16. Part 2a. continued

Sample	Zr	Sn	Ba	Pb	U
MAS-5	b	0.016 ± 0.004	0.04 ± 0.01	3.0 ± 0.4	b
MAS-2	0.11 ± 0.03	<0.005	0.04 ± 0.01	<0.03	c
MAS-8	0.02	0.023 ± 0.005	0.04 ± 0.01	0.10 ± 0.03	c
MAS-10b	0.05 ± 0.01	0.27 ± 0.04	0.08 ± 0.02	2.0 ± 0.3	b
MAS-10a	0.05 ± 0.01	0.09 ± 0.02	0.06 ± 0.01	0.20 ± 0.04	c
MAS-6	0.02	0.22 ± 0.03	0.04 ± 0.01	0.4 ± 0.1	c
MAS-9	0.04 ± 0.01	0.012 ± 0.004	0.06 ± 0.01	0.07 ± 0.02	c
MAS-1	0.04 ± 0.01	0.12 ± 0.02	0.05 ± 0.01	0.09 ± 0.03	c
MAS-3	0.03	<0.005	0.06 ± 0.01	0.02	c
MAS-4	0.04 ± 0.01	0.014 ± 0.004	0.07 ± 0.01	0.04	c
MAS-7	0.01	0.24 ± 0.04	0.03	2.1 ± 0.3	b
KAD-1b	0.05 ± 0.01	0.35 ± 0.05	0.06 ± 0.01	3.0 ± 0.4	b
KAD-1a	0.06 ± 0.01	0.10 ± 0.02	0.07 ± 0.01	0.37 ± 0.05	c
PAI-1	b	0.38 ± 0.06	0.04 ± 0.01	4.1 ± 0.5	b
PAI-2	0.09 ± 0.02	0.14 ± 0.02	0.07 ± 0.01	0.14 ± 0.04	c
PAI-3	0.07 ± 0.02	0.023 ± 0.005	0.12 ± 0.02	0.09 ± 0.03	c

---

[a] All data are given in percent. Specimen MAS-5 contained 0.11 ± 0.04% Mn and 0.08 ± 0.02% Co. For all other specimens, the upper limit for Mn is 0.1%, for Co, 0.05%, for Sb, 0.05%, and for As 0.03%.

[b] High Pb content interferes with determination of this element.

[c] Not detected. The threshold of U detection depends upon several factors, but this threshold is usually about 50 ppm.

Table 16. Part 2b. Identification of Samples

Sample	Site	Culture	Description
MAS-5	Maski	Deccan, c. 1512 A.D., dated at Kadkal, 11 miles distant (Dikshit 1969)	Cobalt blue transparent bangle fragment.
MAS-2	"	"	Black opaque wound elliptical bead.
MAS-8	"	"	Pale yellow-green transparent bangle fragment, with yellow opaque trim, trim not analyzed.
MAS-10b	"	"	Yellow opaque to translucent portion of composite bangle fragment.
MAS-10a	"	"	Blue-green translucent portion of composite bangle fragment (same as 10b).
MAS-6	"	"	Green transparent over yellow opaque core, bangle fragment.
MAS-9	"	"	Blue-green translucent bangle fragment.
MAS-1	"	"	Green translucent chunk.
MAS-3	"	"	Indian red opaque reheated cane bead.
MAS-4	"	"	" " " " " "
MAS-7	"	"	Yellow-green opaque to translucent outer layer of a cored bangle fragment.
KAD-1b	Kadkal	Deccan, c. 1512 A.D., by impressions of Vijayanagar coins (Dikshit 1969)	Yellow opaque to translucent portion of composite bangle fragment.
KAD-1a	"	"	Green translucent portion of composite bangle fragment (same as 1b).
PAI-1	Paithan	Deccan, c. 1512 A.D., dated at Kadkal	Green opaque to translucent bangle fragment, with colorant distributed near surface only.
PAI-2	"	"	Blue-green translucent chunk.
PAI-3	"	"	Blue-green translucent spirally twisted bangle fragment.

Table 16. X-ray Fluorescence Analysis of Glass from Sites of the Medieval Period in India. Part 3a. Possible Factory Site in Gujerat[a]

Sample	Color	Mn	Fe	Cu	Zn	Sr
NAG-1228A	cobalt blue, white	0.6 ± 0.2	0.44 ± 0.08	0.04 ± 0.01	∿ 0.007	0.05 ± 0.01
NAG-628	cobalt blue	0.07	1.6 ± 0.2	0.08 ± 0.02	0.01	0.02
NAG-660	blue-green	0.11 ± 0.04	0.7 ± 0.2	0.7 ± 0.1	<0.02	0.03
NAG-186	black	<0.1	2.1 ± 0.4	0.01	0.02	0.02
NAG-610	black	<0.1	3.2 ± 0.6	0.26 ± 0.05	0.01	0.03
NAG-462	black	<0.1	3.2 ± 0.6	0.03	0.01	0.07 ± 0.02
NAG-500	mottled	<0.1	4.7 ± 0.8	0.01	0.02	0.05 ± 0.01
NAG-472	gray-green	<0.1	2.0 ± 0.4	<0.02	0.01	0.06 ± 0.01
NAG-1029	gray-green	<0.1	3.0 ± 0.6	<0.02	<0.01	0.07 ± 0.02
NAG-100	purple	0.5 ± 0.1	0.35 ± 0.07	<0.02	<0.02	0.06 ± 0.01

Table 16. Part 3a. continued

Sample	Zr	Sn	Ba	Pb	U
NAG-1228A	0.02	2.9 ± 0.4	0.29 ± 0.04	0.23 ± 0.05	b
NAG-628	0.02	∿ 0.003	0.03	0.01	b
NAG-660	0.01	0.016 ± 0.004	0.03	0.06	b
NAG-186	0.02	0.05 ± 0.01	0.03	0.17 ± 0.04	b
NAG-610	0.02	0.031 ± 0.006	0.05 ± 0.01	<0.03	b
NAG-462	0.02	∿ 0.009	0.04 ± 0.01	<0.03	b
NAG-500	0.02	<0.005	0.03	<0.03	b
NAG-472	0.01	<0.005	0.02	<0.03	b
NAG-1029	0.02	<0.005	0.04 ± 0.01	<0.03	b
NAG-100	0.01	<0.005	0.01	<0.03	b

[a] All data are given in percent. Specimen NAG-1228A contained 0.05% Co and 0.01% Ni, and specimen NAG-628 contained 0.08 ± 0.03% Co and 0.06 ± 0.02% Ni. The upper limit for As is 0.03% on all specimens, for Sb it is 0.005% on all specimens except NAG-1228A, which contained 0.02% Sb.

[b] Not detected. The threshold of U detection depends upon several factors, but this threshold is usually about 50 ppm.

Table 16. Part 3b. Identification of Samples

Sample	Site	Culture	Description
NAG-1228A	Nagara		Cobalt blue transparent tetragonal bead with double opaque white disc inside, transecting axis, forming double white stripe on perimeter (as KOL-1).
NAG-623	"		Cobalt blue transparent bangle fragment.
NAG-660	"		Blue-green transparent bangle fragment.
NAG-186	"		Black opaque bangle fragment.
NAG-610	"		Black friable porous chunk, ? slag.
NAG-462	"		Black friable porous chunk, ? slag.
NAG-500	"		Mottled black, gray and green porous chunk, ? slag.
MAG-472	"		Gray-green porous chunk, ? slag.
NAG-1029	"		" " " " " "
NAG-100	"		Purple transparent chunk.

CHAPTER 8. THE GLASS OF IFE

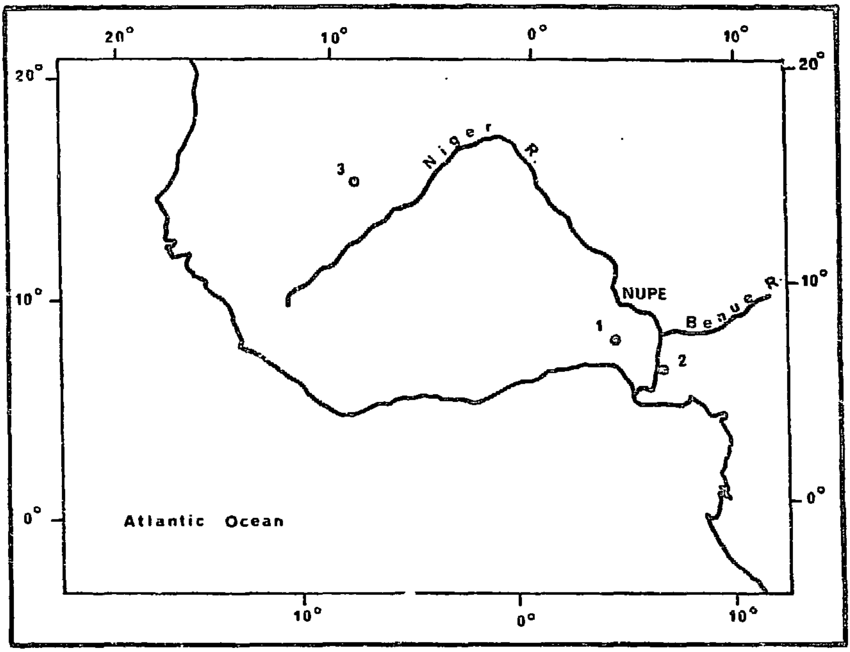
Introduction

Our investigation now turns to West Africa, to a site where remnants of an apparent glass industry have been found. This is Ife, in Nigeria (Lat., 7° 28' N., Long., 4° 32' E.) (see Figure 16).

Ife is traditionally associated with the origins of Yoruba civilization. Some say that mankind himself originated at Ife (Frobenius 1913: I, 306). Others say that Ife was the first place of Yoruba settlement (Fage 1969), perhaps as newcomers destined to merge with earlier inhabitants (Davidson 1966) or perhaps to become their royalty. In historical times Ife has been regarded as the chief and ancestral town of the Yoruba royalty. Rulers of other towns, such as Benin, an Edo town, and Oyo, a Yoruba town, were ritually regarded as tributary descendants of the ruler of Ife.

To some extent the Yoruba civilization may be the cultural descendant of the earlier Nok culture of Nigeria, which is only known archaeologically.

Whether autochthonous, derived, or both, the Yoruba civilization seems to have crystallized several hundred years ago, in the medieval period. Such a dating was earlier proposed on the basis of oral traditions from Benin, although it may be questioned if the oral traditions allow specification to century (see Talbot 1926, Egharevba 1960, Fage 1969, Bradbury 1959, 1964). Over approximately the past decade, archaeological research has yielded radiocarbon dates of the medieval period from Ife, associated with decorative pavements and with other artifacts. Thus, both tradition and archaeology indicate that Ife may have been important in the medieval period.



XBL 728-1540

1 = Ife
2 = Igbo Ukwu
3 = Koumbi Saleh

Figure 16. Chief West African localities mentioned in text.

Beads of coral, stone, and glass often figure in royal regalia in West Africa, and the Yoruba are not an exception to this generality. Upon ceremonial occasions royal personages may wear thousands of beads, as armlets, crowns, necklaces, and in other forms. The tributary-descendent status which the *Oba* (ruler) of Benin had, historically, vis-à-vis the *Oni* (ruler) of Ife is symbolized by the tradition that not only Oranmiyan, who founded the *Oba* institution of Benin, but also the *Oba*'s royal beads, came from Ife. Beaded crowns are symbolic of descent from Oduduwa, the first *Oni* of Ife (Willett 1967).

Glass at Ife

It has been known for generations that glass beads and remnants of glassworking could be found at various places in and near Ife. These include beads, crucible sherds lined with glass, occasional intact glass-lined crucibles, and chunks and lumps of presumed cullet. Glassmaking is not generally known in the area today, and apparently many people of the region do not realize the original function of the crucibles. The mysterious artifacts are regarded with respect, however, and are often found on the altars of local shrines (Fagg and Willett 1962).

A craft of ornament production utilizing these glass pieces exists today, and existed in the nineteenth century as well (Fagg and Willett 1962). The major known locality from which these recent craftsmen have gathered their materials over past decades is the Olokun Grove, a place associated with Olokun, a god of wealth.[19] Frobenius (1913:I) wrote that

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[19] In historical times in West Africa, buried glass beads were indeed a source of wealth for the people in whose territory they lay, since they could be sold to Europeans who resold them in Ghana (see Davison, Giauque and Clark 1971).

the material buried in the Olokun Grove was thought to have been provided by the gods for the prosperity of the people of Ife, and that it was regularly "spent" by the Oni of Ife until depleted. He further recounted that the Grove and its contents were an issue in the nineteenth-century struggle between the original people of Ife and newcomers in the Modeke quarter of Ife.

The first person known to dig in the Olokun Grove and record his findings was Frobenius, who reported that he found pottery vessels provided with lids and lined with glass of different colors, interpretable as glassmakers' crucibles. He also found ash, charcoal, and glass, and other artifacts not related to glassmaking.

Although his report is not entirely clear, it seems that much of the glassmaking material was found in pits which were twelve to twenty-four feet deep. The pits transect a layer of charcoal, ash, and beads at a depth of about sixteen to eighteen feet. It is not clear whether these pits were dug by original glassmelters, by recent craftsmen seeking materials, by representatives of the Oni seeking wealth, or by other treasure-hunters.[20]

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[19] (continued) In some areas digging rights may have comprised a concession which could be awarded by a king.

[20] Frobenius (1913:308) reported that a few glazed crucible sherds were found in the top layer, which was about two and a half feet thick. These sherds could be interpreted as debris from recent diggings, brought up from the depths and then abandoned. About ten feet down he came upon broken crucible sherds and blocks of stone, which he does not describe except to say that they were weathered (1913:94). One wonders if these blocks of stone

The stratigraphy in the Olokun Grove has undoubtedly been severely disturbed as a result of these various diggings. Moreover, it has been largely planted with cocoa today. It seems clear that this is no site at which to investigate the Ife glass industry. It was therefore very interesting when, more recently, further glass artifacts were found at the archaeological site of Ita Yemoo. This site is interpreted as a possible palatial compound, occupied in medieval times, and containing shrines (Ojo 1967, Willett 1959). This site does not seem to have suffered the recent disturbances that occurred at the Olokun Grove, and it therefore seems that glassmaking remnants found there may have useful information to yield.

The site at Ita Yemoo was discovered during construction. It was partially excavated and studied by F. Willett (1959, 1960), who discovered a series of remarkable decorative pavements made from potsherds. Also discovered were sculptures, glass beads, and glass-lined crucible sherds. The site also yielded an intact crucible filled with glass and stone beads (photograph in Willett 1959), but this was not found _in situ_.

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[20] (continued) represent some material used by the glassworkers, perhaps a furnace lining, roofing, a shielding, or even work-benches. In such a case the broken crucible sherds at the ten foot level may represent debris lying on the glassworkers' own working floor. At sixteen to eighteen feet down Frobenius found a level of charcoal, ashes, and beads (1913:94, 309). If the glassworkers had dug pits approximately five feet deep in which to build a fire and melt their glass, as the Nupe glassworkers do today (Nadel 1942: 275), then the lower level of ashes and beads might represent the bottoms of the glassworkers' pits.

Glass artifacts similar to those found at Ita Yemoo were found by Willett in excavations in other localities in Nigeria (see Tables), including Orun Oba Ado, the site at Ife where the heads of the Obas of Benin are ritually buried after death. Orun Oba Ado yielded finished beads, but did not yield evidence of glassworking.

Samples of glass from Ife and from a few other sites were subjected to analysis by neutron activation and X-ray fluorescence methods. The results of X-ray fluorescence have been discussed elsewhere (Davison, Giauque and Clark 1971). Here we shall discuss the results of neutron activation.

Results

Several kinds of glass were found by our analysis of glass specimens from Ife and other sites. These samples have been divided into three Classes. Class I (Table 17) seems to comprise a worthwhile chemical group, whereas the other two Classes do not, because of their heterogeneity.

Discussion

We shall discuss each Class in turn.

Class I (Group I). The results of neutron activation analysis of specimens in Class I are presented in Table 17. Because this Class is a worthwhile chemical group, it is hereafter referred to as the Ife Group I, or simply as Group I. Within this Group, the concentrations of the basic ingredients are fairly constant, varying widely only when iron is used as a coloring agent (ITA-89, ITA-27D, ITA-27C, ITA-27T, ITA-27U). The concentrations of the additives manganese and cobalt, though varying widely, display a consistent ratio, which is discussed below.

On the basis of a combined consideration of glass ingredients and glass appearance, Group I may be divided into a number of categories. Nested within Group I is a subgroup, named Group IA. It consists mainly of the blue-yellow dichroic and corded beads which were the subject of an earlier report (Davison, Giauque and Clark 1971). About half the samples of Group I falls into the nested Group IA. The illustrations in Figure 17 include some samples of Group I, and further samples are shown in Plate V.

Group IA: The Dichroic and Corded Glass. About half the samples in Group I falls into Group IA, and, of these, a little over half exhibits blue/yellow dichroism. In reflected light the dichroic samples appear blue, but in transmitted light they are greenish-yellow. Needless to say, the dichroic effect shows a range in its expression, that is, in some beads the blue/yellow contrast is more marked than in others.

Other samples of Group IA are blue in both reflected and transmitted light, and they exhibit cords.

When the results for the fourteen precisely-known elements are averaged as for two separate groups, defined as "corded beads" and "dichroic beads", the resulting two mean values for each element agree within one standard deviation for every element (Figure 18). One would not expect more than two-thirds of the parameters to agree within the ranges defined by a standard deviation, but in this case all do. In addition, the means agreed within the standard deviations of the means (standard error) for ten of the fourteen elements (Table 18), just over two-thirds. As above, one would not expect more than two-thirds agreement. This evidence, in combination with the fact that one bead (ITA-27N) is both dichroic and corded, forms the basis for our conclusion that dichroic and corded beads are, statistically, chemically indistinguishable and belong in one group. In this group we also include three additional borderline cases, which show

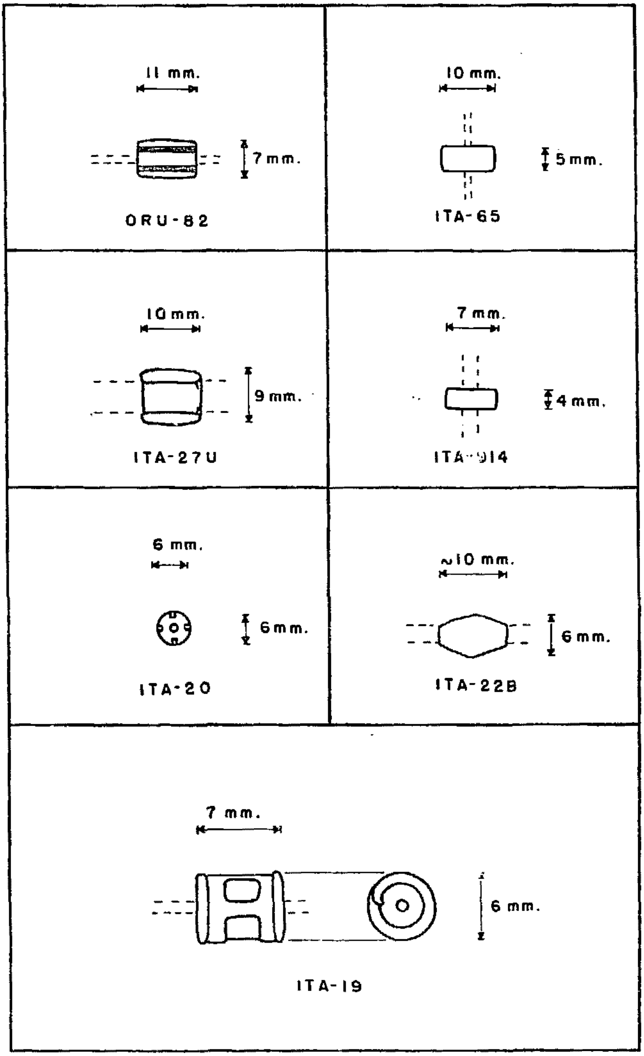

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Figure 17. Diagrams of beads of Ife, Group I (ORU-82, ITA-65, ITA-27U) and Class II (the remainder).

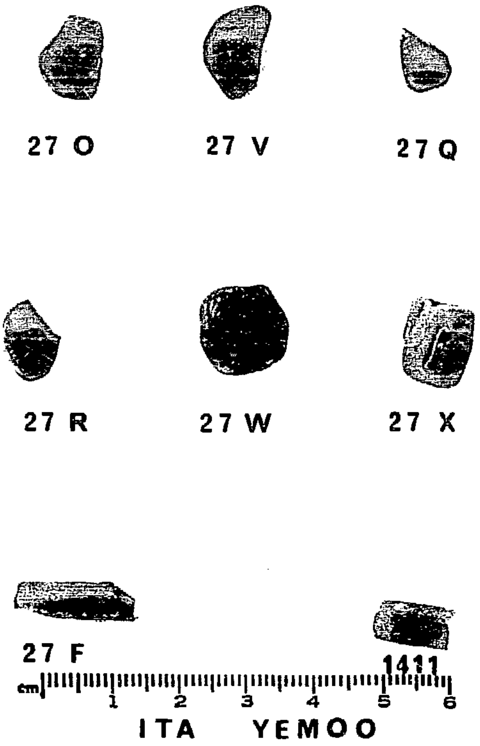

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Plate V. Beads of Ita Yemoo. Upper six are casual.
Corded at lower left, dichroic at lower right.

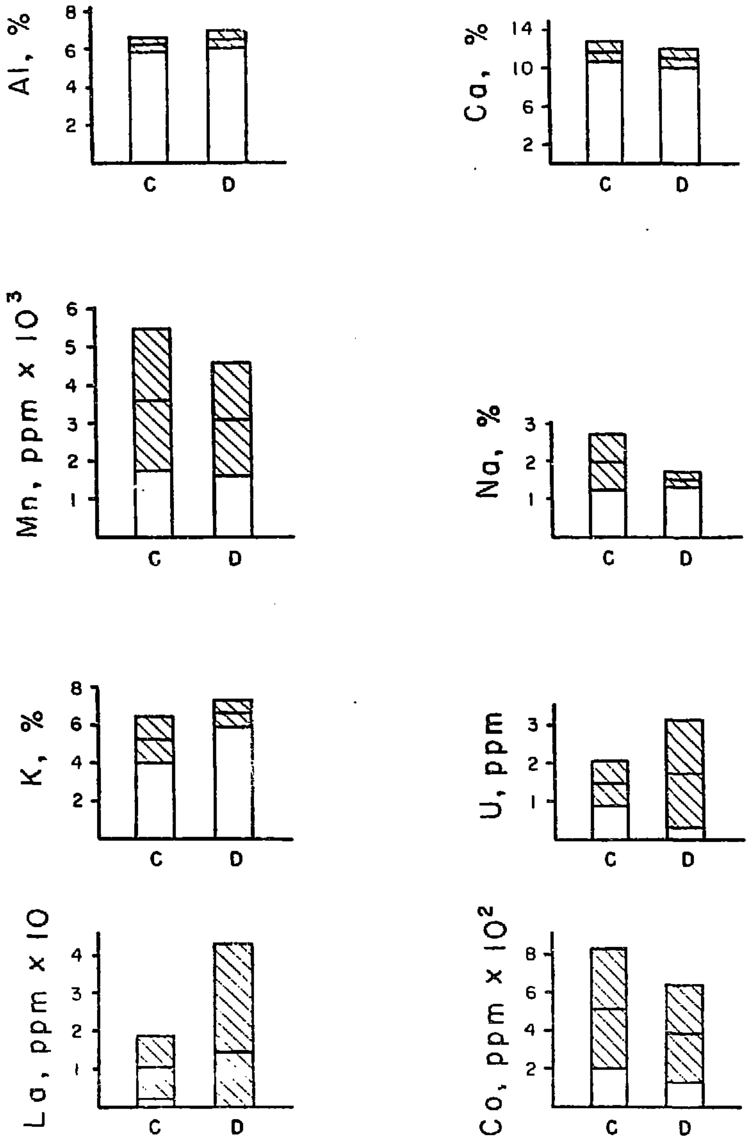

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Figure 18. Elemental concentrations in corded and dichroic beads. The shaded area is the variance.

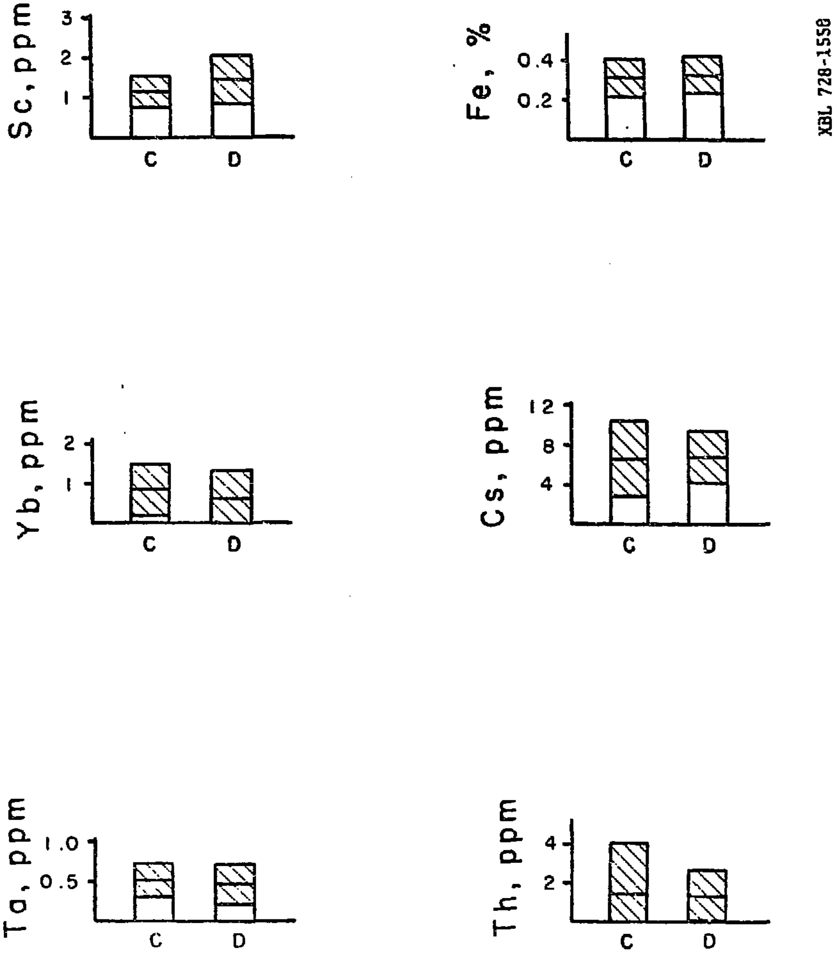


Figure 18. (continued)

chemical agreement with the others and which resemble them visually, but which were excluded from the trial groups by definition. These are: 1) ITA-27N, the bead which is both dichroic and corded; 2) ITA-1030, a bead which is only slightly turbid and seems to fall short of exhibiting dichroism; and 3) OLO-8A, not a bead, but a dichroic lump of presumed cullet. Altogether these samples form Group IA.

The dichroic effect is probably due to simple light-scattering. When an intense small beam of light is passed through a piece of this glass and the piece viewed perpendicularly to the direction of the beam, the path of the beam in the glass is visible. This visibility is made possible by light scattering. In suitable diffuse transmitted light the piece of glass will appear yellowish-green, while the path of the intense incident beam, viewed perpendicularly to the direction of the beam, appears blue. This effect may be seen in members of Group I, but it was best observed in the two dichroic glass sherds found at Ife, one of which was analyzed and found not to belong to Group I (Table 21, IFE-291). In general, these two sherds do not scatter blue light as noticeably as do the beads and cullet.

The corded effect is simply the arrangement of the glass in cords, giving the glass the appearance of a viscous stretched material, such as toffee (see Plate V, ITA-27F).

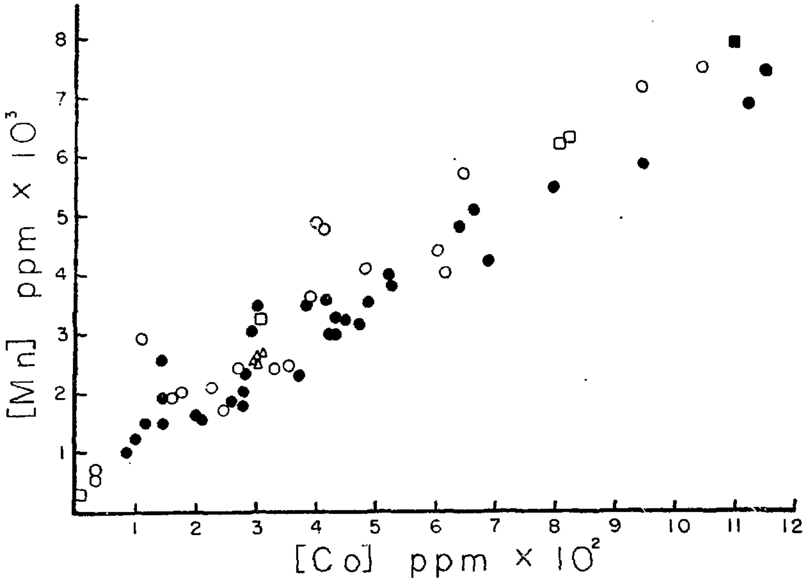
The visual difference between corded and dichroic beads could well be related to physical factors, rather than to the presence or absence of any ingredient undetected by our analyses. There are a number of effects in glass that depend on delicate balances of several factors, such as the rate of cooling. These balances are something of an art to achieve. When such effects are achieved in glass, they are said to "strike". If the dichroic effect is related simply and only to the cooling of the glass, then presumably a corded bead would appear dichroic, and vice versa, if reheated and cooled appropriately.

Manganese and Cobalt in Group I. A very persistent feature of the glasses of Group I is the preponderance of manganese over cobalt. Although the exact ratio of manganese to cobalt varies, on the average, omitting ITA-65 (see below), this ratio is about nine to one (9.3 ± 3.8). Figure 19 shows the correlation between the concentrations of these two elements in all samples of Group I. Table 19 lists the ratios individually.

This correlation can be explained by the use of an ingredient containing both manganese and cobalt in a fairly constant ratio. It seems possible that the ingredient was a deliberate additive, used for its cobalt content rather than for its manganese content. The presence of cobalt in the samples can be readily explained since most of the samples are blue, but it is difficult to state a purpose for the manganese, since none of the samples are colorless nor are any of them purple. All but five are some shade of blue, and at least a third are vivid dark cobalt blue.

There are some samples for which it is difficult to be certain what role the manganese/cobalt component plays. These include four black (extremely dark green) samples (ITA-89, ITA-27D, ITA-27C, ITA-27U) and one green sample (ITA-27T). It is conceivable that the glassmaker at one point intended these samples to be blue, but later, intentionally or not, added some ten times the usual amount of iron, causing them to be green and black.

In addition, it is difficult to be certain if the cobalt content of the glass makes a contribution to the color of the blue-green samples (for example, ITA-863, ITA-100, ITA-30B, ITA-27"O", ITA-27V, ITA-27Q, ITA-27R).



□ = Beads in Group I excluded from categories below.

■ = IGB-N3C (bead from Igbo Ukwu).

○ = Crucible linings and cullet in Group I but not in Group IA.

● = Group IA.

▷ = Blue-green casual beads.

XBL 728-1538

Figure 19. Manganese and cobalt in Ife Group I.

The color of these samples cannot be explained by copper, since no significant amount of copper is present in them.

The problem of understanding the role of the manganese/cobalt component in the dichroic samples is even more complex. Cobalt is not a necessary ingredient in blue/yellow dichroic glass (see IFE-291, GLO-1, and GLO-3 in Table 21), but one cannot dismiss the possibility that the component may have been added by glassmakers who were not aware that blue/yellow dichroic glasses could be made without it. It may be possible that the blue color of the dichroic samples is sometimes aided by the cobalt present, for the specimen ORU-183, the highest in cobalt, is a darker blue than usual in reflected light. However, the help given by cobalt seems slight and insufficient to eliminate the yellowish appearance in transmitted light.[21]

One sample appears definitely to contain none of the manganese/cobalt component. This is ITA-65, a very pale blue-green glass. ITA-27T and ITA-863 have very little, if any, of this component. These three samples show on the extreme left of Figure 19.

There is considerable variation in the individual ratios of manganese to cobalt (Table 19 and Figure 19). However, if one considers a likely

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[21] Cobalt in glass need not always effect its usual blue color. According to Weyl (1951) this color is achieved when the cobalt ion is present as a "network former" and is surrounded by four oxygen atoms. In other circumstances a cobalt-containing glass can be green, yellow, or pink. It is most probably the cobalt which gives rise to the blue color in the corded specimens, which may be specimens in which the dichroic effect did not "strike" (or vice versa).

way that these two elements may have entered the glass together, it seems unreasonable to demand that the correlation show much less scatter than it does. It was proposed above that these two elements may have entered the glass in a cobalt colorant which was abundantly "contaminated" by manganese. Such a colorant could be the substance known as wad, or asbolite. This substance is a naturally-occurring mixture frequently considered an ore of manganese. It often contains considerable cobalt, and, when it contains between 4-35% cobalt, it is given the special name asbolite and is also considered to be an ore of cobalt (see Appendix 2). Because it is a mixture, one would not expect all aliquots of wad to show a precisely consistent ratio of manganese to cobalt, and therefore one would not expect glasses colored with it to show a precisely consistent ratio of manganese to cobalt. Instead, one might expect a correlation to show considerable scatter, as does Figure 19.

Class II. Class II (Table 20) consists of soda-lime glasses that bear a general resemblance to one another. The illustrations of Figure 17 include some specimens from Class II. Class II includes crucible linings, yellow beads in a poor state of preservation, and both styles of glass bead found in the intact crucible from Ita Yemoo (Willett 1959). This class does not show any characteristic manganese/cobalt ratio. The glasses of Class II show some parallels to glasses of Igbo Ukwu. These parallels are discussed in Chapter 9.

Class III. This Class consists of specimens that had compositions not falling into Group I or Class II. It consists of miscellaneous and unique samples, and must be regarded as a very general glass grouping.

Class III (Table 21) includes three blue/yellow dichroic samples that do not belong to Group I. They are: IFE-291, one of two blue/yellow dichroic sherds found at Ife by Braunholtz, presumably surface finds, and deposited in the British Museum c. 1946; and GLO-1 and GLO-3, two chunks of glass from Glozel, a medieval glass factory site in France (Franchet 1926; Garrod 1968). These three specimens were analyzed because they were dichroic and therefore resembled the dichroic beads. However, after chemical analysis they were found not to match the latter, e.g., see differences in the concentrations of cobalt, barium, iron, and many other elements (Tables 17 and 21).

Manufacture of the Glasses Found at Ife

We cannot prove that the glasses found at Ife were or were not made of raw materials at any particular place, or even on any particular continent. However, the manufacture of the glass can be explained by reference to known areas or traditions of production. The glass is not so idiosyncratic that one would hypothesize a hitherto undiscovered manufacturing area or tradition.

Group I, in its constituents, resembles European glasses of the medieval and colonial periods. Blue/yellow dichroic glasses in particular are known in several European contexts, as discussed elsewhere (Davison, Giauque and Clark 1971). Class II consists of rather ordinary soda-lime glasses, undiagnostic of manufacture except that medieval Europe would seem an unlikely source. As noted in Chapter 2, such glasses were extensively made in ancient and modern Europe, and in ancient, medieval, and modern times in the Near East.

The manganese/cobalt component gives no useful hint about the place of manufacture of the glass of Group I or about the source of the manganese/cobalt component itself. A short discussion of cobalt colorants will be found in Appendix 2.

There is no evidence that any of the glasses found at Ife were made from raw materials in sub-Saharan West Africa. The glass shows no particular idiosyncracies which might alert one to the possibility of local manufacture. No storage lots of sand or alkali are known from archaeological investigations in West Africa. The dichroic and corded beads are cane beads, the manufacture of which requires a knowledge of the art of glassblowing, but there has been no indication that glassblowing was known in sub-Saharan West Africa. No iron blowpipe or pontil has been preserved.

It is always possible that glassmaking from raw materials and glassblowing might have existed in West Africa without leaving traces. However, at our present state of knowledge there is not sufficient reason to hypothesize the existence of a West African center of production from raw materials, for which no tangible evidence has been reported, in order to explain glasses which fit into the mainstream of production in Europe and the Near East.

If the glass was not made from raw materials in West Africa, then the remnants, including the crucible linings, may be explained as the remnants of reworking activities. In such activities, already-formed glasses would be melted down and reworked. There is considerable evidence for this sort of activity at other times and places in history, e.g., in Southeast Asia or the British Isles (Newton 1971; Charleston 1963; Lamb 1965a; Pliny, in Winbolt 1933; Hall et al. 1964; Krieger 1943; Sordinas 1965; Nadel 1942; Frobenius 1913; Brill 1970:159; Bowdich 1918; and others).

Reworking: Group I (Class I). As our crucible linings and presumed cullet show, glass was being worked at Ife. The question naturally arises whether dichroic and corded beads might be considered a product or a raw material of this activity. It seems unlikely that the dichroic and corded beads were produced at Ife, for the reason mentioned above, that these beads show evidence of glassblowing. There is, however, some evidence that the dichroic and corded beads may have formed some of the raw material of the Ife glass industry. This is the discovery of an incompletely-melted fragment of a dichroic cane bead adherent to two pieces of (cobalt blue) glass found in the Olokun Grove. All three had been melted together just enough to adhere (Plate VI). Moreover, we have seen several dichroic lumps of cullet from the Olokun Grove, although we only analyzed one.

If dichroic and corded beads, among other things, were being melted at Ife, what was being made from them? Attention is drawn to a series of rather unusual blue-green beads recovered from the excavations at Ita Yemoo (Plate V, ITA-27O, ITA-27V, ITA-27Q, ITA-27R, ITA-27W, ITA-27X). For brevity, we designate these beads as "casual". They appear to be made by a rather ad hoc combination of drawing, winding, and pressing, but not blowing.

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Plate VI. Dichroic Bead Adherent to Cullet.

Some bear applied stripes, which are not marvered in, which can be picked off with the fingernail, and which are sometimes crooked (Plates V, VII). One casual bead, ITA-27X (not analyzed) shows dichroism, and bears a stripe design like that on the analyzed specimen ITA-27Q (Plate VII). Another casual bead, ITA-27W (not analyzed) verges on dichroism. Four of the casual beads were analyzed, and all fell into Group I. Moreover the four resemble one another very strongly with respect to their ingredients. We suggest that the casual beads may represent the sort of item produced at Ife by the reworking of imported glass of Group I. Local reworking could explain the relatively elevated iron content of the casual beads, by contamination with this ubiquitous element upon reworking, perhaps from iron tools.

For the remainder of the beads in Group I, it is difficult to judge if they were more often products or raw materials. Except for ORU-82, a cane bead (Figure 17), their form is such that they could have been made without the use of glassblowing (Figure 17). Our samples were limited; further investigations may clarify this point.

<u>Reworking: Class II</u>. Class II, soda-lime glasses, shows that the evidence of reworking which has been excavated at Ita Yemoo is not restricted to potassium glasses, since the seven soda-lime glass specimens found *in situ* at Ita Yemoo include crucible linings. The Class also includes yellow beads in a poor state of preservation. Figure 17 shows examples of glasses of Class II.

Class II is too ordinary and too broadly defined to be distinctive and useful diagnostically as a chemical group. Its chief criterion of membership (a soda-lime glass) is lax enough to allow beads of widely varying

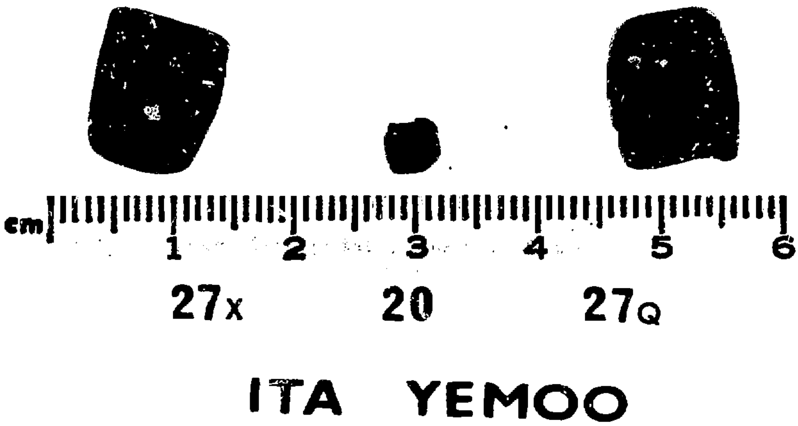

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Plate VII. Striped Beads of Ita Yemoo.
Possible import at center, "casual"
beads at sides.

manufacture to be members. For example, the class includes the bead ITA-20. This is a blue reheated cane bead with stripes of opaque white framed by red (Figure 17, Plate VII). Its manufacture and design are typical of European production from about the seventeenth century and perhaps earlier, yet it fits into the same Class with material from the tenth-to-twelfth-century site of Ita Yemoo. A considerable number (about 100) of this mass-produced bead was found in an intact crucible at Ita Yemoo, but not in archaeological context (for photograph see Willett 1959). In the same jar with the numerous beads of ITA-20 style was a similar number of beads closely resembling the bead ITA-19 (Figure 17). This bead style shows a rather casual degree of workmanship. The applied decorations are not marvered in. Although there is a large number of these beads, our sample seems individually and laboriously made. This bead which belongs to Class II may be the product of reworking of glasses having compositions like Class II. ITA-19 need not be of the same date as ITA-20, nor need they be of the same date as the other soda-lime glasses found <u>in situ</u> at Ita Yemoo or Orun Oba Ado.

Reworking: The Wider Context in West Africa

The art of reworking glass is found in several parts of sub-Saharan West Africa.

The Nupe of Northern Nigeria include among their numbers a glass-working caste. Although some small knowledge of glass manufacture from raw materials exists within this caste, the majority of Nupe glass products are made by reworking imported glass (Nadel 1942:274-278). The raw materials include bottle sherds and imported glass beads.

Besides the Nupe, other groups in West Africa rework imported glass beads into homemade objects, particularly ornaments. In 1819 the missionary Bowdich, who apparently did not believe the account, wrote that the Ashanti

> pretend that imitations [of decorated glass beads] are made in the country, which they call boiled beads, alleging that they are *broken aggry beads ground into powder*, and boiled together....
>
> (Bowdich 1819:268, emphasis ours).

Such processes of bead-making have been described from more recent observations in Ghana and Togo (Krieger 1943; Sordinas 1965).[22] The methods involve the use of molds and of powdered imported glass, including powdered imported glass beads.

The Accra Museum was recently observed (Clark 1972) to have an exhibit of such bead-making processes.

Less clear accounts of similar activities in Africa in the past appear in some historical writings (Hutton 1821:192; Gluck 1937:97).

Links With Other Sites

The Tables show that beads and cullet belonging to Group IA (dichroic and corded) are known from Ilesha, Koumbi Saleh, Gao, and Onikroga (near the Ossi River), in addition to Ita Yemoo, Orun Oba Ado, and the Olokun Grove. It has previously been indicated, on the basis of X-ray fluorescence analysis, that a corded bead recovered from the excavations at Tegdaoust may belong to the dichroic and corded group (Davison, Giauque and Clark 1971).

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[22] A few beads which may have originated in this manner were bought in the 1940's in St. Louis (Sénégal), Abidjan (Ivory Coast), and Tamale (Ghana). They are preserved in the van Riet Lowe bead collection (University of the Witwatersrand), where some are a donation of R. Mauny.

This bead did not receive neutron activation analysis and cannot be shown to belong to Group IA. The occurrence of specimens in the medieval desert entrepôts of Koumbi Saleh, Gao, and possibly Tegdaoust, is consistent with our hypothesis of medieval European manufacture and importation into West Africa, presumably via North African trade routes.

One bead from Igbo Ukwu may be considered to match Group I at Ife. This was IGB-N3C, a sample from Type N3 (Shaw 1970). It shows the manganese/cobalt ratio characteristic of Ife Group I, and its elemental concentrations fall within one standard deviation of the Group I elemental means for nine of the fourteen precisely-determined elements (Table 17). Two of those which do not fall within one standard deviation are manganese and cobalt, which do show the correlation characteristic of Group I (Figure 19). Their unusually high concentration of manganese and cobalt is the reason they do not fall within one standard deviation of agreement with the Group I means for these two elements.

Four other beads of Type N3 did not resemble Ife Group I. The data from IGB-N3C have not been included in any parameters representing Ife Group I. (The beads of Igbo Ukwu are discussed in the following chapter.)

Dating of the Industry at Ife

Stratigraphic evidence at Ife has not yet come to light which can resolve more than one period; a simplest-hypothesis rule therefore would demand only one period of glassworking be defined. As discussed below, this "single" period of glassworking could have existed as early as medieval times and persisted into the present, with recent activities centered at the Olokun Grove. Our greatest present need therefore is to be able to resolve chronological periods or breaks in the record of glassworking at Ife.

At least some of the earlier reworking appears to date to c. the tenth to twelfth centuries A.D., because remnants of glassworking, including crucible sherds from Group I and Class II, were recovered from in situ at Ita Yemoo, which is thought to have been occupied from about the tenth to twelfth centuries A.D. (see Willett 1971:366).[23] Such a dating is consistent with glass history with respect to both Group I and Class II, as discussed below. No samples of Class III came from Ita Yemoo.

Group I: Dating Considerations. The glass of Group I is a potassium glass. As stated in Chapter 2, such glasses are associated chiefly with medieval Europe.[24] The onset of production of this sort of glass in Europe is not clear, but informed estimates place the beginning in about the ninth to tenth centuries A.D. (Geilmann 1955:150; Chambon 1958:100; Turner 1956c:288T). Potassium glasses remained in use until the centuries after the Renaissance, when it gradually ceased to be used for high quality products generally, and to be restricted to certain luxury types of glass. However, it continued to be used for utilitarian objects, such as bottles,

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[23] Two radiocarbon dates from below the decorative potsherd pavement gave the results 960 ± 130 A.D. (BM-261) and 1160 ± 130 A.D. (BM-259). Two radiocarbon dates from above the pavement gave the results 1060 ± 130 A.D. (BM-262) and 1150 ± 200 A.D. (M-2119).

[24] Potassium glasses are usually associated with Christian rather than Muslim Europe, although no rigorous survey has established this association. There is no problem in visualizing Christian-made glasses reaching Muslim traders in North Africa. As Bovill wrote (1958:111) of the medieval period, "Christian shipping lay in every port from Tripoli to Agadir...."

well into the colonial period (see Honey 1946). This fact should be kept in mind when dealing with glasses reworked in West Africa. Without the radiocarbon dates from Ife or the specimen from Koumbi Saleh, the glass of Group I could be considered recent.

As stated above, the radiocarbon dates from Ita Yemoo date at least some of the reworking at Ife to about the tenth to twelfth centuries A.D. Some evidence that Group I might have actually been in manufacture slightly earlier, such as the ninth century, is provided by the radiocarbon dates from Orun Oba Ado, where four beads belonging to Group I were recovered. ORU-17 came from Pit 3, which yielded a radiocarbon date of 800 ± 120 A.D. (M-2114); ORU-207 and ORU-82 came from Pit 5, which yielded the same date (800 ± 120 A.D., M-2115), and ORU-179a came from Pit 11, which yielded a date of 560 ± 130 A.D. (BM-265). The ninth century dates seem confirmed by two approximately tenth century radiocarbon dates from Pit 6 at the same site, 940 ± 150 A.D. (M-2116) and 990 ± 130 A.D. (BM-264) (see Willett 1971). The approximately sixth century date is an isolated determination, unconfirmed elsewhere at similar sites in Nigeria, nor would it readily be acceptable to glass historians for a glass of the composition of Group I.

The medieval dating of Group I is supported by other documentary and archaeological evidence independent of Ife and of Yoruba history. As already noted, a dichroic bead of Group I came from the excavations of Koumbi Saleh, a site identified as the capital of medieval Ghana and an important desert entrepôt known from documentary sources to have existed in the tenth century (Mauny 1961, Bovill 1958), and to have been destroyed *c.* 1240 A.D. (Davidson 1959:89). This site has yielded a radiocarbon date commensurate with this period, 1210 ± 120 A.D. (Sa-77, Fagan 1965).

It thus seems possible that Group I beads were made in medieval Europe, perhaps as early as *c.* the ninth to tenth centuries A.D., and then traded across the Sahara to present-day Nigeria. The reworking of Group I beads may have been carried out at any time(s) after the glass appeared in West Africa. It seems clear from the evidence at Ita Yemoo that at least some of the reworking of Group I glass may have been carried out in the tenth to twelfth centuries, or, soon after importation.

Class II: Dating Considerations. The occurrence of samples belonging to Class II *in situ* at Ita Yemoo shows that some soda-lime glasses as well were being reworked by about the tenth to twelfth centuries A.D. One cannot estimate the date and place of manufacture of these glasses closely at all, except to say that they probably post-date the fourth to fifth century A.D. (see below). Class II is too broadly defined to permit the conclusion that its members share a specific common origin. A medieval Islamic or post-Renaissance European origin would both be reasonable; indeed Class II may contain samples of both.

It is the use of tin as an opacifier which indicates that all members of Class II post-date the fourth to fifth centuries A.D. Before this time, antimony was the usual opacifier in use (Sayre 1963, 1964). After this time, it went out of use until the seventeenth to eighteenth centuries A.D., when it reappeared (Turner and Rooksby 1962, Kunckel 1679). During the centuries that it was out of use, it was presumably replaced by tin. The use of tin did not disappear when antimony reappeared, and for modern glasses (seventeenth century and later) either opacifier may be encountered.

Class III: Dating Considerations. Class III cannot be used to date the glassworking industry at Ife with any more precision than Class II. It is an exceedingly general class of miscellany that were analyzed during the research. Only three of its nine members came from Ife, and of these only one piece, a fragment from the Olokun Grove (OLO-2), appears to be a remnant from glassworking. However, glass found in the Olokun Grove may be the results of recent manufacture and/or reworking, and of little aid in establishing dates. The remaining two pieces from Ife were sherds, one from the Olokun Grove (OLO-8e), and one from the surface generally (IFE-291). No samples of Class III came from Ita Yemoo.

A Possible Interpretation

Ife holds a special place among Yoruba towns, for it symbolizes Yoruba origins, sometime in the medieval period. A medieval date is concordant with radiocarbon dates obtained in excavations at Ita Yemoo and Orun Oba Ado, with oral traditions from Benin, and with glass history. The importance of Ife in Yoruba history is attested by its role in traditions, as previously pointed out. Although the traditions differ, they share in common the indication that Ife was important "in the beginning".

The glass of Group I, quite likely medieval European in manufacture, may have been obtained as beads by these earliest Yoruba, and may have been buried in burials, compounds, or shrines at the ancestral site of Yoruba settlement, Ife, to be later rediscovered once or many times. This glass may have been, or may have come to be, symbolic of, or even a monopoly of, royalty. Some such situation would be consistent with the place of beads in royal regalia (compare Igbo Ukwu, Chapter 9). Local glassworkers of medieval and later periods may have exploited these medieval glasses, perhaps along with other glasses contemporary with themselves. Glasses belonging to Class II and Class III (OLO-2, Table 21) were involved in the reworking activity.

From time to time, the items involved in the glassworking activity may have been placed in shrines, perhaps because the fragments were mysterious. In the shrines the glass pieces may have accompanied other artifacts of varying ages, as is the case with present-day shrines.

Glass reworking which is carried out today, usually involving specimens from the Olokun Grove, is not reported to involve melting of the glass (Fagg and Willett 1962), but simply drilling. It is not known whether the present-day craftsmen are the direct heirs of a glassworking tradition which once contained, but has now lost, the knowledge of melting, or whether they know how to melt but prefer not to, or whether their activities are unrelated to those evidenced in the archaeological record at Ife.

Summary

The archaeological remains of the Ife glass industry are here interpreted as evidence of a reworking activity. At least some of the glass itself appears to have originated in medieval Europe, perhaps as early as the ninth to tenth centuries A.D., as is indicated by radiocarbon dates from Orun Oba Ado, where artifacts of the glass were included in ritual burials.

Reworking may have been carried out at different periods which are now blurred in the stratigraphic record. The presence of crucible linings _in situ_ at Ita Yemoo indicates that at least some of the reworking was carried out during or by the tenth to twelfth centuries A.D., the period to which occupation of this site is dated. Such a medieval date is consistent with the compositions of all our samples found _in situ_ at Ita Yemoo.

Table 17a. Ife Group I: Neutron Activation Analysis[a,b]

Sample	Description	Color
ITA-30C	bead, cane, corded	cobalt blue
ITA-27I	"	"
ORU-207	"	"
ITA-30D	"	"
ITA-27K	"	"
ITA-27E	"	"
ITA-27G	"	"
ITA-27B	"	"
ITA-27F	"	"
ITA-27H	"	"
ITA-1442	"	"
ORU-33	"	"
ITA-920	bead, cane	dichroic
OLD-27	"	"
ILE-233A	"	"
ITA-27A	"	"
ORU-17	"	"
ORU-179A	"	"
ITA-27J	"	"
ITA-855	"	"
ITA-1411	"	"
KOU-1	"	"
ITA-27L	"	"
GAO-1	"	"
ITA-27M	"	"
OSS-1	"	"
ITA-94B	"	"
ITA-94C	"	"
ORU-183	"	"
ITA-27N	" , corded	"
ITA-1030	" , turbid	cobalt blue
OLO-8A	cullet	dichroic

Table 17a. continued

Sample	Description	Color
ITA-27"O"	casual barrel	blue-green
ITA-27V	" bicone	"
ITA-27Q	" barrel, with stripe	"
ITA-27R	" bicone	"
ITA-863	crucible lining	"
ITA-30B	cullet	"
ITA-100	crucible lining	"
ITA-30A	"	cobalt blue
ITA-1386	"	"
ITA-94A	cullet	"
ITA-27A	"	"
ITA-27B	"	"
ITA-1035	crucible lining	"
OLO-8B	cullet	"
OLO-8C	"	"
OLO-8D	"	"
OLO-3	crucible lining	"
OLO-1B	cullet	"
OLO-337	crucible lining	"
ITA-65	bead, short cylinder	blue-green
ITA-27P	bead, fragment	cobalt blue
ORU-82	bead, cane long cylinder, with four Indian red stripes	"
ITA-27U	bead, barrel	black (dark green)
ITA-89	crucible lining	" "
ITA-27D	cullet	" "
ITA-27C	"	" "
ITA-27T	" , corded	green

Table 17a. continued

Sample	Color	Al (%)	Ca (%)	Cu (%)
-30C	co bl.	6.15 ± 0.23	11.01 ± 0.69	b
-27I	"	6.70 ± 0.21	11.25 ± 0.73	b
-207	"	n.d.[d]	10.16 ± 0.54	b
-30D	"	6.17 ± 0.21	14.04 ± 0.86	b
-27K	"	5.88 ± 0.15	9.94 ± 0.75	b
-27E	"	6.10 ± 0.27	11.98 ± 0.91	b
-27G	"	6.63 ± 0.16	12.65 ± 0.82	b
-27B	"	6.18 ± 0.13	11.98 ± 0.77	b
-27F	"	5.37 ± 0.28	12.31 ± 1.19	b
-27H	"	6.57 ± 0.20	11.95 ± 1.00	b
-1442	"	6.63 ± 0.17	11.70 ± 1.07	b
-33	"	6.06 ± 0.28	11.48 ± 1.49	b
-920	dich.	5.91 ± 0.09	9.31 ± 0.59	b
-27	"	n.d.	10.98 ± 0.57	b
-233A	"	6.41 ± 0.17	8.87 ± 0.73	b
-27A	"	6.19 ± 0.10	12.36 ± 0.66	b
-17	"	n.d.	9.68 ± 0.64	b
-179A	"	6.51 ± 0.15	12.07 ± 0.66	b
-27J	"	6.03 ± 0.17	12.55 ± 0.78	b
-855	"	6.24 ± 0.20	11.23 ± 0.80	b
-1411	"	6.82 ± 0.14	11.33 ± 0.60	b
-1	"	6.48 ± 0.13	9.89 ± 0.78	b
-27L	"	6.71 ± 0.20	11.41 ± 0.82	b
-1	"	5.56 ± 0.12	10.90 ± 0.79	b
-27M	"	7.09 ± 0.18	12.81 ± 0.80	b
-1	"	6.58 ± 0.29	11.47 ± 0.56	b
-94B	"	6.77 ± 0.29	11.53 ± 1.04	b
-94C	"	6.86 ± 0.45	11.73 ± 1.25	b
-183	"	7.53 ± 2.12	10.61 ± 0.88	b
-27N	"	6.19 ± 0.30	12.54 ± 0.77	b
-1030	"	6.51 ± 0.13	12.35 ± 1.00	b
-8A	"	6.53 ± 0.22	10.64 ± 0.82	b

Table 17a. continued

Sample	Color	Al (%)	Ca (%)	Cu (%)
-27"O"	bl-gr.	6.82 ± 0.29	10.88 ± 0.88	b
-27V	"	6.61 ± 0.16	9.51 ± 0.71	b
-27Q	"	6.07 ± 0.17	9.15 ± 0.75	b
-27R	"	6.60 ± 0.18	9.96 ± 0.73	b
-863	"	6.98 ± 0.15	11.08 ± 0.66	b
-30B	"	7.05 ± 0.18	11.68 ± 0.75	b
-100	"	5.85 ± 0.13	9.98 ± 0.64	b
-30A	co bl.	6.61 ± 0.22	10.18 ± 0.82	b
-1386	"	4.62 ± 0.69	11.13 ± 0.71	b
-94A	"	6.69 ± 0.18	11.20 ± 0.80	b
-27A	"	7.13 ± 0.16	11.85 ± 0.75	b
-27B	"	6.79 ± 0.15	10.89 ± 0.86	b
-1035	"	6.13 ± 2.08	11.86 ± 1.15	b
-8B	"	7.04 ± 0.37	10.76 ± 0.87	b
-8C	"	5.59 ± 0.27	11.64 ± 1.00	b
-8D	"	6.26 ± 0.36	12.10 ± 1.19	b
-3	"	6.72 ± 0.38	11.72 ± 1.24	b
-1B	"	n.d.	10.87 ± 2.45	b
-337	"	6.18 ± 0.63	7.36 ± 1.52	b
-65	bl-gr.	8.95 ± 0.23	9.99 ± 0.89	b
-27P	co bl.	5.40 ±0.49	10.90 ± 1.29	b
-82	"	7.58 ± 4.51	9.90 ± 1.60	b
-27U	black	6.25 ±0.13	10.56 ± 0.77	b
-89	"	6.12 ±0.25	8.56 ± 0.93	b
-27D	"	6.33 ±0.38	10.46 ± 1.10	b
-27C	"	6.32 ±0.17	9.47 ± 0.91	b
-27T	green	7.04 ±0.20	7.23 ± 0.81	0.021 0.007
Mean and RMSD[a]		6.46 ±0.63	10.94 ± 1.28	b

Table 17a. continued

Sample	Color	Mn	Na (%)	K (%)
-30C	co bl.	1,493 ± 22	1.72 ± 0.03	6.28 ± 0.71
-27I	"	1,604 ± 24	1.27 ± 0.02	6.00 ± 0.61
-207	"	1,773 ± 51	1.26 ± 0.03	4.88 ± 1.03
-30D	"	2,310 ± 46	1.53 ± 0.03	5.84 ± 0.73
-27K	"	3,023 ± 43	1.43 ± 0.03	5.34 ± 0.78
-27E	"	2,995 ± 59	1.50 ± 0.03	5.78 ± 0.77
-27G	"	3,516 ± 59	2.04 ± 0.04	5.62 ± 0.89
-27B	"	3,825 ± 110	1.51 ± 0.04	6.01 ± 1.13
-27F	"	4,235 ± 60	3.36 ± 0.04	3.06 ± 0.81
-27H	"	5,486 ± 107	2.45 ± 0.04	4.02 ± 0.95
-1442	"	5,841 ± 81	2.49 ± 0.04	6.61 ± 0.93
-33	"	7,471 ± 132	3.20 ± 0.07	3.16 ± 1.46
-920	dich.	1,213 ± 35	1.33 ± 0.03	6.84 ± 1.01
-27	"	1,493 ± 43	1.61 ± 0.03	6.79 ± 1.04
-233A	"	2,577 ± 62	1.55 ± 0.04	7.43 ± 1.11
-27A	"	1,981 ± 58	1.65 ± 0.04	5.80 ± 0.99
-17	"	1,567 ± 44	1.57 ± 0.03	5.60 ± 1.02
-179A	"	1,852 ± 103	1.47 ± 0.03	6.43 ± 0.57
-27J	"	2,013 ± 31	1.64 ± 0.03	5.19 ± 0.64
-855	"	3,457 ± 100	1.30 ± 0.03	6.35 ± 1.15
-1411	"	3,479 ± 97	1.71 ± 0.04	5.84 ± 1.09
-1	"	3,566 ± 58	1.56 ± 0.03	7.74 ± 0.73
-27L	"	2,994 ± 51	1.35 ± 0.03	6.11 ± 0.81
-1	"	3,266 ± 54	1.40 ± 0.03	6.79 ± 0.75
-27M	"	3,209 ± 54	1.00 ± 0.03	7.16 ± 0.88
-1	"	3,155 ± 55	1.50 ± 0.03	7.34 ± 0.75
-94B	"	4,808 ± 81	1.55 ± 0.03	6.65 ± 0.93
-94C	"	5,051 ± 86	1.94 ± 0.04	7.33 ± 1.03
-183	"	6,895 ± 115	1.77 ± 0.03	7.06 ± 0.87
-27N	"	988 ± 15	1.79 ± 0.03	3.89 ± 0.57
-1030	co bl.	3,977 ± 69	3.12 ± 0.05	2.21 ± 0.88
-8A	dich.	2,294 ± 41	1.51 ± 0.03	5.54 ± 0.73

Table 17a. continued

Sample	Color	Mn	Na (%)	K (%)
-27"O"	bl-gr.	2,496 ± 36	1.64 ± 0.03	5.36 ± 0.76
-27V	"	2,606 ± 36	1.71 ± 0.03	6.70 ± 0.78
-27Q	"	2,501 ± 36	1.59 ± 0.03	5.70 ± 0.74
-27R	"	2,656 ± 37	1.71 ± 0.03	4.71 ± 0.68
-863	"	501 ± 10	3.09 ± 0.04	3.57 ± 0.52
-30B	"	2,921 ± 53	1.51 ± 0.03	7.28 ± 0.77
-100	"	1,990 ± 29	1.50 ± 0.03	6.41 ± 0.73
-30A	co bl.	2,098 ± 39	1.62 ± 0.03	6.82 ± 0.70
-1386	"	1,711 ± 26	1.83 ± 0.02	5.50 ± 0.49
-94A	"	2,403 ± 44	1.43 ± 0.03	6.07 ± 0.69
-27A	"	2,460 ± 45	1.40 ± 0.03	6.07 ± 0.71
-27B	"	4,097 ± 74	2.20 ± 0.04	4.58 ± 0.81
-1035	"	5,693 ± 94	2.54 ± 0.04	4.42 ± 0.85
-8B	"	1,958 ± 29	1.27 ± 0.02	6.31 ± 0.65
-8C	"	2,416 ± 35	3.27 ± 0.04	0.61 ± 0.56
-8D	"	4,033 ± 71	3.39 ± 0.06	1.45 ± 0.76
-3	"	4,387 ± 86	3.07 ± 0.05	5.92 ± 0.88
-1B	"	7,156 ±119	3.49 ± 0.04	1.76 ± 0.95
-337	"	7,498 ±147	3.11 ± 0.05	2.66 ± 0.90
-65	bl gr.	280 ± 9	5.50 ± 0.06	2.92 ± 0.54
-27P	co bl.	6,227 ± 87	1.09 ± 0.03	7.06 ± 0.96
-82	"	6,338 ±105	2.67 ± 0.04	3.97 ± 0.82
-27U	black	3,235 ± 56	1.82 ± 0.03	4.49 ± 0.67
-89	"	3,589 ± 53	2.09 ± 0.03	4.08 ± 0.71
-27D	"	4,802 ± 68	1.74 ± 0.03	4.16 ± 0.71
-27C	"	4,778 ± 82	1.80 ± 0.03	4.21 ± 0.75
-27T	green	730 ± 16	3.44 ± 0.05	5.89 ± 0.60
Mean and RMSD		3,305 ± 1,762	1.99 ± 0.83	5.35 ± 1.63

Table 17a. continued

Sample	Color	U	La
-30C	co bl.	1.66 ± 0.02	4.05 ± 0.37
-27I	"	0.98 ± 0.02	6.43 ± 0.40
-207	"	2.51 ± 0.12	4.58 ± 0.18
-30D	"	1.32 ± 0.04	9.90 ± 0.78
-27K	"	0.76 ± 0.02	4.24 ± 0.38
-27E	"	1.12 ± 0.04	3.52 ± 0.77
-27G	"	1.23 ± 0.04	3.91 ± 0.82
-27B	"	2.57 ± 0.11	12.24 ± 0.22
-27F	"	1.80 ± 0.03	12.04 ± 0.54
-27H	"	1.61 ± 0.05	30.65 ± 1.23
-1442	"	1.25 ± 0.03	21.31 ± 0.70
-33	"	0.87 ± 0.04	13.66 ± 0.81
-920	dich.	0.03 ± 0.03	2.84 ± 0.07
-27	"	2.91 ± 0.12	3.18 ± 0.20
-233A	"	0.98 ± 0.08	4.32 ± 0.19
-27A	"	2.65 ± 0.09	7.33 ± 0.20
-17	"	5.28 ± 0.16	12.85 ± 0.28
-179A	"	4.62 ± 0.20	7.80 ± 0.22
-27J	"	2.29 ± 0.03	4.49 ± 0.44
-855	"	0.72 ± 0.08	6.26 ± 0.18
-1411	"	1.51 ± 0.08	4.40 ± 0.18
-1	"	1.02 ± 0.04	4.76 ± 0.80
-27L	"	0.96 ± 0.04	10.42 ± 0.86
-1	"	1.12 ± 0.04	6.81 ± 0.87
-27M	"	0.96 ± 0.04	17.70 ± 0.94
-1	"	0.79 ± 0.02	11.31 ± 0.37
-94B	"	0.86 ± 0.04	6.60 ± 0.96
-94C	"	1.19 ± 0.05	10.46 ± 1.10
-183	"	1.60 ± 0.03	124.25 ± 1.14
-27N	"	1.76 ± 0.02	3.19 ± 0.36
-1030	co bl.	0.64 ± 0.05	4.71 ± 1.12
-8A	dich.	1.16 ± 0.02	2.66 ± 0.38

Table 17a. continued

Sample	Color	U	La
-27"O"	bl-gr.	1.20 ± 0.03	11.96 ± 0.49
-27V	"	1.22 ± 0.03	10.98 ± 0.53
-27Q	"	1.19 ± 0.03	12.58 ± 0.50
-27R	"	1.19 ± 0.03	12.01 ± 0.51
-863	"	0.97 ± 0.02	5.97 ± 0.44
-30B	"	0.89 ± 0.03	2.79 ± 0.60
-100	"	1.22 ± 0.02	3.92 ± 0.36
-30A	co bl.	0.98 ± 0.03	3.22 ± 0.62
-1386	"	0.81 ± 0.01	5.45 ± 0.29
-94[illegible]	"	1.26 ± 0.03	3.67 ± 0.65
-27A	"	1.02 ± 0.04	12.75 ± 0.77
-27B	"	1.25 ± 0.04	16.52 ± 0.91
-1035	"	2.32 ± 0.02	14.87 ± 0.43
-8B	"	0.87 ± 0.02	2.57 ± 0.35
-8C	"	0.72 ± 0.02	9.46 ± 0.48
-8D	"	1.21 ± 0.03	33.89 ± 0.69
-3	"	1.39 ± 0.06	77.74 ± 1.66
-1B	"	1.26 ± 0.02	8.15 ± 0.44
-337	"	2.08 ± 0.06	14.70 ± 1.19
-65	bl-gr.	1.85 ± 0.03	4.56 ± 0.53
-27P	co bl.	0.73 ± 0.02	24.27 ± 0.55
-82	"	1.14 ± 0.02	19.05 ± 0.49
-27U	black	1.42 ± 0.05	22.23 ± 1.10
-89	"	1.52 ± 0.03	23.87 ± 0.69
-27D	"	1.30 ± 0.03	17.42 ± 0.58
-27C	"	1.33 ± 0.05	17.10 ± 1.09
-27T	green	1.14 ± 0.04	9.58 ± 0.87
Mean and RMSD		1.43 ± 0.86	13.29 ±18.55

Table 17a. continued

Sample	Color	Co	Sc
-30C	co bl.	145.77 ± 1.17	0.69 ± 0.02
-27I	"	203.45 ± 1.58	0.75 ± 0.03
-207	"	276.25 ± 1.61	1.27 ± 0.03
-30D	"	282.14 ± 2.88	1.28 ± 0.04
-27K	"	291.45 ± 2.22	0.72 ± 0.03
-27E	"	423.60 ± 4.26	1.12 ± 0.04
-27G	"	484.63 ± 5.21	0.98 ± 0.05
-27B	"	526.44 ± 2.99	1.10 ± 0.04
-27F	"	686.89 ± 5.03	1.12 ± 0.05
-27H	"	800.03 ± 7.95	1.83 ± 0.07
-1442	"	944.83 ± 6.78	1.23 ± 0.07
-33	"	1,152.10 ± 9.87	1.96 ± 0.10
-920	dich.	101.98 ± 0.64	0.88 ± 0.01
-27	"	116.00 ± 0.73	0.83 ± 0.02
-233A	"	141.29 ± 0.99	1.41 ± 0.02
-27A	"	145.50 ± 0.86	0.94 ± 0.01
-17	"	208.13 ± 1.45	1.02 ± 0.02
-179A	"	257.18 ± 1.67	1.36 ± 0.03
-27J	"	278.14 ± 2.11	3.14 ± 0.04
-855	"	300.70 ± 1.74	1.37 ± 0.03
-1411	"	384.18 ± 2.57	2.27 ± 0.03
-1	"	415.63 ± 3.61	1.41 ± 0.05
-27L	"	430.07 ± 4.66	1.08 ± 0.05
-1	"	434.70 ± 3.86	1.30 ± 0.06
-27M	"	444.82 ± 4.78	1.53 ± 0.04
-1	"	472.98 ± 4.23	1.58 ± 0.05
-94B	"	642.44 ± 6.88	1.55 ± 0.06
-94C	"	668.62 ± 7.18	1.16 ± 0.06
-183	"	1,125.10 ± 9.42	2.50 ± 0.09
-27N	"	86.60 ± 0.76	0.79 ± 0.02
-1030	"	526.79 ± 5.71	1.30 ± 0.06
-8A	"	372.59 ± 3.23	1.33 ± 0.04

Table 17a. continued

Sample	Color	Co	Sc
-27"O"	bl-gr.	295.15 ± 2.23	1.66 ± 0.03
-27V	"	297.77 ± 2.24	1.56 ± 0.03
-27Q	"	300.43 ± 2.25	1.57 ± 0.03
-27R	"	305.89 ± 2.30	1.65 ± 0.03
-863	"	31.55 ± 0.35	0.47 ± 0.01
-30B	"	110.73 ± 1.17	1.24 ± 0.02
-100	"	166.09 ± 1.31	1.16 ± 0.02
-30A	co bl.	226.59 ± 2.29	0.63 ± 0.03
-1386	"	243.74 ± 2.09	1.43 ± 0.03
-94A	"	267.09 ± 2.71	1.07 ± 0.04
-27A	"	353.99 ± 3.55	0.91 ± 0.05
-27B	"	483.67 ± 4.84	2.11 ± 0.07
-1035	"	644.48 ± 5.43	2.12 ± 0.06
-8B	"	157.60 ± 1.24	1.02 ± 0.02
-8C	"	327.15 ± 2.41	0.76 ± 0.03
-8D	"	620.42 ± 5.31	1.45 ± 0.05
-3	"	597.10 ± 5.92	2.42 ± 0.06
-1B	"	945.10 ± 7.90	1.73 ± 0.08
-337	"	1,054.50 ± 10.42	2.77 ± 0.13
-65	bl-gr.	1.89 ± 0.07	0.89 ± 0.01
-27P	co bl.	805.21 ± 5.93	2.20 ± 0.06
-82	"	823.16 ± 6.89	1.84 ± 0.07
-27U	black	307.59 ± 3.35	5.19 ± 0.05
-8J	"	389.21 ± 2.88	6.75 ± 0.05
-27D	"	402.35 ± 2.98	4.48 ± 0.05
-27C	"	405.68 ± 4.38	4.40 ± 0.05
-27T	green	33.77 ± 0.43	1.97 ± 0.02
Mean and RMSD		413.03 ±275.52	1.67 ± 1.13

Table 17a. continued

Sample	Color	Fe (%)	Yb	Cs
-30C	co bl.	0.22 ± 0.01	0.63 ± 0.05	6.20 ± 0.20
-27I	"	0.25 ± 0.02	0.55 ± 0.07	10.30 ± 0.30
-207	"	0.48 ± 0.02	0.52 ± 0.06	1.10 ± 0.20
-30D	"	0.37 ± 0.02	0.94 ± 0.10	8.20 ± 0.30
-27K	"	0.21 ± 0.02	0.70 ± 0.07	14.80 ± 0.30
-27E	"	0.28 ± 0.03	0.62 ± 0.12	9.50 ± 0.40
-27G	"	0.34 ± 0.03	0.65 ± 0.12	6.70 ± 0.40
-27B	"	0.30 ± 0.02	0.85 ± 0.08	7.60 ± 0.30
-27F	"	0.19 ± 0.03	1.72 ± 0.09	2.40 ± 0.40
-27H	"	0.45 ± 0.04	1.27 ± 0.17	4.40 ± 0.60
-1442	"	0.29 ± 0.04	2.27 ± 0.14	4.00 ± 0.60
-33	"	0.43 ± 0.06	-0.24 ± 0.21	5.10 ± 0.80
-920	dich.	0.30 ± 0.01	0.43 ± 0.04	7.30 ± 0.10
-27	"	0.22 ± 0.01	0.42 ± 0.04	4.50 ± 0.10
-233A	"	0.28 ± 0.01	0.38 ± 0.05	5.60 ± 0.20
-27A	"	0.32 ± 0.01	0.82 ± 0.04	8.00 ± 0.10
-17	"	0.35 ± 0.01	0.33 ± 0.07	2.50 ± 0.20
-179A	"	0.44 ± 0.02	0.46 ± 0.06	3.60 ± 0.20
-27J	"	0.29 ± 0.02	1.63 ± 0.09	3.70 ± 0.30
-855	"	0.40 ± 0.02	-0.12 ± 0.06	3.50 ± 0.20
-1411	"	0.60 ± 0.02	0.60 ± 0.08	10.00 ± 0.30
-1	"	0.30 ± 0.03	0.07 ± 0.14	9.00 ± 0.40
-27L	"	0.26 ± 0.03	0.68 ± 0.13	10.40 ± 0.40
-1	"	0.31 ± 0.04	-0.05 ± 0.17	8.60 ± 0.50
-27M	"	0.26 ± 0.03	1.52 ± 0.13	9.70 ± 0.40
-1	"	0.47 ± 0.03	0.14 ± 0.10	5.30 ± 0.40
-94B	"	0.31 ± 0.04	0.35 ± 0.13	8.60 ± 0.50
-94C	"	0.29 ± 0.04	0.78 ± 0.16	9.10 ± 0.50
-183	"	0.29 ± 0.05	2.67 ± 0.18	7.70 ± 0.70
-27N	"	0.34 ± 0.01	0.48 ± 0.05	7.30 ± 0.20
-1030	co bl.	0.22 ± 0.04	0.55 ± 0.15	2.20 ± 0.40
-8A	dich.	0.33 ± 0.02	-0.04 ± 0.09	8.80 ± 0.30

Table 17a. continued

Sample	Color	Fe (%)	Yb	Cs
-27"O"	bl-gr.	1.35 ± 0.02	0.95 ± 0.08	8.50 ± 0.30
-27V	"	1.39 ± 0.03	1.09 ± 0.09	8.10 ± 0.30
-27Q	"	1.45 ± 0.02	0.90 ± 0.07	8.30 ± 0.30
-27R	"	1.54 ± 0.03	0.94 ± 0.09	8.20 ± 0.30
-863	"	0.20 ± 0.01	0.58 ± 0.04	2.20 ± 0.10
-30B	"	0.31 ± 0.01	0.47 ± 0.06	4.60 ± 0.20
-100	"	0.29 ± 0.01	0.45 ± 0.06	8.40 ± 0.20
-30A	co bl.	0.16 ± 0.02	0.34 ± 0.07	8.50 ± 0.30
-1386	"	0.41 ± 0.02	0.42 ± 0.07	3.30 ± 0.20
-94A	"	0.24 ± 0.04	0.43 ± 0.21	8.40 ± 0.30
-27A	"	0.12 ± 0.04	0.76 ± 0.22	10.10 ± 0.40
-27B	"	1.00 ± 0.06	1.19 ± 0.30	10.80 ± 0.50
-1035	"	0.57 ± 0.03	2.75 ± 0.13	14.50 ± 0.50
-8B	"	0.23 ± 0.01	0.42 ± 0.06	4.00 ± 0.20
-8C	"	0.20 ± 0.02	0.50 ± 0.07	2.70 ± 0.30
-8D	"	0.29 ± 0.03	0.34 ± 0.11	2.10 ± 0.40
-3	"	0.22 ± 0.04	7.87 ± 0.29	5.20 ± 0.40
-1B	"	0.39 ± 0.04	1.12 ± 0.13	5.10 ± 0.60
-337	"	0.48 ± 0.10	1.78 ± 0.46	14.80 ± 0.80
-65	bl-gr.	0.59 ± 0.01	0.59 ± 0.04	4.00 ± 0.10
-27P	co bl.	0.35 ± 0.03	1.96 ± 0.12	3.10 ± 0.50
-82	"	0.42 ± 0.04	0.39 ± 0.12	17.50 ± 0.60
-27U	black	5.09 ± 0.08	1.65 ± 0.14	6.40 ± 0.30
-89	"	4.94 ± 0.05	2.08 ± 0.11	5.00 ± 0.40
-27D	"	4.71 ± 0.05	1.58 ± 0.12	6.80 ± 0.40
-27C	"	4.85 ± 0.08	1.25 ± 0.14	7.30 ± 0.40
-27T	green	2.46 ± 0.04	0.72 ± 0.07	10.30 ± 0.30
Mean and RMSD		0.34 ± 0.14[f] 1.43 ± 0.83[g] 4.41 ± 1.10[h]	0.95 ± 1.13	7.02 ± 3.46

Table 17a. continued

Sample	Color	Ta	Th
-30C	co bl.	0.46 ± 0.00	0.67 ± 0.04
-27I	"	0.84 ± 0.01	0.60 ± 0.05
-207	"	0.58 ± 0.01	9.90 ± 1.11
-30D	"	0.72 ± 0.01	0.42 ± 0.09
-27K	"	0.57 ± 0.01	0.44 ± 0.06
-27E	"	0.54 ± 0.01	0.66 ± 0.11
-27G	"	0.83 ± 0.01	0.46 ± 0.11
-27B	"	0.31 ± 0.01	0.48 ± 2.05
-27F	"	0.23 ± 0.01	1.30 ± 0.10
-27H	"	0.30 ± 0.01	0.84 ± 0.17
-1442	"	0.33 ± 0.01	1.02 ± 0.14
-33	"	0.66 ± 0.01	0.88 ± 0.20
-920	dich.	0.25 ± 0.00	0.62 ± 0.39
-27	"	0.37 ± 0.00	0.50 ± 0.46
-233A	"	0.70 ± 0.00	1.13 ± 0.61
-27A	"	0.65 ± 0.00	0.71 ± 0.56
-17	"	0.19 ± 0.00	0.31 ± 0.91
-179A	"	0.44 ± 0.00	1.34 ± 1.45
-27J	"	0.54 ± 0.01	4.31 ± 0.07
-855	"	0.39 ± 0.00	1.04 ± 1.21
-1411	"	0.55 ± 0.01	0.78 ± 1.68
-1	"	0.24 ± 0.01	1.49 ± 0.12
-27L	"	0.43 ± 0.01	0.33 ± 0.11
-1	"	0.40 ± 0.01	3.10 ± 0.15
-27M	"	0.22 ± 0.01	0.50 ± 0.10
-1	"	0.43 ± 0.01	1.33 ± 0.10
-94B	"	0.22 ± 0.01	0.39 ± 0.14
-94C	"	0.99 ± 0.01	0.67 ± 0.15
-183	"	1.10 ± 0.01	4.30 ± 0.22
-27N	"	0.67 ± 0.00	1.19 ± 0.04
-1030	co bl.	0.19 ± 0.01	0.71 ± 0.13
-8A	dich.	0.72 ± 0.01	-0.06 ± 0.08

Table 17a. concluded

Sample	Color	Ta	Th
-27"0"	bl-gr.	0.95 ± 0.01	1.33 ± 0.06
-27V	"	0.95 ± 0.01	1.19 ± 0.07
-27Q	"	0.94 ± 0.01	1.22 ± 0.06
-27R	"	1.00 ± 0.01	1.19 ± 0.07
-863	"	0.24 ± 0.00	0.90 ± 0.03
-30B	"	1.61 ± 0.01	1.10 ± 0.05
-100	"	0.45 ± 0.00	0.64 ± 0.04
-30A	co bl.	0.40 ± 0.00	0.26 ± 0.06
-1386	"	1.16 ± 0.01	0.94 ± 0.06
-94A	"	0.57 ± 0.01	2.39 ± 0.22
-27A	"	0.39 ± 0.01	4.39 ± 0.25
-27B	"	0.97 ± 0.01	5.73 ± 0.34
-1035	"	2.10 ± 0.01	2.03 ± 0.13
-8B	"	0.38 ± 0.00	0.98 ± 0.04
-8C	"	1.53 ± 0.01	0.58 ± 0.06
-8D	"	0.25 ± 0.01	0.93 ± 0.11
-3	"	0.63 ± 0.01	1.95 ± 0.20
-1B	"	0.96 ± 0.01	2.36 ± 0.18
-337	"	6.36 ± 0.03	10.80 ± 0.62
-65	bl-gr.	1.14 ± 0.00	6.80 ± 0.05
-27P	co bl.	0.13 ± 0.01	5.23 ± 0.12
-82	"	2.99 ± 0.01	2.55 ± 0.16
-27U	black	2.04 ± 0.01	2.02 ± 0.10
-89	"	1.85 ± 0.01	2.81 ± 0.09
-27D	"	1.86 ± 0.01	1.77 ± 0.09
-27C	"	1.80 ± 0.01	1.17 ± 0.11
-27T	green	2.38 ± 0.01	1.63 ± 0.05
Mean and RMSD		0.88 ± 0.95	1.82 ± 2.15

Table 17b. Bead from Igbo Ukwu: Neutron Activation Analysis[a,i]

Sample	Description	Color	Al (%)
IGB-N3C	bead, reheated cane	cobalt blue	6.56 ± 0.22

Ca (%)	Mn	Na (%)	K (%)
10.43 ± 1.41	7,928 ± 141	2.28 ± 0.07	3.43 ± 1.86

U	La	Co	Sc
1.58 ± 0.05	18.64 ± 0.99	1,104.80 ± 9.47	2.99 ± 0.10

Fe (%)	Yb	Cs	Ta
0.66 ± 0.06	0.94 ± 0.21	12.80 ± 0.80	1.64 ± 0.01

Th
1.71 ± 0.20

Notes to Table 17

a. All data are given in parts per million unless otherwise indicated. Negative numbers are an artifact of the calculations, meaning that the element is so low in concentration as to be undetectable. Within sample categories, the samples are arranged approximately in order of increasing cobalt. Stripes and trimmings were, of course, analyzed separately or not at all.

b. Imprecisely-determined elements are excluded from this Table. Those for which a mean concentration could be determined are (with mean and root mean square deviation): V, 45 ± 91 ppm; Dy, 5 ± 3 ppm; Eu, 0.8 ± 1.1 ppm; Sr, 576 ± 457 ppm; Ga, 228 ± 174 ppm; Lu, 0.12 ± 0.13 ppm; Nd, 12.8 ± 17.8 ppm; Sn, 130 ± 84 ppm; Ba, 268 ± 254 ppm; Ni, 110 ± 65 ppm; Tb, 0.29 ± 0.44 ppm; Hf, 1.18 ± 0.71 ppm. Precisely-determined lanthanides averaged: Sm, 2.60 ± 3.78 ppm; Ce, 26.6 ± 17.7 ppm. For the remaining elements, the following upper limits of concentration were obtained, given with an estimated representative counting error: Mg, 3.6 ± 2.0%; Cu, when not used as an additive, 280 ± 150 ppm; Cl, 0.2 ± 0.1%; In, 30 ± 12 ppm; As, 90 ± 65 ppm; Ti, 0.20 ± 0.09 ppm; Au, 0.3 ± 0.3 ppm; Mo, 10 ± 1 ppm; W, 2 ± 1 ppm; Ho, 5.0 ± 0.3 ppm; Ag, 6 ± 2 ppm; Sb, 20 ± 1 ppm; Ir, 0.02 ± 0.01 ppm; Cr, 95 ± 2 ppm; Hg, assuming none is lost in the reactor, 0.7 ± 0.8 ppm; Rb, 600 ± 50 ppm; Zn, 300 ± 50 ppm. Pb was determined by X-ray fluorescence on the following seventeen samples of Group I: ITA-27B, ITA-920, ITA-27A, ITA-855, ITA-1411, ITA-1386, ITA-1035, ITA-89, KOU-1, GAO-1, OLD-27, ILE-233a, OLO-1B, ORU-183, ORU-17, ORU-207, ORU-179a. In all cases the result was below the approximate limit of detection of 0.05%.

c. This crucible lining also has green regions.

d. Not determined.

e. Root mean square deviation (see Chapter 3).

f. For all samples except the four "casual" and five black and green samples.

g. For the four "casual" samples, ITA-27"O", ITA-27V, ITA-27Q, ITA-27R.

h. For the five black and green samples, ITA-89, ITA-27D, ITA-27C, ITA-27T, ITA-27U.

i. The upper limits given in note b are all appropriate for IGB-N3C. For those for which means were calculated for Group I, IGB-N3C gave the following concentrations: V, 67 ± 42 ppm; Dy, 12 ± 1 ppm; Ga, 753 ± 192 ppm; Sm, 2.75 ± 0.02 ppm; Lu, 0.16 ± 0.03 ppm; Nd, 15.9 ± 3.1 ppm; Ce, 48.7 ± 1.6 ppm; Sn, 250 ± 18 ppm; Eu, 0.5 ± 0.1 ppm; Ba, 318 ± 143 ppm; Ni, 138 ± 58 ppm; Tb, 0.28 ± 0.08 ppm; Hf, 1.83 ± 0.68 ppm. Each of these is similar to the concentrations displayed by Ife Group I. The Pb content of IGB-N3C was estimated by X-ray fluorescence analysis to be < 0.1%.

Table 18. "Corded Bead" and "Dichroic Bead" Trial Subgroups:
Means and Standard Deviations of the
Means of the Elemental Concentrations

Element	Corded	Dichroic
Al	6.22 ± 0.12	6.51 ± 0.13
Ca	11.71 ± 0.32	11.10 ± 0.27
Mn	3631. ± 538.	3093. ± 356.
Na	1.98 ± 0.21	1.52 ± 0.05
K	5.22 ± 0.35	6.62 ± 0.17
U	1.47 ± 0.17	1.73 ± 0.34
La	10.54 ± 2.41	14.46 ± 6.93
Co	518.13 ± 91.51	386.32 ± 62.03
Sc	1.17 ± 0.12	1.49 ± 0.15
Fe	0.32 ± 0.03	0.34 ± 0.02
Yb	0.87 ± 0.19	0.65 ± 0.17
Cs	6.69 ± 1.08	6.89 ± 0.63
Ta	0.53 ± 0.06	0.48 ± 0.06
Th	1.47 ± 0.77	1.35 ± 0.31

Table 19. Ratio of Manganese to Cobalt in Group I

Sample	Ratio
ITA-30C	10.2
ITA-27I	7.9
ORU-207	6.4
ITA-30D	8.2
ITA-27K	10.4
ITA-27E	7.1
ITA-27G	7.3
ITA-27B	7.3
ITA-27F	6.2
ITA-27H	6.9
ITA-1442	6.2
ORU-33	6.5
ITA-27N	11.4
ITA-1030	7.5
OLO-8A	6.2
ITA-920	11.9
ORU-27	12.9
ILP-233A	18.2
ITA-27A	13.6
OLD-17	7.5
ORU-179A	7.2
ITA-27J	7.2
ITA-855	11.5
ITA-1411	9.1
KOU-1	8.6
ITA-27L	7.0
GAO-1	7.5
ITA-27M	7.2
OSS-1	6.7
ITA-94B	7.5
ITA-94C	7.6
ORU-183	6.1
ITA-27"O"	8.5
ITA-27V	8.8
ITA-27Q	8.3
ITA-27R	8.7
ITA-30B	26.4
ITA-100	12.0
ITA-863	15.9
(ITA-65	148.1)[a]
ITA-30A	9.3
ITA-1386	7.0
ITA-94A	9.0
ITA-27A	6.9
ITA-27B	8.5
ITA-1035	8.8
OLO-8B	12.4
OLO-8C	7.4
OLO-8D	6.5
OLO-3	7.3
OLO-1B	7.6
OLO-337	7.1
ITA-27P	7.7
ORU-82	7.7
ITA-89	9.2
ITA-27D	11.9
ITA-27C	11.8
ITA-27T	21.6
ITA-27U	10.5
(IGB-N3C	7.2)[a]

[a] Not included in mean, 9.3 ± 3.8.

Table 20. Ife Class II: Neutron Activation Analysis[a,b]

Sample	Description	Color
ITA-22B	bead, biconical	opaque yellow
ITA-21A	" , short cylinder	opaque grayish yellow
ITA-21B	" , long cylinder	opaque greenish yellow
ITA-914	" , short cylinder	transparent blue-green
ITA-1421	crucible lining	" "
ITA-885	" "	" "
ITA-1077	" "	" "
ITA-20	bead, reheated cane	opaque blue, with four stripes of opaque white framed by Indian red
ITA-19A	trim, composite bead	Indian red
ITA-19B	core, " "	transparent dark green
ITA-19C	trim, " "	opaque yellow
ORU-57A	bead, cane, subdiscoid	translucent blue-green
ORU-206B	" " "	opaque to translucent blue-green
ORU-206A	" wound, "	translucent blue-green
ORU-179C	" fragment	blue-green
ORU-179B	" "	translucent blue-green

Table 20. continued

Sample	Color	Al (%)	Cl (%)	Mn
-22B	yellow	1.10 ± 0.09	0.99 ± 0.18	6,939 ± 166
-21A	gy-yel.	0.84 ± 0.27	1.10 ± 0.17	4,617 ± 136
-21B	gr-yel.	1.08 ± 0.31	1.31 ± 0.16	3,677 ± 106
-914	bl-gr.	1.83 ± 0.06	0.89 ± 0.09	365 ± 20
-1421	"	3.58 ± 0.17	0.53 ± 0.05	620 ± 14
-885	"	3.42 ± 0.36	0.57 ± 0.05	273 ± 13
-1077	"	6.21 ± 0.25	0.39 ± 0.11	379 ± 12
-20	blue	3.92 ± 0.06	0.72 ± 0.10	613 ± 16
-19A	IR	3.56 ± 0.13	0.75 ± 0.10	1,103 ± 21
-19B	green	4.44 ± 0.59	0.53 ± 0.10	1,272 ± 29
-19C	yellow	2.82 ± 0.18	0.96 ± 0.23	4,924 ± 104
-57A	bl-gr.	2.41 ± 0.28	1.46 ± 0.14	396 ± 26
-206B	"	3.26 ± 0.21	0.54 ± 0.15	1,355 ± 28
-206A	"	2.30 ± 0.26	1.36 ± 0.09	496 ± 20
-179C	"	3.79 ± 0.29	1.27 ± 0.27	925 ± 39
-179B	"	1.55 ± 0.06	1.33 ± 0.15	357 ± 31

Table 20. continued

Sample	Color	Na (%)	Cu	U
-22B	yellow	10.65 ± 0.17	< 200	0.81 ± 0.04
-21A	gy-yel.	10.79 ± 0.16	11,678 ± 272	1.28 ± 0.16
-21B	gr-yel.	11.86 ± 0.17	4,074 ± 202	-0.29 ± 0.22
-914	bl-gr.	7.37 ± 0.11	11,361 ± 214	0.39 ± 0.13
-1421	"	5.64 ± 0.05	6,418 ± 92	0.63 ± 0.02
-885	"	6.10 ± 0.05	7,894 ± 96	0.54 ± 0.02
-1077	"	5.80 ± 0.06	4,486 ± 93	1.05 ± 0.05
-30	blue	7.93 ± 0.09	7,344 ± 127	1.82 ± 0.04
-19A	IR	9.04 ± 0.10	10,063 ± 153	1.24 ± 0.03
-19B	green	8.03 ± 0.08	9,389 ± 160	0.83 ± 0.10
-19C	yellow	11.22 ± 0.11	1,214 ± 157	4.21 ± 0.13
-57A	bl-gr.	14.07 ± 0.12	13,849 ± 167	1.20 ± 0.06
-20C	"	10.82 ± 0.14	10,277 ± 191	1.15 ± 0.04
-206A	"	13.42 ± 0.11	12,948 ± 156	0.75 ± 0.03
-179C	"	9.20 ± 0.16	9,014 ± 281	0.50 ± 0.22
-179B	"	13.64 ± 0.21	11,991 ± 264	0.91 ± 0.17

Table 20. continued

Sample	Color	La	Co	Ag
-22B	yellow	6.93 ± 0.89	6.12 ± 0.18	2.6 ± 0.5
-21A	gy-yel.	8.30 ± 0.38	4.96 ± 0.12	4.7 ± 0.3
-21B	gr-yel.	7.97 ± 0.41	5.04 ± 0.16	1.7 ± 0.3
-914	bl-gr.	10.40 ± 0.34	7.21 ± 0.12	4.9 ± 0.3
-1421	"	11.66 ± 0.47	56.03 ± 0.56	1.8 ± 0.5
-885	"	10.26 ± 0.47	15.18 ± 0.21	3.0 ± 0.3
-1077	"	7.36 ± 1.14	21.39 ± 0.40	2.0 ± 0.8
-20	blue	8.43 ± 0.79	11.19 ± 0.22	3.0 ± 0.6
-19A	IR	13.40 ± 0.74	99.66 ± 1.01	5.1 ± 0.7
-19B	green	5.98 ± 1.92	5.18 ± 0.54	4.0 ± 1.3
-19C	yellow	11.67 ± 2.29	13.61 ± 0.61	10.0 ± 1.7
-57A	bl-gr.	14.47 ± 1.78	11.44 ± 0.34	9.1 ± 0.8
-206B	"	11.78 ± 0.87	57.86 ± 0.61	4.8 ± 0.6
-206A	"	11.75 ± 0.81	5.47 ± 0.21	6.2 ± 0.5
-179C	"	15.33 ± 0.64	76.63 ± 0.60	4.8 ± 0.7
-179B	"	11.31 ± 0.48	7.38 ± 0.13	7.6 ± 0.4

Table 20. continued

Sample	Color	Sc	Fe (%)	Yb
-22B	yellow	1.66 ± 0.02	0.61 ± 0.02	0.54 ± 0.08
-21A	gy-yel.	1.96 ± 0.01	0.57 ± 0.01	1.16 ± 0.05
-21B	gr-yel.	1.74 ± 0.01	0.64 ± 0.02	1.45 ± 0.07
-914	bl-gr.	1.75 ± 0.01	0.51 ± 0.01	1.01 ± 0.05
-1421	"	2.00 ± 0.02	0.71 ± 0.02	0.84 ± 0.06
-885	"	1.57 ± 0.01	0.44 ± 0.01	0.78 ± 0.05
-1077	"	2.02 ± 0.03	1.08 ± 0.03	0.97 ± 0.10
-20	blue	2.27 ± 0.02	0.74 ± 0.02	1.20 ± 0.10
-19A	IR	3.62 ± 0.03	1.73 ± 0.03	1.07 ± 0.09
-19B	green	3.77 ± 0.05	1.09 ± 0.06	1.75 ± 0.23
-19C	yellow	3.67 ± 0.07	0.97 ± 0.05	1.06 ± 0.24
-57A	bl-gr.	3.87 ± 0.03	1.09 ± 0.04	1.81 ± 0.13
-206B	"	4.11 ± 0.02	1.31 ± 0.02	0.99 ± 0.05
-206A	"	3.44 ± 0.02	0.87 ± 0.02	1.19 ± 0.09
-179C	"	3.85 ± 0.03	1.35 ± 0.02	1.23 ± 0.08
-179B	"	3.32 ± 0.02	0.93 ± 0.01	1.05 ± 0.05

Table 20. continued

Sample	Color	Ta	Sb	Sn
-22B	yellow	0.19 ± 0.01	13.0 ± 0.6	10,869 ± 22
-21A	gy-yel.	0.45 ± 0.00	40.8 ± 1.1	5,597 ± 15
-21B	gr-yel.	0.36 ± 0.00	112.0 ± 3.5	6,779 ± 14
-914	bl-gr.	1.47 ± 0.01	28.2 ± 0.9	b
-1421	"	0.46 ± 0.00	11.9 ± 0.6	b
-885	"	0.21 ± 0.00	17.6 ± 0.8	b
-1077	"	0.52 ± 0.01	10.8 ± 0.6	b
-20	blue	3.40 ± 0.01	16.0 ± 0.8	666 ± 10
-19A	IR	2.17 ± 0.01	21.7 ± 1.0	417 ± 8
-19B	green	1.61 ± 0.01	146.4 ± 7.2	9,908 ± 33
-19C	yellow	0.68 ± 0.02	23.6 ± 1.5	8,083 ± 34
-57A	bl-gr.	0.39 ± 0.01	67.0 ± 2.6	b
-206B	"	1.07 ± 0.01	35.1 ± 1.5	354 ± 5
-206A	"	0.28 ± 0.00	83.0 ± 3.8	220 ± 7
-179C	"	0.73 ± 0.01	22.2 ± 0.6	b
-179B	"	0.30 ± 0.00	21.7 ± 0.6	b

Table 20. concluded

Sample	Color	Th	Hf	Zn
-22B	yellow	2.62 ± 0.05	2.43 ± 0.15	41 ± 4
-21A	gy-yel.	2.31 ± 0.03	9.77 ± 0.18	788 ± 5
-21B	gr-yel.	1.97 ± 0.04	3.32 ± 0.12	149 ± 4
-914	bl-gr.	2.61 ± 0.03	3.26 ± 0.10	133 ± 3
-1421	"	2.57 ± 0.05	2.38 ± 0.14	69 ± 5
-885	"	2.26 ± 0.04	2.51 ± 0.12	61 ± 3
-1077	"	1.83 ± 0.07	1.72 ± 0.22	216 ± 8
-20	blue	2.74 ± 0.06	2.10 ± 0.17	277 ± 6
-19A	IR	3.35 ± 0.07	2.97 ± 0.20	329 ± 8
-19B	green	7.04 ± 0.17	2.48 ± 0.41	68 ± 13
-19C	yellow	16.37 ± 0.22	4.56 ± 0.45	429 ± 18
-57A	bl-gr.	4.03 ± 0.10	3.19 ± 0.26	103 ± 8
-206B	"	3.66 ± 0.05	4.22 ± 0.17	652 ± 8
-206A	"	3.12 ± 0.07	2.62 ± 0.18	311 ± 6
-179C	"	3.50 ± 0.06	3.34 ± 0.18	345 ± 8
-179B	"	2.93 ± 0.03	2.87 ± 0.10	100 ± 3

Notes to Table 20

a. All data are given in parts per million unless otherwise indicated. Stripes and trimming are, of course, analyzed separately or not at all.

b. For the following elements, the upper limits of concentration, with a representative counting error, are: Mg, 3 ± 2%; Ca, 7.7 ± 1.7%; V, 75 ± 50 ppm; Dy, 30 ± 5 ppm; K, 6 ± 2%; Sr, 0.2 ± 0.3%; Ga, 275 ± 120 ppm; In, 11 ± 7 ppm; As, 400 ± 70 ppm; Sm, 2.29 ± 0.05 ppm; Ti, 0.35 ± 0.10 ppm; Lu, 0.17 ± 0.04 ppm; Au, 0.34 ± 0.01 ppm; Nd, 18 ± 4 ppm; Mo, 10 ± 2 ppm; W, 12 ± 2 ppm; Ho, 1.6 ± 0.3 ppm; Ce, 30 ± 1 ppm; Cs, 11.0 ± 0.3 ppm; Ir, 0.019 ± 0.003 ppm; Cr, 55 ± 3 ppm; Hg, assuming none is lost in the reactor, 0.5 ± 0.3 ppm; Eu, 0.6 ± 0.2 ppm; Ba, 450 ± 100 ppm; Ni, 60 ± 20 ppm; Rb, 620 ± 30 ppm; Tb, 0.33 ± 0.05 ppm. Pb was determined by X-ray fluorescence analysis as follows: -22B, 8 ± 2%; -21A, 3.6 ± 0.6%; -21B, 7 ± 2%; -914, 0.12 ± 0.05%; -1421, ∿ 0.04%; -885, ∿ 0.05%; -1077, ∿ 0.06%; -20, ∿ 0.05%; ITA-19 as a whole, 2.3 ± 0.4%, probably mostly from the yellow trim; -57A, < 0.05%; -206B, 0.08 ± 0.04%; -206A, 0.12 ± 0.05%; -179C, 0.2 ± 0.1%; -179B, ∿ 0.04%.

c. Crucible lining also had streaks of Indian red.

Table 21. Ife Study, Class III (Miscellaneous): Neutron Activaton Analysis[a,b]

Sample	Site	Description
IFE-291	Ife	sherd
GLO-1	Glozel	cullet
GLO-3	"	"
GLO-2	"	"
WUN-10A	Wunmonije Head No. 10	bead, cane, short cylinder
OLO-2	Olokun Grove	fragment, corded
OLO-8E	" "	sherd
ILE-235	Ilesha	bead, short cylinder
OLD-117	Old Oyo	bead, cane, long cylinder

Sample	Color	Al (%)
-291	dichroic	2.06 ± 0.10
-1	"	4.57 ± 0.12
-3	" , opal	4.37 ± 0.16
-2	transparent green	2.06 ± 0.09
-10A	very dark (transparent) cobalt blue	5.60 ± 0.37
-2	transparent cobalt blue	0.55 ± 0.26
-8E	bright, transparent cobalt blue	0.27 ± 0.07
-235	transparent green (? "Annagrün")	0.37 ± 0.04
-117	opaque pale cobalt blue	0.88 ± 0.05

Table 21. continued

Sample	Color	Ca (%)	Mn
-291	dichroic	12.61 ± 0.89	4,484 ± 340
-1	"	7.24 ± 0.80	5,497 ± 92
-3	"	8.85 ± 0.92	5,953 ± 89
-2	green	9.04 ± 0.92	6,202 ± 104
-10A	co bl.	0.49 ± 2.27	12,085 ± 193
-2	"	6.54 ± 0.72	1,357 ± 32
-8E	"	7.55 ± 1.31	386 ± 26
-235	green	1.05 ± 0.59	27 ± 15
-117	co bl.	6.81 ± 0.71	3,282 ± 94

Sample	Color	Na (%)	K (%)
-291	dichroic	4.90 ± 0.70	1.10 ± 1.09
-1	"	1.07 ± 0.04	8.90 ± 1.21
-3	"	0.81 ± 0.02	6.15 ± 0.53
-2	green	1.72 ± 0.05	10.23 ± 0.33
-10A	co bl.	4.54 ± 0.06	4.22 ± 1.36
-2	"	12.56 ± 0.11	0.84 ± 0.75
-8E	"	13.13 ± 0.14	2.45 ± 1.00
-235	green	5.40 ± 0.09	10.12 ± 1.19
-117	co bl.	8.43 ± 0.13	6.59 ± 1.53

Table 21 . continued

Sample	Color	Cu	U
-291	dichroic	b	1.27 ± 0.03
-1	"	b	7.59 ± 0.06
-3	"	b	6.20 ± 0.05
-2	green	b	2.41 ± 0.04
-10A	co bl.	3,260 ± 208	1.47 ± 0.06
-2	"	b	8.68 ± 0.15
-8E	"	b	5.22 ± 0.08
-235	green	4,382 ± 126	2,893. ± 53.
-117	co bl.	b	n.d.

Sample	Color	La	Co
-291	dichroic	16.42 ± 0.76	5.70 ± 0.15
-1	"	40.47 ± 0.81	4.32 ± 0.10
-3	"	47.31 ± 0.81	7.98 ± 0.15
-2	green	42.35 ± 0.85	4.96 ± 0.12
-10A	co bl.	21.00 ± 1.66	1,533.70 ± 12.97
-2	"	4.62 ± 3.22	283.09 ± 2.49
-8E	"	3.32 ± 1.60	891.99 ± 6.53
-235	green	n.d.	1.19 ± 0.27
-117	co bl.	n.d.	419.83 ± 8.52

Table 21. continued

Sample	Color	Sc	Fe (%)	Yb
-291	dichroic	2.49 ± 0.02	0.75 ± 0.02	1.31 ± 0.08
-1	"	4.04 ± 0.02	0.85 ± 0.02	2.93 ± 0.09
-3	"	4.32 ± 0.02	0.86 ± 0.02	2.57 ± 0.09
-2	green	1.80 ± 0.02	0.52 ± 0.01	1.21 ± 0.07
-10A	co bl.	3.57 ± 0.15	0.74 ± 0.09	0.26 ± 0.34
-2	"	0.49 ± 0.04	0.25 ± 0.05	2.90 ± 0.21
-8E	"	0.37 ± 0.08	0.10 ± 0.05	0.63 ± 0.18
-235	green	0.30 ± 0.01	0.07 ± 0.02	n.d.
-117	co bl.	1.55 ± 0.31	1.42 ± 0.61	n.d.

Sample	Color	Ta	Sb	Sn
-291	dichroic	0.35 ± 0.00	12.8 ± 0.7	86 ± 7
-1	"	1.69 ± 0.01	1.4 ± 0.1	202 ± 5
-3	"	1.47 ± 0.01	1.1 ± 0.1	185 ± 5
-2	green	0.79 ± 0.01	0.4 ± 0.1	156 ± 5
-10A	co bl.	0.57 ± 0.02	7.9 ± 0.6	63 ± 41
-2	"	0.27 ± 0.01	642.2 ±29.3	45 ± 16
-8E	"	0.13 ± 0.01	85.3 ± 3.3	76 ± 14
-235	green	0.05 ± 0.01	2.8 ± 0.2	33 ± 37
-117	co bl.	0.67 ± 0.14	4,560.7 ±141.9	52 ± 222

Table 21. concluded

Sample	Color	Th	Ba	Hf
-291	dichroic	3.97 ± 0.06	457 ± 64	2.43 ± 0.16
-1	"	21.48 ± 0.11	1,265 ± 57	4.09 ± 0.17
-3	"	18.52 ± 0.10	1,438 ± 64	4.31 ± 0.18
-2	green	7.48 ± 0.06	1,262 ± 57	1.89 ± 0.14
-10A	co bl.	5.16 ± 0.34	616 ± 381	2.52 ± 1.10
-2	"	1.10 ± 0.15	2,851 ± 220	1.88 ± 0.39
-8E	"	0.61 ± 0.16	1,275 ± 114	1.03 ± 0.59
-235	green	n.d.	n.d.	51.45 ± 0.94
-117	co bl.	2.91 ± 2.71	1,202 ± 808	10.17 ± 4.17

Notes to Table 21

a. All data are given in parts per million unless otherwise indicated.

b. Most imprecisely-determined elements are omitted from this Table. For the remainder, the following upper limits, with a representative counting error, are: Mg, 5.0 ± 1.5%; V, 90 ± 75 ppm; Cl, 1.0 ± 0.1%; Dy, 14 ± 2 ppm; Cu, where not used as an additive, 400 ± 200 ppm; Sr, 0.11 ± 0.06%; Ga, 900 ± 150 ppm; In, 2 ± 1 ppm; Ti, 0.16 ± 0.03 ppm; Lu, 0.37 ± 0.03 ppm; Au, 0.04 ± 0.01 ppm; Nd, 42 ± 3 ppm; Mo, 6.5 ± 1.0 ppm; W, 1.8 ± 0.5 ppm; Ho, 2.6 ± 0.2 ppm; Ag, 4.0 ± 0.5 ppm; Ir, 0.08 ± 0.01 ppm; Cr, 51 ± 46 ppm except for ILE-235, which gave the result 646 ± 6 ppm; Hg, assuming none is lost in the reactor, 0 ± 0 ppm; Eu, 4 ± 4 ppm; Rb, 900 ± 80 ppm; Tb, 1.0 ± 0.6 ppm; Zn, 210 ± 5 ppm; Ni, 80 ± 50 ppm except for WUN-10A, which gave the result 488 ± 82 ppm, and for OLD-117, which gave the result 341 ± 193 ppm; As, 83 ± 2 ppm except for OLO-2, 2424.2 ppm, OLO-8E, 471.9 ± 11.6 ppm, OLD-117, which gave the result 0.12 ± 0.05% by X-ray fluorescence, and ILE-235, which gave the result < 0.05% by X-ray fluorescence. WUN-10A has no detectable As. Upper limits for the precisely-determined lanthanides are: Sm, 8.8 ± 0.03 ppm; and Ce, 70 ± 2 ppm, except for ILE-235, in which Ce was not determined. Pb was determined by X-ray fluorescence analysis with the following results: GLO-1, < 0.02%, GLO-2, < 0.02%; WUN-10A, ∿ 0.1%; ILE-235, 0.2 ± 0.1%; OLD-117, 0.3 ± 0.1%. For the others it was not determined.

CHAPTER 9. BEADS FROM IGBO UKWU

Introduction

The site of Igbo Ukwu (Lat. 6°1' N., Long. 7°1' E.) lies in Eastern Nigeria (Figure 16). It was excavated by Thurstan Shaw, and a complete report has been published (Shaw 1970).

Over 150,000 glass beads were excavated from this site, nearly all from the two localities Igbo Richard and Igbo Isaiah. These beads were divided by the excavator into seventeen glass Types, designated by letters of the English alphabet, with numbered subdesignations according to size. The Types and sizes are completely described by Shaw (1970), and Shaw's Plate V may be consulted on the appearance of the beads.

It will be appreciated that with some 150,000 glass beads falling into only seventeen Types, large numbers of beads of the different Types were present. In our study one, or a few, of each Type were analyzed.

Results

Tables 22 and 23 present the results of neutron activation analysis of beads from Igbo Ukwu.

Discussion

The beads from Igbo Ukwu can be divided into four mutually exclusive Classes on the basis of their ingredients, particularly the sodium and aluminum. The majority of beads falls into Class I (Table 22). Beads in Class I are generally characterized by a relatively high sodium and low aluminum. They show relatively low tantalum, low scandium, low cesium, and a frequent use of manganese.

Beads in Class II are generally characterized by a relatively medium sodium and high aluminum. They show a relatively elevated scandium and a sparing use of manganese, or no use.

Class III consists of three beads which did not fit into Classes I or II (or IV). These beads show a relatively high aluminum and high sodium. Class III should probably be regarded as a class of miscellaneous leftovers.

Beads in Class IV are generally characterized by a relatively low sodium and high aluminum. They show a high calcium and low zinc, antimony, and tin, metals which are not correlated with one another in any of the Classes.

In all the four Classes the concentration of rare earths is similar.

There is no consistent manganese/cobalt ratio in the Classes, even if only cobalt blue examples are considered. Nor is there any consistent ratio of cobalt to arsenic or to nickel. We cannot judge the question of a possible relationship between cobalt and zinc, since the determination of these two elements is not independent, where cobalt is high. Several of the cobalt blue beads contain considerable copper (Table 22), but no cobalt/copper correlation is demonstrable.

The Classes do not follow the division of the site into the localities Igbo Isaiah and Igbo Richard. Each of the four Classes contains bead Types that are common to both Igbo Richard and Igbo Isaiah (Types L, M, N, and P, see Shaw 1970:225). Bead Types peculiar to Igbo Isaiah occur only in Class I.

Further research would be required to explore the relationship between our Classes and Shaw's Types, since we have not analyzed a large number of any Type. In a few cases we analyzed a few members of one Type. With the limited data thus available, agreement of Shaw's Types with our

Classes is fairly good. In only two cases do beads of the same Type fall into different Classes. Beads of Type N fall into Classes I and IV, and beads of Type M fall into Classes I and III.

Links with Other Sites

There are some parallels between glasses of Igbo Ukwu and glasses of Ife. The glass of Igbo Ukwu Class IV resembles Ife Group I, and the soda-lime samples from Ife (Ife Class II) can be arranged so as to parallel the three soda-lime Classes of Igbo Ukwu.

Let us discuss Igbo Ukwu Class IV first. The specimen IGB-N3C probably matches Ife Group I, as discussed in Chapter 8. In addition, the five other beads of Igbo Ukwu Class IV resemble Ife Group I (see Figure 20). These five consist of three samples from Type V and two samples from Type S. With respect to Type V, if the additives manganese and cobalt are removed from consideration, leaving twelve elements precisely determined for Ife Group I, only IGB-V1 displays elemental concentrations falling within one standard deviation of the means for Ife Group I for at least two-thirds of the elements. Each of the other two beads presents matching concentrations in less than two-thirds of the cases. Visually, IGB-V1 looks like IGB-V2 and IGB-V3 rather than like any member of Ife Group I, and we think it suitable that the same dispensation be made for IGB-V1 that is made for IGB-V2 and IGB-V3. These three samples give conflicting evidence as to whether Type V may be considered to match Ife Group I, and, for the present, Type V is considered not to match.

With respect to Type S, if the three additives manganese, cobalt, and iron are removed from consideration, leaving eleven elements precisely determined for Ife Group I, then IGB-S3 matches while IGB-S2 does not. The

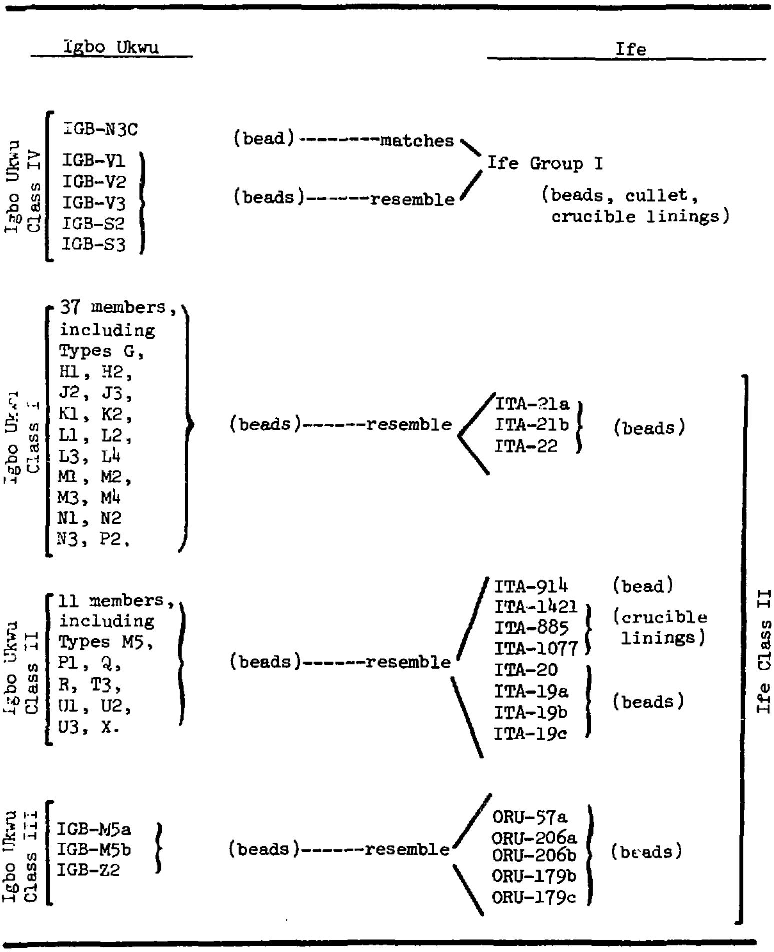

Figure 20. Likenesses between glass of Igbo Ukwu and Ife.

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evidence again conflicts as to whether a Type matches Ife Group I, and for the present Type S is considered not to match.

Analogous reasoning was not used for Type N on the basis of several considerations. The difference between IGB-N3C and other Type N beads is quite marked, whereas the differences among Types S and V are not, and thus it seems reasonable to split Type N whereas it does not seem reasonable to split Types S and V. Furthermore IGB-N3C shows the same additives and ratio of additives as does Ife Group I, making the resemblance easier to recognize.

Turning to the soda-lime glasses, we noted above that the soda-lime glasses of Igbo Ukwu fall into three Classes (which perhaps should be regarded as two valid Classes plus a Class of miscellany). On the basis of their aluminum and sodium content the soda-lime glasses of Ife can be arranged so as to parallel the Classes of Igbo Ukwu (see Figure 20). Specimens from Ita Yemoo which parallel Class I, low aluminum and high sodium, are ITA-22B, ITA-21B, and ITA-21A. Those which parallel Class II (high aluminum and medium sodium) are ITA-914, ITA-1421, ITA-885, ITA-1077, ITA-20, ITA-19A, ITA-19B, and perhaps ITA-19C (since ITA-19A, ITA-19B, and ITA-19C are all from the same bead). Those which parallel Class III are ORU-57A, ORU-206B, ORU-206A, ORU-179C, and ORU-179B.

According to our usual criterion of matching (agreement within one standard deviation for two-thirds or more of the precisely-determined elements, omitting glassmakers' additives where appropriate), many soda-lime samples of Ita Yemoo can be considered to match the Classes of Igbo Ukwu. ITA-22B matches Igbo Ukwu Class I, while ITA-914, ITA-1421, ITA-885, ITA-1077, ITA-20, and ITA-19A match Igbo Ukwu Class II. Igbo Ukwu Class III is too scant to bear discussion in this context.

Some of the beads of Igbo Ukwu might be described as "casual", in the sense that we have used this term for beads of Ife. These are the Types G, H, and J, all appearing to have been individually and laboriously decorated with spirals, dots, or other features, which are often not marvered in. The question naturally arises whether these beads may have any relationship to the glass-working industry of Ife. Present evidence does not support any such link. All analyzed samples of G, H, and J fell into Igbo Ukwu Class I, and no crucible lining or piece of cullet from Ife matched or paralleled Igbo Ukwu Class I. The three samples from Ife which paralleled this Class were all beads.

On the other hand, one bead, three crucible linings, a casual bead, and an apparent European import bead of approximately the seventeenth century (ITA-20), all from Ife, matched Igbo Ukwu Class II (see Figure 20). There is thus more evidence of some commonality between glass of Ife and Igbo Ukwu Class II than there is between glass of Ife and Igbo Ukwu Class I with its casual Types G, H, and J.

A word of caution must be inserted at this point. We do not maintain that there is a very meaningful link between soda-lime samples of Ife and of Igbo Ukwu. We suspect that the Classes of Igbo Ukwu are taxonomically general. Tests of matching of individual samples against general classificatory (taxonomic) groupings are not always meaningful since, in principle, if a classification is general enough then anything will match it. Matching becomes more significant in measure as the classification against which individual samples are compared becomes more specific and distinctive.

Origin and Dating

IGB-N3C probably matches Ife Group I, and therefore most likely shares a common origin, perhaps in medieval Europe (see Chapter 8). The fact that a number of soda-lime samples from Ife match soda-lime Classes from Igbo Ukwu indicates that these samples share, respectively, common origins. As mentioned in Chapter 8, we are not able to name a specific origin of these soda-lime glasses from their ingredients. A reasonable general origin for them would be either the Near East or Europe after the fourth to fifth centuries A.D.

The radiocarbon date from Igbo Richard indicates that the beads were buried sometime after approximately the ninth century A.D. Wood from a stool in Igbo Richard gave the date 850 ± 120 A.D. (I-2008, Shaw 1968). Similar dates came from Igbo Jonah (a locality of Igbo Ukwu having no significant glass bead content): 875 ± 130 A.D. (HV-1514), 840 ± 110 A.D. (HV-1515), and 840 ± 145 A.D. (I-1784) (Shaw 1968, 1970).

On the other hand, two approximately fifteenth-century dates are associated with Igbo Ukwu. One radiocarbon date from Igbo Jonah gave the result 1450 ± 70 (HV-1516, Shaw 1968), and a date from charcoal associated with artifacts stylistically similar to those of Igbo Ukwu gave the result 1495 ± 95 A.D. (GX-0942, Shaw 1968).

If the ninth-century date is close to the true age of the beads then the soda-lime glasses may be considered likely to have been made in the Near East, or in Islamic lands. If the site is as late as the fifteenth century, then either a Near Eastern or European provenience may be about equally likely because by that time soda-lime glasses were being made in Europe as well as in the Near East.

Further research is required in order to tie the beads of Igbo Ukwu to specific regions of manufacture. In particular, there is a need for research into factory sites, an issue which we touch upon in our last chapter.

Table 22a. Igbo Ukwu Class I:
Neutron Activation Analysis[a,b]

Sample	Color	Mn	Na (%)
IGB-L2A	yellow	8,522 ± 138	11.13 ± 0.14
IGB-L1A	"	8,261 ± 213	12.43 ± 0.20
IGB-L3C	"	8,080 ± 81	10.23 ± 0.11
IGB-L4B	"	7,900 ± 110	11.02 ± 0.12
IGB-L2B	"	5,589 ± 83	10.68 ± 0.12
IGB-L3B	"	9,399 ± 124	10.05 ± 0.11
IGB-L1B	"	11,423 ± 238	12.03 ± 0.19
IGB-L3A	"	6,527 ± 97	11.97 ± 0.13
IGB-L2C	"	7,616 ± 105	10.56 ± 0.11
IGB-J2A	"	6,835 ± 100	10.49 ± 0.14
IGB-J2B	"	7,823 ± 116	10.36 ± 0.15
IGB-J2C	"	4,523 ± 69	11.38 ± 0.15
IGB-K1B	green	5,139 ± 116	10.62 ± 0.19
IGB-K1A	"	4,087 ± 93	10.94 ± 0.20
IGB-K2A	"	3,354 ± 40	10.95 ± 0.11
IGB-K2B	"	3,344 ± 40	10.97 ± 0.11
IGB-P2	"	3,336 ± 53	11.94 ± 0.15
IGB-J3	blue-green	288 ± 26	11.44 ± 0.12
IGB-M4A	"	303 ± 10	10.59 ± 0.14
IGB-M3A	"	314 ± 18	10.41 ± 0.09
IGB-M4B	"	258 ± 10	8.96 ± 0.12
IGB-M3B	cobalt blue	2,664 ± 44	9.77 ± 0.09
IGB-M2B	"	8,510 ± 183	11.83 ± 0.20
IGB-M2A	"	8,234 ± 177	11.89 ± 0.20
IGB-M1	blue	8,779 ± 106	11.49 ± 0.14
IGB-H2	cobalt blue	8,540 ± 162	11.65 ± 0.21
IGB-H1B	"	9,609 ± 185	11.22 ± 0.22
IGB-H1A	"	6,210 ± 119	10.81 ± 0.19
IGB-H1C	"	7,541 ± 143	10.30 ± 0.18
IGB-G	"	11,440 ± 215	11.45 ± 0.20
IGB-N2A	"	11,330 ± 230	11.41 ± 0.18
IGB-N1A	"	8,831 ± 214	11.63 ± 0.18
IGB-N3B	"	8,380 ± 199	10.97 ± 0.24
IGB-N1B	"	6,541 ± 119	11.28 ± 0.14
IGB-N2B	"	10,602 ± 129	10.43 ± 0.14
IGB-N3D	"	10,522 ± 245	11.00 ± 0.23
IGB-N3E	"	10,409 ± 254	10.59 ± 0.25
Mean and RMSD[c]		6,785 ±3,282	10.99 ± 0.70

Table 22a. continued

Sample	Color	Cu	U	Ba
-L2A	yellow	b	0.64 ± 0.05	252 ± 19
-L1A	"	b	3.48 ± 0.05	173 ± 18
-L3C	"	b	1.26 ± 0.11	278 ± 37
-L4B	"	b	0.78 ± 0.08	241 ± 36
-L2B	"	b	0.88 ± 0.07	203 ± 35
-L3B	"	b	0.94 ± 0.08	226 ± 39
-L1B	"	b	2.17 ± 0.05	203 ± 20
-L3A	"	b	0.90 ± 0.07	245 ± 30
-L2C	"	b	1.45 ± 0.07	167 ± 33
-J2A	"	b	0.63 ± 0.06	195 ± 29
-J2B	"	b	0.64 ± 0.09	209 ± 42
-J2C	"	b	1.02 ± 0.07	364 ± 31
-K1B	green	2,998 ± 255	0.61 ± 0.04	194 ± 20
-K1A	"	4,925 ± 276	0.60 ± 0.04	152 ± 22
-K2A	"	5,096 ± 159	0.60 ± 0.04	155 ± 19
-K2B	"	3,814 ± 154	0.56 ± 0.04	138 ± 20
-P2	"	8,354 ± 185	0.74 ± 0.07	223 ± 34
-J3	blue-green	7,362 ± 145	0.67 ± 0.06	89 ± 23
-M4A	"	18,821 ± 193	0.64 ± 0.05	122 ± 20
-M3A	"	10,673 ± 121	0.75 ± 0.04	110 ± 21
-M4B	"	8,151 ± 150	0.80 ± 0.04	125 ± 18
-M3B	cobalt blue	6,943 ± 100	0.79 ± 0.04	138 ± 18
-M2B	"	b	0.51 ± 0.04	205 ± 22
-M2A	"	b	0.64 ± 0.04	241 ± 23
-M1	blue	b	0.78 ± 0.04	231 ± 23
-H2	cobalt blue	b	0.67 ± 0.06	285 ± 31
-H1B	"	b	0.83 ± 0.08	246 ± 40
-H1A	"	b	0.61 ± 0.06	228 ± 29
-H1C	"	b	0.69 ± 0.05	242 ± 26
-G	"	b	0.84 ± 0.06	327 ± 30
-N2A	"	b	0.75 ± 0.04	270 ± 21
-N1A	"	b	0.74 ± 0.04	221 ± 17
-N3B	"	b	0.73 ± 0.09	239 ± 43
-N1B	"	2,026 ± 122	0.63 ± 0.05	214 ± 19
-N2B	"	1,360 ± 249	1.34 ± 0.07	248 ± 37
-N3D	"	b	0.79 ± 0.07	354 ± 36
-N3E		b	1.16 ± 0.10	363 ± 50
Mean and RMSD		7,799 ± 4,807[d]	0.90 ± 0.54	219 ± 67

Table 22a. continued

Sample	Color	La	Co
-L2A	yellow	6.44 ± 0.92	5.79 ± 0.16
-L1A	"	7.36 ± 0.90	5.28 ± 0.19
-L3C	"	7.35 ± 1.78	14.05 ± 0.46
-L4B	"	11.37 ± 1.56	7.60 ± 0.22
-L2B	"	8.33 ± 1.47	8.12 ± 0.28
-L3B	"	6.74 ± 1.54	7.84 ± 0.31
-L1B	"	9.41 ± 0.91	2.53 ± 0.11
-L3A	"	8.73 ± 1.25	6.04 ± 0.21
-L2C	"	4.96 ± 1.40	4.30 ± 0.17
-J2A	"	6.34 ± 1.34	5.60 ± 0.23
-J2B	"	6.64 ± 2.01	5.06 ± 0.33
-J2C	"	8.73 ± 1.47	8.53 ± 0.21
-K1B	green	6.12 ± 0.89	21.71 ± 0.32
-K1A	"	7.35 ± 1.00	31.31 ± 0.45
-K2A	"	4.95 ± 1.02	27.55 ± 0.42
-K2B	"	6.99 ± 1.03	26.38 ± 0.44
-P2	"	9.18 ± 1.42	5.90 ± 0.24
-J3	blue-green	8.63 ± 1.35	3.56 ± 0.18
-M4A	"	5.91 ± 0.95	36.93 ± 0.49
-M3A	"	7.19 ± 0.88	19.14 ± 0.31
-M4B	"	8.12 ± 0.95	364.20 ± 3.27
-M3B	cobalt blue	7.04 ± 0.76	198.06 ± 1.79
-M2B	"	5.38 ± 0.79	239.28 ± 2.08
-M2A	"	5.66 ± 0.82	258.43 ± 2.25
-M1	blue	6.76 ± 0.98	284.25 ± 3.40
-H2	cobalt blue	6.99 ± 1.47	490.89 ± 5.03
-H1B	"	6.78 ± 1.97	641.84 ± 6.69
-H1A	"	5.06 ± 1.44	1,097.90 ±10.66
-H1C	"	7.71 ± 1.25	582.19 ± 5.76
-G	"	7.13 ± 1.41	770.57 ± 7.59
-N2A	"	9.62 ± 0.97	615.06 ± 5.19
-N1A	"	7.39 ± 0.85	377.14 ± 3.26
-N3B	"	5.45 ± 1.98	928.66 ±10.62
-N1B	"	8.43 ± 1.04	858.53 ± 7.38
-N2B	"	8.58 ± 1.63	1,388.90 ±16.38
-N3D	"	6.26 ± 1.62	490.26 ± 5.71
-N3E	"	10.12 ± 2.20	829.88 ± 9.72
Mean and RMSD		7.33 ± 1.51	612.7 ± 332.0[e]
			12.6 ± 10.5[f]

Table 22a. continued

Sample	Color	Sc	Fe (%)	Yb
-L2A	yellow	1.41 ± 0.02	0.29 ± 0.01	0.65 ± 0.07
-L1A	"	1.41 ± 0.02	0.49 ± 0.02	0.48 ± 0.07
-L3C	"	1.95 ± 0.04	0.39 ± 0.03	0.86 ± 0.19
-L4B	"	1.69 ± 0.02	0.36 ± 0.02	0.80 ± 0.10
-L2B	"	1.54 ± 0.03	0.33 ± 0.02	0.77 ± 0.12
-L3B	"	1.97 ± 0.03	0.43 ± 0.03	0.84 ± 0.14
-L1B	"	1.72 ± 0.02	0.61 ± 0.02	0.99 ± 0.07
-L3A	"	2.75 ± 0.03	0.60 ± 0.02	0.92 ± 0.12
-L2C	"	1.53 ± 0.02	0.37 ± 0.02	0.62 ± 0.09
-J2A	"	1.27 ± 0.03	0.38 ± 0.02	0.71 ± 0.14
-J2B	"	1.28 ± 0.03	0.36 ± 0.03	0.73 ± 0.21
-J2C	"	2.01 ± 0.03	0.75 ± 0.02	0.82 ± 0.10
-K1B	green	1.23 ± 0.02	0.31 ± 0.01	0.62 ± 0.06
-K1A	"	1.36 ± 0.02	0.35 ± 0.02	0.59 ± 0.07
-K2A	"	1.38 ± 0.02	0.45 ± 0.02	0.79 0.09
-K2B	"	1.39 ± 0.02	0.38 ± 0.02	0.55 ± 0.10
-P2	"	2.11 ± 0.03	0.70 ± 0.03	0.74 ± 0.10
-J3	blue-green	1.99 ± 0.03	0.76 ± 0.03	0.89 ± 0.10
-M4A	"	1.52 ± 0.02	0.37 ± 0.02	0.74 ± 0.08
-M3A	"	1.59 ± 0.02	0.40 ± 0.02	0.61 ± 0.07
-M4B	"	1.96 ± 0.05	0.55 ± 0.03	0.85 ± 0.14
-M3B	cobalt blue	1.96 ± 0.02	0.57 ± 0.01	0.31 ± 0.05
-M2B	"	1.24 ± 0.03	0.42 ± 0.02	0.50 ± 0.06
-M2A	"	0.53 ± 0.03	0.20 ± 0.02	0.62 ± 0.07
-M1	blue	1.39 ± 0.04	0.49 ± 0.02	0.55 ± 0.94
-H2	cobalt blue	1.51 ± 0.08	0.68 ± 0.06	0.89 ± 0.27
-H1B	"	2.04 ± 0.12	0.79 ± 0.08	0.78 ± 0.37
-H1A	"	1.90 ± 0.12	0.93 ± 0.08	0.88 ± 0.32
-H1C	"	2.02 ± 0.08	0.86 ± 0.05	0.76 ± 0.23
-G	"	2.00 ± 0.10	0.90 ± 0.07	0.63 ± 0.29
-N2A	"	1.94 ± 0.06	0.77 ± 0.04	0.69 ± 0.13
-N1A	"	1.61 ± 0.05	0.64 ± 0.03	0.77 ± 0.11
-N3B	"	1.71 ± 0.16	0.88 ± 0.11	1.06 ± 0.49
-N1B	"	1.67 ± 0.08	0.66 ± 0.04	0.52 ± 0.16
-N2B	"	2.22 ± 0.13	1.23 ± 0.09	0.62 ± 0.30
-N3D	"	1.89 ± 0.10	0.75 ± 0.07	0.97 ± 0.28
-N3E	"	2.66 ± 0.17	1.13 ± 0.11	1.03 ± 0.49
Mean and RMSD		1.71 ± 0.42	0.58 ± 0.25	0.73 ± 0.17

Table 22a. continued

Sample	Color	Ta	Sb	Sn
-L2A	yellow	1.04 ± 0.01	4.8 ± 0.3	9,941 ± 20
-L1A	"	0.20 ± 0.00	21.9 ± 1.0	4,936 ± 12
-L3C	"	0.50 ± 0.01	12.2 ± 0.9	19,777 ± 52
-L4B	"	0.23 ± 0.01	7.2 ± 0.4	11,461 ± 24
-L2B	"	0.35 ± 0.01	8.8 ± 0.5	11,357 ± 26
-L3B	"	0.25 ± 0.01	9.3 ± 0.6	15,601 ± 35
-L1B	"	0.28 ± 0.01	3.5 ± 0.2	7,721 ± 16
-L3A	"	0.57 ± 0.01	1.8 ± 0.2	14,755 ± 30
-L2C	"	0.19 ± 0.01	10.8 ± 0.5	17,782 ± 33
-J2A	"	0.20 ± 0.01	10.9 ± 0.7	14,067 ± 40
-J2B	"	0.19 ± 0.01	25.2 ± 1.5	18,638 ± 57
-J2C	"	0.39 ± 0.01	1.6 ± 0.2	6,861 ± 23
-K1B	green	0.17 ± 0.00	4.5 ± 0.3	1,833 ± 9
-K1A	"	0.16 ± 0.00	11.8 ± 0.8	2,647 ± 11
-K2A	"	0.16 ± 0.00	9.5 ± 0.6	3,422 ± 15
-K2B	"	0.17 ± 0.01	10.2 ± 0.7	2,882 ± 16
-P2	"	0.33 ± 0.01	14.9 ± 0.6	4,370 ± 16
-J3	blue-green	0.22 ± 0.01	12.5 ± 0.8	113 ± 12
-M4A	"	0.17 ± 0.01	22.9 ± 1.1	6,231 ± 15
-M3A	"	0.17 ± 0.00	18.8 ± 0.9	5,780 ± 13
-M4B	"	0.25 ± 0.01	17.4 ± 1.5	6,307 ± 24
-M3B	cobalt blue	0.22 ± 0.00	9.5 ± 0.4	3,115 ± 7
-M2B	"	0.16 ± 0.00	1.1 ± 0.1	92 ± 5
-M2A	"	0.19 ± 0.00	15.6 ± 0.8	134 ± 5
-M1	blue	0.20 ± 0.01	0.9 ± 0.1	116 ± 9
-H2	cobalt blue	0.18 ± 0.01	2.5 ± 0.4	1,193 ± 33
-H1B	"	0.25 ± 0.02	-0.8 ± 0.1	245 ± 40
-H1A	"	0.23 ± 0.02	-1.7 ± 0.1	829 ± 40
-H1C	"	0.19 ± 0.01	-0.7 ± 0.1	1,366 ± 27
-G	"	0.24 ± 0.01	1.1 ± 0.4	370 ± 36
-N2A	"	0.21 ± 0.01	1.5 ± 1.9	689 ± 30
-N1A	"	0.26 ± 0.01	0.7 ± 1.2	102 ± 20
-N3B	"	0.24 ± 0.02	2.3 ± 0.8	848 ± 49
-N1B	"	0.21 ± 0.01	4.4 ± 2.9	1,109 ± 43
-N2B	"	0.27 ± 0.02	2.2 ± 0.3	177 ± 33
-N3D	"	0.25 ± 0.01	0.6 ± 0.4	152 ± 30
-N3E	"	0.31 ± 0.02	2.9 ± 0.9	284 ± 52
Mean and RMSD		0.26 ± 0.16	7.6 ± 7.3	7,493 ± 6,070[e] 223 ± 177[f]

Table 22a. concluded

Sample	Color	Th	Hf
-L2A	yellow	3.11 ± 0.05	3.00 ± 0.14
-L1A	"	2.67 ± 0.05	3.27 ± 0.15
-L3C	"	12.82 ± 0.18	4.17 ± 0.31
-L4B	"	9.24 ± 0.09	3.22 ± 0.17
-L2B	"	7.48 ± 0.10	3.23 ± 0.20
-L3B	"	8.30 ± 0.12	3.49 ± 0.24
-L1B	"	3.04 ± 0.05	6.55 ± 0.20
-L3A	"	5.45 ± 0.09	2.61 ± 0.24
-L2C	"	4.95 ± 0.07	3.03 ± 0.16
-J2A	"	1.52 ± 0.08	2.89 ± 0.22
-J2B	"	1.44 ± 0.12	3.17 ± 0.30
-J2C	"	2.86 ± 0.07	4.22 ± 0.22
-K1B	green	1.72 ± 0.04	3.04 ± 0.16
-K1A	"	1.73 ± 0.05	2.54 ± 0.17
-K2A	"	1.73 ± 0.06	2.61 ± 0.19
-K2B	"	1.76 ± 0.07	2.66 ± 0.20
-P2	"	3.50 ± 0.08	3.36 ± 0.22
-J3	blue-green	1.62 ± 0.08	2.10 ± 0.21
-M4A	"	2.75 ± 0.06	1.44 ± 0.16
-M3A	"	1.32 ± 0.05	2.29 ± 0.14
-M4B	"	2.80 ± 0.11	3.75 ± 0.37
-M3B	cobalt blue	1.55 ± 0.04	3.36 ± 0.17
-M2B	"	1.44 ± 0.05	2.71 ± 0.19
-M2A	"	1.55 ± 0.06	3.27 ± 0.21
-M1	blue	0.46 ± 0.09	3.18 ± 0.28
-H2	cobalt blue	1.45 ± 0.23	3.12 ± 0.69
-H1B	"	1.68 ± 0.30	5.15 ± 0.96
-H1A	"	0.97 ± 0.31	3.80 ± 0.97
-H1C	"	1.35 ± 0.20	3.41 ± 0.63
-G	"	1.83 ± 0.27	4.63 ± 0.82
-N2A	"	4.05 ± 0.13	4.09 ± 0.44
-N1A	"	2.85 ± 0.10	4.40 ± 0.34
-N3B	"	<2.61 ± 0.41	2.02 ± 1.23
-N1B	"	3.20 ± 0.16	3.40 ± 0.56
-N2B	"	3.39 ± 0.32	3.23 ± 0.97
-N3D	"	2.38 ± 0.25	3.25 ± 0.75
-N3E	"	2.35 ± 0.43	3.64 ± 1.28
Mean and RMSD		3.15 ± 2.58[g]	3.33 ± 0.91

Table 22b. Igbo Ukwu Class II:

Neutron Activation Analysis[a,h]

Sample	Color	Al (%)	Mn
IGB-T3A	greenish-yellow	5.86 ± 0.22	254 ± 15
IGB-T3B	" "	5.62 ± 0.29	643 ± 20
IGB-T3C	" "	6.31 ± 0.36	304 ± 21
IGB-R	cobalt blue	4.00 ± 0.69	4,398 ± 37
IGB-X	Indian red	6.23 ± 0.19	562 ± 11
IGB-U3	" "	5.44 ± 0.14	408 ± 18
IGB-U1	" "	4.45 ± 0.10	415 ± 15
IGB-U2	" "	4.62 ± 0.19	414 ± 12
IGB-P1	green	3.93 ± 0.18	376 ± 8
IGB-Q	blue-green	2.11 ± 0.05	233 ± 7
IGB-M5C	" "	4.42 ± 0.78	270 ± 20
Mean and RMSD[c]		4.82 ± 1.24	388 ± 133[f]

Table 22c. Igbo Ukwu Class III:

Neutron Activation Analysis[a,i]

Sample	Color	Al (%)	Mn
IGB-M5A	blue-green	3.18 ± 0.57	626 ± 27
IGB-M5B	" "	2.13 ± 1.00	353 ± 35
IGB-Z2	green	1.57 ± 0.91	1,045 ± 21

Table 22b. continued

Sample	Color	Na (%)	Cu	U
-T3A	gr-yel.	6.07 ± 0.06	3,390 ± 109	1.40 ± 0.07
-T3B	"	5.36 ± 0.06	3,462 ± 123	1.45 ± 0.07
-T3C	"	5.41 ± 0.06	2,772 ± 117	1.32 ± 0.07
-R	co bl.	7.54 ± 0.06	7,451 ± 148	1.94 ± 0.07
-X	IR	4.99 ± 0.06	3,012 ± 73	1.42 ± 0.03
-U3	"	7.65 ± 0.08	11,588 ± 153	1.44 ± 0.06
-U1	"	8.54 ± 0.09	12,564 ± 153	0.98 ± 0.05
-U2	"	8.58 ± 0.10	12,494 ± 180	0.97 ± 0.05
-P1	green	8.96 ± 0.07	8,807 ± 92	0.80 ± 0.03
-Q	bl-gr.	6.74 ± 0.09	7,140 ± 120	0.72 ± 0.03
-M5C	"	7.93 ± 0.08	7,943 ± 145	0.70 ± 0.07
Mean and RMSD		7.07 ± 1.43	7,329 ± 3,803	1.20 ± 0.39

Table 22c. continued

Sample	Color	Na (%)	Cu	U
-M5A	bl-gr.	10.43 ± 0.11	10,886 ± 210	0.96 ± 0.11
-M5B	"	12.25 ± 0.13	15,499 ± 273	1.14 ± 0.13
-Z2	green	10.68 ± 0.07	11,020 ± 133	0.91 ± 0.06

Table 22b. continued

Sample	Color	Ba	La	Co
-T3A	gr-yel.	72 ± 32	9.41 ± 1.59	12.75 ± 0.47
-T3B	"	99 ± 33	10.67 ± 1.59	16.22 ± 0.55
-T3C	"	77 ± 33	5.79 ± 1.59	11.04 ± 0.46
-R	co bl.	202 ± 23	9.94 ± 1.49	504.81 ± 4.73
-X	IR	93 ± 11	6.41 ± 0.60	39.90 ± 0.45
-U3	"	155 ± 22	8.93 ± 1.37	9.32 ± 0.28
-U1	"	212 ± 21	10.34 ± 1.25	9.45 ± 0.27
-U2	"	227 ± 23	13.46 ± 1.26	9.68 ± 0.26
-P1	green	214 ± 12	20.76 ± 0.83	7.34 ± 0.16
-Q	bl-gr.	207 ± 12	9.58 ± 0.63	4.30 ± 0.10
-M5C	"	153 ± 39	10.37 ± 1.71	5.43 ± 0.26
Mean and RMSD		155 ± 61	10.52 ± 3.97	12.54 ± 10.21[f]

Table 22c. continued

Sample	Color	Ba	La	Co
-M5A	bl-gr.	261 ± 57	9.96 ± 2.52	38.92 ± 0.78
-M5B	"	233 ± 69	10.44 ± 3.03	11.18 ± 0.56
-Z2	green	166 ± 22	10.39 ± 1.44	32.74 ± 0.51

Table 22b. continued

Sample	Color	Sc	Fe (%)	Yb
-T3A	gr-yel.	2.07 ± 0.05	4.94 ± 0.11	1.05 ± 0.19
-T3B	"	2.47 ± 0.06	5.14 ± 0.12	1.00 ± 0.21
-T3C	"	2.04 ± 0.05	4.48 ± 0.11	1.08 ± 0.20
-R	co bl.	2.90 ± 0.07	1.12 ± 0.05	1.12 ± 0.19
-X	IR	1.84 ± 0.02	2.49 ± 0.04	0.74 ± 0.07
-U3	"	6.85 ± 0.05	2.03 ± 0.05	1.01 ± 0.15
-U1	"	5.85 ± 0.04	1.98 ± 0.04	1.07 ± 0.13
-U2	"	5.92 ± 0.04	1.95 ± 0.04	1.13 ± 0.13
-P1	green	3.40 ± 0.02	1.75 ± 0.03	1.10 ± 0.08
-Q	bl-gr.	2.02 ± 0.01	0.60 ± 0.01	0.77 ± 0.04
-M5C	"	2.41 ± 0.03	0.71 ± 0.03	1.00 ± 0.12
Mean and RMSD		3.43 ± 1.85	2.88 ± 1.53[e] 0.66 ± 0.78[f]	1.01 ± 0.13

Table 22c. continued

Sample	Color	Sc	Fe (%)	Yb
-M5A	bl-gr.	3.53 ± 0.05	0.90 ± 0.04	1.26 ± 0.17
-M5B	"	4.44 ± 0.07	1.23 ± 0.06	1.66 ± 0.22
-Z2	green	3.04 ± 0.03	0.93 ± 0.03	1.19 ± 0.12

Table 22b. continued

Sample	Color	Cs	Ta	Sb
-T3A	gr-yel.	2.80 ± 0.30	0.49 ± 0.01	24.6 ± 1.8
-T3B	"	4.00 ± 0.40	0.53 ± 0.01	11.0 ± 1.0
-T3C	"	2.50 ± 0.30	0.42 ± 0.01	8.6 ± 0.8
-R	co bl.	4.30 ± 0.50	1.41 ± 0.01	24.2 ± 1.3
-X	IR	4.60 ± 0.10	1.00 ± 0.00	9.1 ± 0.5
-U3	"	2.40 ± 0.20	0.72 ± 0.01	22.0 ± 1.4
-U1	"	4.60 ± 0.20	0.81 ± 0.01	38.3 ± 2.3
-U2	"	5.00 ± 0.20	0.82 ± 0.01	36.5 ± 2.0
-P1	green	30.30 ± 0.50	1.14 ± 0.01	24.5 ± 1.2
-Q	bl-gr.	1.80 ± 0.10	1.69 ± 0.01	23.7 ± 1.1
-M5C	"	8.50 ± 0.30	1.02 ± 0.01	17.1 ± 0.9
Mean and RMSD		6.44 ± 8.12	0.91 ± 0.39	21.78 ± 9.96

Table 22c. continued

Sample	Color	Cs	Ta	Sb
-M5A	bl-gr.	2.50 ± 0.30	0.56 ± 0.01	23.0 ± 1.3
-M5B	"	2.60 ± 0.40	0.97 ± 0.02	23.4 ± 1.4
-Z2	green	9.20 ± 0.30	0.54 ± 0.01	27.9 ± 1.5

Table 22b. concluded

Sample	Color	Sn	Th	Hf
-T3A	gr-yel.	149 ± 21	2.22 ± 0.15	2.06 ± 0.41
-T3B	"	135 ± 23	1.82 ± 0.16	2.47 ± 0.46
-T3C	"	119 ± 22	1.81 ± 0.15	2.42 ± 0.43
-R	co bl.	223 ± 33	6.50 ± 0.17	1.78 ± 0.50
-X	IR	161 ± 7	1.48 ± 0.05	1.38 ± 0.15
-U3	"	167 ± 16	2.27 ± 0.11	2.43 ± 0.32
-U1	"	300 ± 15	2.48 ± 0.10	3.12 ± 0.29
-U2	"	322 ± 14	2.58 ± 0.10	3.03 ± 0.29
-P1	green	207 ± 7	4.82 ± 0.07	3.10 ± 0.18
-Q	bl-gr.	238 ± 3	2.35 ± 0.03	3.24 ± 0.12
-M5C	"	187 ± 9	2.11 ± 0.08	2.44 ± 0.25
Mean and RMSD		201 ± 66	2.77 ± 1.51	2.50 ± 0.60

Table 22c. concluded

Sample	Color	Sn	Th	Hf
-M5A	bl-gr.	263 ± 13	2.93 ± 0.12	3.00 ± 0.36
-M5B	"	180 ± 18	3.49 ± 0.16	3.24 ± 0.46
-Z2	green	142 ± 10	7.00 ± 0.10	2.93 ± 0.25

Notes to Table 22

a. All data are given in parts per million unless otherwise indicated. Trimmings are not included in the samples analyzed.

b. Imprecisely-determined elements (see Chapter 3) are omitted from this Table. Those which could be averaged for the Class gave the following means and root mean square deviations: Al, 0.7 ± 1.1%; Ca, 4.99 ± 2.26%; V, 45 ± 53 ppm; Cl, 0.7 ± 0.3%; K, 2.8 ± 1.6%; Sr, 0.2 ± 0.2%; Ga, 526 ± 352 ppm; As, 59 ± 78 ppm; Lu, 0.09 ± 0.07 ppm; Nd, 5.4 ± 2.3 ppm; Mo, 3.9 ± 2.8 ppm; Ho, 0.6 ± 0.5 ppm; Ag, 4.7 ± 13.6 ppm; Eu, 0.25 ± 0.09 ppm; Ni, 41 ± 40 ppm; Tb, 0.15 ± 0.05 ppm; Cs, 0.8 ± 0.8 ppm. As is not elevated in cobalt blue samples. Elements for which upper limits of concentration for the Class could be determined are as followw, given with an estimated representative counting error: Mg, 6 ± 5%; Dy, 36 ± 8 ppm; Cu, where not used as an additive, 0.09 ± 0.05%; In, 28 ± 26 ppm; Ti, 0.35 ± 0.05 ppm; Au, 0.27 ± 0.02 ppm; W, 9 ± 3 ppm; Ir, 0.047 ± 0.010 ppm; Cr, 106 ± 9 ppm; Rb, 120 ± 100 ppm; Hg, assuming none is lost in the reactor, 1 ± 1 ppm; Zn, 0.14% in high-cobalt samples, otherwise 200 ppm. Precisely-determined lanthanides omitted from the Table averaged as follows: Sm, 1.13 ± 1.17 ppm; Ce, 12.7 ± 2.8 ppm.

c. Root Mean Square Deviation (see Chapter 3).

d. In green and blue-green samples.

e. Where this additive is apparently used (in the case of Sn, > 800 ppm).

f. Where this additive is apparently not used (in the case of Sn, < 700 ppm).

g. Omitting IGB-N3B.

h. Imprecisely-determined elements (see Chapter 3) are omitted from this Table. Those which could be averaged gave the following means and root mean square deviations for the Class: Ca, 3.2 ± 1.7%; V, 36 ± 25 ppm; Cl, 0.5 ± 0.3%; K, 3.2 ± 0.8%; Sr, 0.05 ± 0.06%; Ga, 71 ± 125 ppm; As, 109 ± 70 ppm; Lu, 0.09 ± 0.05 ppm; Nd, 8.3 ± 3.9 ppm; Mo, 3.2 ± 2.3 ppm; Ho, 0.8 ± 0.5 ppm; Ag, 4.5 ± 4.0 ppm; Eu, 0.38 ± 0.11 ppm; Ni, 48 ± 52 ppm; Tb, 0.21 ± 0.06 ppm. As is not elevated in cobalt blue samples. Elements for which an upper limit could be determined are, with an estimated representative counting error: Mg, 4.6 ± 2.5%; Dy, 6.6 ± 1.1 ppm; In, 10 ± 9 ppm; Ti, 0.36 ± 0.04 ppm; Au, 0.14 ± 0.02 ppm; W, 1 ± 1 ppm; Ir, 0.007 ± 0.007 ppm; Cr, 104 ± 3 ppm; Hg, assuming none is lost in the reactor, 0.5 ± 0.4 ppm; Rb, 434 ± 30 ppm; Zn, 452 ± 20 ppm. Precisely-determined lanthanides omitted from the Table averaged: Sm, 1.62 ± 0.48 ppm; Ce, 20.27 ± 7.46 ppm.

i. Imprecisely-determined elements are omitted from this Table. Upper limits of each, given with an estimated representative counting error are: Mg, 0 ± 3%; Ca, 9 ± 4%; V, 150 ± 90 ppm; Cl, 1.3 ± 0.3%; Dy, 9 ± 2 ppm; K, 3 ± 1%; Sr, 0.2 ± 0.1%; Ga, 340 ± 230 ppm; In, 16 ± 12 ppm; As, 200 ± 60 ppm; Sm, 1.88 ± 0.03 ppm; Ti, 0.1 ± 0.1 ppm; Lu, 0.17 ± 0.08 ppm; Au, 0.24 ± 0.04 ppm; Nd, 25 ± 7 ppm; Mo, 6 ± 3 ppm; W, 2 ± 2 ppm; Ho, 3 ± 1 ppm; Ag, 12 ± 2 ppm; Ce, 26 ± 2 ppm; Cs, 9.2 ± 0.3 ppm; Ir, 0.004 ± 0.009 ppm; Cr, 51 ± 3 ppm; Hg, assuming none is lost in the reactor, 0 ± 1 ppm; Eu, 0.6 ± 0.2 ppm; Ni, 50 ± 30 ppm; Rb, 80 ± 15 ppm; Tb, 0.3 ± 0.1 ppm; Zn, 460 ± 20 ppm.

Table 23. Igbo Ukwu Class IV:

Neutron Activation Analysis[a,b]

Sample	Color	Al (%)	Ca (%)
IGB-V1	colorless	6.64 ± 0.32	13.94 ± 1.58
IGB-V2	"	7.84 ± 0.40	15.29 ± 1.80
IGB-V3	"	7.29 ± 0.46	15.43 ± 1.76
IGB-S2	green	7.37 ± 0.36	14.87 ± 1.49
IGB-S3	"	7.07 ± 0.43	11.83 ± 1.52
IGB-N3C	cobalt blue	6.56 ± 0.22	10.43 ± 1.41
Mean and RMSD[c]		7.13 ± 0.48	13.63 ± 2.06

Sample	Color	Mn	Na (%)	U
-V1	none	638 ± 14	2.81 ± 0.05	0.97 ± 0.06
-V2	"	447 ± 14	3.49 ± 0.05	0.76 ± 0.05
-V3	"	578 ± 17	3.71 ± 0.05	0.72 ± 0.05
-S2	green	492 ± 23	2.53 ± 0.04	2.49 ± 0.07
-S3	"	481 ± 23	2.67 ± 0.04	2.53 ± 0.07
-N3C	co bl.	7,928 ±141	2.28 ± 0.07	1.58 ± 0.05
Mean and RMSD		527 ± 79[d]	2.91 ± 0.56	1.51 ± 0.84

Table 23. continued

Sample	Color	Ba	La	Co
-V1	none	108 ± 22	4.47 ± 1.10	3.64 ± 0.17
-V2	"	176 ± 22	4.29 ± 1.03	3.94 ± 0.24
-V3	"	185 ± 20	3.52 ± 1.04	19.49 ± 0.54
-S2	green	150 ± 21	9.37 ± 1.11	6.31 ± 0.30
-S3	"	166 ± 20	7.73 ± 1.08	6.21 ± 0.22
-N3C	co bl.	617 ± 29	18.64 ± 0.99	1,104.80 ± 9.47
Mean and RMSD		234 ± 190	8.00 ± 5.68	7.92 ± 6.59[d]

Sample	Color	Sc	Fe (%)	Yb
-V1	none	0.93 ± 0.03	0.30 ± 0.02	0.95 ± 0.12
-V2	"	0.81 ± 0.03	0.27 ± 0.03	0.79 ± 0.14
-V3	"	0.91 ± 0.03	0.24 ± 0.03	0.74 ± 0.14
-S2	green	2.06 ± 0.05	2.48 ± 0.07	1.28 ± 0.19
-S3	"	2.07 ± 0.03	2.60 ± 0.06	1.25 ± 0.14
-N3C	co bl.	2.99 ± 0.10	0.66 ± 0.06	0.94 ± 0.21
Mean and RMSD		1.63 ± 0.88	0.37 ± 0.20[d] 2.54 ± 0.85[e]	0.99 ± 0.23

Table 23. concluded

Sample	Color	Cs	Ta
-V1	none	2.50 ± 0.20	4.62 ± 0.02
-V2	"	2.60 ± 0.20	2.25 ± 0.01
-V3	"	2.80 ± 0.20	0.36 ± 0.01
-S2	green	8.70 ± 0.40	2.09 ± 0.01
-S3	"	8.90 ± 0.30	2.04 ± 0.01
-N3C	co bl.	12.80 ± 0.80	1.64 ± 0.01
Mean and RMSD		6.38 ± 4.36	2.17 ± 1.39

Sample	Color	Th	Hf
-V1	none	1.19 ± 0.08	1.22 ± 0.19
-V2	"	1.19 ± 0.09	1.04 ± 0.23
-V3	"	1.26 ± 0.10	0.66 ± 0.25
-S2	green	3.80 ± 0.15	1.72 ± 0.37
-S3	"	3.92 ± 0.11	1.99 ± 0.27
-N3C	co bl.	1.71 ± 0.20	1.83 ± 0.68
Mean and RMSD		2.18 ± 1.32	1.41 ± 0.52

Notes to Table 23

a. All data are given in parts per million unless otherwise indicated.

b. Imprecisely-determined elements are omitted from this Table. Those which could be averaged for the Class gave the following means and root mean square deviations: V, 86 ± 80 ppm; Cl, 0.16 ± 0.10%; K, 3.2 ± 0.9 % ; Sr, 0.10 ± 0.08%; Ga, 166 ± 293 ppm; Lu, 0.09 ± 0.06 ppm; Nd, 6.7 ± 5.3 ppm; Mo, 3.9 ± 2.4 ppm; Ho, 0.7 ± 0.4 ppm; Eu, 0.27 ± 0.13 ppm; Ni, 33 ± 51 ppm; Tb, 0.17 ± 0.06 ppm. The following upper limits were obtained (with an estimated representative counting error): Mg, 2 ± 3%; Dy, 12 ± 1 ppm; Cu, 233 ± 110 ppm; In, 18 ± 23 ppm; As, 5 ± 3 ppm; Ti, 0.12 ± 0.05 ppm; Au, 0.05 ± 0.02 ppm; W, 4 ± 1 ppm; Ag, 2 ± 1 ppm; Sb, 1.2 ± 0.3 ppm; Sn, 110 ± 150 ppm; Ir, 0.01 ± 0.01 ppm; Cr, 27 ± 3 ppm; Hg, assuming none is lost in the reactor, 0.5 ± 0.5 ppm; Rb, 330 ± 60 ppm; Zn, 75 ± 60 ppm. Precisely-determined lanthanides omitted from this Table averaged: Sm, 1.22 ± 0.78 ppm; Ce, 16.83 ± 15.97 ppm.

c. Root Mean Square Deviation (see Chapter 3).

d. Where this additive is apparently not used.

e. Where this additive is apparently used.

PART IV. CONCLUSIONS

CHAPTER 10. CONCLUSIONS

Summary

This report has presented the results of neutron activation analysis of nearly four hundred glass samples, mostly beads, from archaeological sites in sub-Saharan Africa. On the basis of these analyses, a number of discrete groups of glass have been distinguished, groups which cross-cut sites. These results are summarized in Figure 1 (Chapter 1).

We have assumed that these groups reflect commonalities in the origin of the samples. The origin of a group was tautologically defined in Chapter 1 as "that entity, of whatever duration and distribution in space-time, which is responsible for the manufacture of a chemical (bead) group." We feel that the more specific and limited the chemical group, then the more restricted in space-time its origin must be.

At the present time it is not possible to name a very specific origin of any of our bead groups, and the general origins which we have suggested are summarized in Table 24. The best-traced group is Ife Group I. for which we have suggested a medieval European origin on two grounds: 1) that Group I, being a potassium glass, resembles glasses of medieval Europe and 2) that blue/yellow dichroic glasses are known from European contexts.

Although the potassium glasses point towards medieval Europe, the soda-lime glasses from southern, eastern, and west African sites point to no specific origins (see Table 25). They would fit into European or Near Eastern traditions of manufacture[24], although probably not medieval European.

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[24] Soda-lime glasses are well-known inside the Soviet Union as well (*e.g.*, Besborodov and Zadneprovsky 1967). Indian and Chinese traditions of glassmaking are dimly perceived in many respects. Our small knowledge is summarized by Dikshit (1969) and Ayers (1965), respectively.

The same vague assessment has been made of glass beads found in Southeast Asian sites: soda-lime glasses which could fit into Occidental or Near Eastern traditions of manufacture (Lamb 1965a, 1965b). Clearly further research is needed, especially a direct approach in the actual areas of possible manufacture, as distinct from the rather indirect approach taken here.

Remarks and Prospectus

The Classificatory Approach. It follows from our hierarchical classificatory approach and from our tautological definition of origin that the origin of a very general glass group may be so general that it includes factories which are discontinuously distributed in space-time. In fact factories may be combined into one origin in a manner which might appear absurd if the identity of the factories were independently known. This situation is merely a consequence of insufficient resolution between the products of two or more factories. Presumably, as chemical groups become progressively resolved through the accumulation of information, so will their origins become progressively resolved.

Our classificatory approach is suited to encompass an anticipated growth in resolution: as soon as sufficient information is available, any group may be subdivided, with a corresponding subdivision in its origin. When it becomes possible to specify origins on the basis of empirical data from factory sites, then our tautological definition of origin will have been outgrown and should be shed. In the meantime the classificatory approach allows for an expression of the relative status of chemical groups even though one is ignorant of their "absolute" status, that is, whether the groups represent single batches, single factories, combinations of factories, continents, and so forth.

A classification must be regarded as a heuristic simplifying device. Were all the glasses that ever existed fully analyzed and documented, they may not fit neatly into a single large classification or "tree" of glassmaking. As in many other fields of endeavor, systems of order are conveniences for the research who bears in mind the "complementarity between truth and clarity."

Sampling. Glasses have been analyzed for major and trace elements for years, but it has not been customary to follow the sampling procedures taken here, that is, to take multiple samples of objects that look sufficiently alike to be considered mass-produced.

This type of sampling makes possible an estimate of the degree of variability expectable in glass artifacts that visually appear to be "the same". We have found that the homogeneity in a group of like glass artifacts, although not great when compared to pottery or obsidian, is sufficient to allow the formation of mutually exclusive glass groups.

It was stated previously that the procedure of random sampling of African beads was not carried out here. In the study of the Mapungubwe oblates, of the M_1 beads, of trade wind beads, and of dichroic and corded beads, samples were taken of artifacts that looked alike. In two other cases it was the scope of material which was sampled. These were the beads of Igbo Ukwu and all the samples of Ife which were not dichroic or corded. Except for those samples which fell into Group I at Ife, little interpretation can be drawn from these samples, except perhaps that they might be interpreted as a control for our abilities to recognize chemical groups on visual cues. This situation does not contradict our basic hypothesis that chemical groups can be distinguished without regard to visual attributes, but it does indicate that chemical groups can be distinguished with an economy of effort if visual cues are considered. Of course, if our aim is a chemical characterization of all beads in general, then restricting our attention to a few visually recognizable styles of artifact introduces bias. However, if our aim is to study a particular artifact style or chemical group for the light which it may shed on an archaeological problem, then it is appropriate to focus on a few visually recognizable entities.

Proposed Comprehensive Classification of Glass Beads in Southeast Africa. We would like to propose, for further testing, a comprehensive classification of glass beads in Southeast Africa. This hypothesized classification is given in Table 26. In this Table we relate our hypothesized assemblages to Schofield's classifications (1938, 1942, 1943, 1958).

For west and central Africa, we propose no comprehensive classification because our research in this area has been restricted. However, we can say, on the basis of visual examination of many west African beads, that we do not find the Southeast African assemblages recognizably present in west Africa, and *vice versa*, except for nineteenth- and twentieth-century material.

The Study of Glass. As repeatedly indicated in our earlier chapters, especially Chapter 2, very broad ethnic units, such as "India", are inappropriate molds in which to cast a detailed study of glass manufacture, on account of the international character of glassmaking. Chemical categories in glass need not reflect broad ethnic units at all. For practical purposes of tracing origins, soda-lime glasses must be regarded as nearly pan-cultural and pan-chronological.

What is needed is a very great increase in resolution within such general categories of glass. Until precise resolution is attained, precise chemical categories like some of our groups cannot be placed in perspective within general chemical categories, because the latter are not known in comparable detail. The successful tracing of origins of glasses awaits extensive, highly resolved, comparative, empirical research.

There are two obvious ways to increase resolution in the study of glass manufacture. The first is the comparative study of entities that are restricted in time and space. It has been customary to study broad entities, such as medieval cathedral windows. It is now time to focus on highly resolved subunits within such entities.

The second way to increase resolution is by analyzing for trace elements. However, we fail to see how analysis for trace elements can be confidently interpreted unless carried out on samples restricted in provenience in time and space.

Factory sites might be considered the natural units of glassmaking. A single factory site can be more or less delimited in time and space. Tests of relationship of neighboring factories can be carried out if factory sites are investigated. It would be desirable to estimate the degree of chemical variability at one factory relative to the variability between factories. For the study of these and other fundamental questions, it is to factory sites that we should like to see future research turn.

Table 24. Summary of Suggested Proveniences

Approximate Dating[a]	Glass Group	Glass Type	Possible Provenience, <u>assuming correct dating</u>
11th-20th centuries	TWBCG	soda-lime	unknown, perhaps Europe and/or Near East
9th-17th centuries	Ife Class II	"	"
11th-15th centuries	Mapungubwe Chemical Group	"	Near East
11th century	M_1 Chemical Group	"	"
9th-12th centuries	Ife Chemical Group I	potassium	Europe
9th century	Igbo Ukwu Classes I-III	soda-lime	Near East
9th century	Igbo Ukwu Class IV	potassium	Europe

[a] A group need not span the entire range given as its dating, but may belong to an unknown range within the span.

Table 25. Chief Glass Types Commonly Expectable for Selected Regions in the Medieval Period

	Medieval Near East (and areas of Europe in contact with same)	Medieval Europe	Medieval India
glass types:	soda-lime	potassium	uncertain
opacifier:	tin, lead	tin, lead	uncertain

Table 26. Proposed Comprehensive Classification of Glass Beads in Southeast Africa

Visually Recognized Assemblage or Series	Chemical Group	Schofield's Classification
1. Unreheated canes of Gokomere, Zhizo Hill, etc. (Robinson 1966, Summers 1967)	none	none
2. Mapungubwe oblates	Mapungubwe	First Series (1938, 1942)
3. M_1 beads, garden roller beads	M_1	Blue-green cylinders and garden roller beads (fabricated cylinders) (1938, 1958)
4. Trade wind beads, Series A heirloom beads	Trade Wind Bead	Second Series (1938, 1942), Arab beads (1942), coastal beads (1958), some ancestral beads (1938, 1958)
5. The eighteenth-century series (e.g., Mjelele Valley Burial Assemblage, includes Series B heirloom beads, Series B at For Jesus, "white crackle" beads, many transparent beads)	none, under study, high antimony frequent	none
6. The nineteenth-century series (e.g., Dingaanstadt Assemblage, see Schofield 1958)	none	Third Series (1938), Zulu beads (1958), Lifecane beads (1958), beads of Malawi (1943)
7. The twentieth-century assemblage (includes many nineteenth-century styles, and beads like Type Z3 of Igbo Ukwu (Shaw 1970)	none	none

APPENDICES

Appendix 1. Provenience of Beads:

Details Not Given in Text

Sample	Provenience and Excavator
FJE-A4-3	Fort Jesus, VII, AK4e, Kirkman
FJE-remainder	" " X, A9D, Kirkman
KIL-IR14	Kilwa, Per. II, SEB, ZLL, SS(2), Chittick
KIL-IR11	" " E of GM, Area K, SS(1), Chittick
KIL-HKCV3	" Per. IIIA, HK, CV(3) , "
KIL-GM2	" Per. IIIA-B, GM, SW, SS, W 100 cm., "
KIL-GRY9	" " " " " " "
KIL-GM1	" " " " " " "
KIL-IR13	" " " " " " "
KIL-IR12	" Per. IIIB, LW, K, SS(1) , "
KIL-GRY12	" " " " " "
KIL-GRY8	" " " " " "
KIL-LWK1	" " " ", SS(2) , "
KIL-LWK2	" " " " " "
KIL-GRY10	" Per. IV, KK, MBV(3) , "
KIL-GRY11	" " " " "
KIL-GRY1	" " " " "
KIL-MBG	" " ", MBG(3) , "
KIL-MBG1-5	" " ", MGB, soak pit , "
KIL-IR15-18	" " " " " "
KIL-GRY4-7	" " " " " "
GER-1A-E	" Per. V, Gereza, A(2) , "
GER-2A-E	" " " " "
VOH-all	Vohémar, No. 48-2-24, Poirier and Millot
NYA-GRY16	Nyangwe Fort (Inyanga), XXXIVb, 30-40" near wall, No. 7472a, Summers
LUA-1-9	Luanze, L, 1(2), Garlake
KAO-183G-J	Kaole House, 2C, SW Room, below possible floor, Chittick
KAO-172A	" , Tr. A1(4), "

Appendix 1. continued

Sample	Provenience and Excavator
GED-all	Gedi, below floor of tomb, Kirkman
MFL-4	Mapela, JNF A(3), Garlake
DAM-1	Dambarare, 64, CES 62 1/2, skull, Garlake
DAM-2-3	" , 75, CES 6S-, "
MAT-all	Matendere, midden, No. 5950, Caton-Thompson
MAK-1	Makoli, Type I, v. Riet Lowe No. 33/59, Inskeep
MAK-2	" , Type II, " " "
LUS-1	Lusaka Cave, " 18/40, Clark
MOD-all	Modjadje's location, " 33/37, Krige (not excavated)
STA-all	Santa Ana (in Manila), Fox
POR-all	Porac, "
MAN-all	Manunggol Cave, Chamber B, Palawan Is., Fox
KAB-all	Kab'wan Cave, Lipuun Point, " "
BUT-all	Butong, Fox
CAL-all	Calatagan, Fox
SIR-3295	Siraf, No. 3295, B, (386), S69-70, Whitehouse
ITA-1030	Ita Yemoo, Tr. XIII, (3a), Willett
ITA-920	" , 8B(2), "
ITA-855	" , Tr. XIII, (1B), "
ITA-1386	" " , (19B), "
ITA-1035	" " , (4A), "
ILE-233a	Ilesha, grave, rt. arm of Skeleton I, Willett
OLD-27	Old Oyo, surface, "
OSS-1	Onikroga (Ossi River Site), found by R. Hide in a "cache" of beads, no archaeological data
KOU-1	Koumbi Saleh, No. MAL-49-195, Mauny and Thomassey
GAO-1	Gao, surface, from medieval town, No. MAL-50-13, Mauny
ORU-206a	Orun Oba Ado, Pit 11, Willett

Appendix 2. Cobalt Colorants in Glass

Cobalt colorants have occasioned some discussion in the literature (Garner 1956a, 1956b), and it may be appropriate to comment on this topic here.

It is not possible routinely to diagnose the source of a cobalt ore used in a glass from a pattern of trace elements in the glass. In order to do so, not only must a trace element pattern diagnostic of some cobalt source be demonstrated to exist, but also one must show that the pattern is recognizable in the finished glass. These are formidable requirements.

It may be doubted whether there exist many patterns of trace elements associated with cobalt that point exclusively to single mines or sources. The same cobalt ores can occur globally, and different cobalt ores can occur in the same mine. Certainly the burden of proof lies on the person who asserts such associations.

The cobalt ores are usually grouped into three broad chemical types: arsenic-containing ores, sulfur-containing ores, and product-of-oxidation ores (Young 1962, Andrews 1962). Some ores are chemical compounds; others are mixtures. The arsenic- and sulfur-containing ores are the commonest (U.S. Bur. Mines 1950).

The product-of-oxidation ores are worthy of comment in the present context. The ore erythrite has a red color, which may aid in its identification in historical texts, such as in a Persian description of a faience technique (Ritter 1935:35). Another product-of-oxidation ore is asbolite (asbolane), a special class of wad, an ore of cobalt rich in manganese, as discussed in Chapter 8.

Besides occurring as above, cobalt often occurs in manganese ores (U.S. Bur. Mines 1950, Andrews 1962, Young 1962), and also in association with several metals such as copper and zinc. Indeed, cobalt ores almost never occur along in nature: their mining is almost always the by-product of some other mining endeavor.

It has been stated in the glass literature (Garner 1956a, 1956b) that cobalt ores occurring in the Near East are arseniferous while those occurring in China are manganiferous. These generalizations should be regarded with the greatest caution. They rest upon no analyses of ores, and they were put forward essentially without documentation (Garner 1956a, 1956b).

In point of fact, little is published of cobalt ores in the Near East. Recent authoritative works do not list this region as even a minor supplier of cobalt, nor do they systematically discuss this region. Only some miscellaneous information is reported (see U.S. Bur. Mines 1950, Andrews 1962).

In Garner's work, the evidence which was supposed to characterize Near Eastern, arsenical, non-manganiferous (or very low manganese) cobalt colorants in use from antiquity until c. the fourteenth century A.D. consisted of a single piece of glass, for which it was assumed that the colorant was locally obtained, which contained a trace amount of manganese, and in which arsenic was never detected (Garner 1956a, 1956b).

Garner's high-arsenic, low-manganese prescription for Near Eastern cobalt colorants seems poorly substantiated, not only because of inadequate reported analyses, but also because of the range of possibilities in the global distribution of cobalt ores. Arsenical ores of cobalt occur abundantly outside of the Near East and manganiferous ores of cobalt occur abundantly outside of China. It has not been proven that manganiferous ores of cobalt cannot occur in the Near East or that arseniferous ores cannot occur in China. The finding of ancient Near Eastern glasses appearing to contain manganiferous cobalt colorants (Sayre 1963, 1964) need demand no cobalt source exotic to the Near East. The same may be said of manganiferous cobalt blue glasses found in the Occident (Sayre 1963, 1964), and the reverse may be said of arsenical cobalt ores appearing to occur in Chinese glazes (Garner 1956b, Banks and Merrick 1967).

Clearly caution is required when considering generalizations about ores, and appropriate notes of caution are indeed implicit in more recent studies (Sayre 1963, 1964).

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