6.1. General

A work of art reflects, not only the progress of civilization, and degree of culture, but also the extent of technological perfection attained, at the time they were actually made. As the one aspect, is intimately interlinked with the other, scholars are no longer satisfied with a knowledge of the artistic and cultural background of those times, or of the socio-historical and ethnologic advancement only; but are equally eager to know, as much, as possible, concerning the chemical composition, and scientific analysis, of the metallic works of art then existing, as well. Such data, is of great interest and value to research workers, investigating in those fields of study. While a good deal is known, about the artistic value of early copper and bronze objects found, in different parts of Gujarat, little or no information is available, concerning their chemical, spectrographical, and metallurgical analysis. This lacunae, induced the author to undertake such an investigation, and study the techniques used by the metal workers of ancient Gujarat, in turning out beautiful works of metallic art, and craft and which have attained world wide attention. Such data would prove of very
great value, not only to Indologists, but to art critics and art historians as well.

6.2. Data obtained from analysis

This analysis was undertaken, to find out the ingredients, in the metal composition of such articles, and determine the characteristic features of their artistic and archaeological interest, and find out if possible, their approximate period in the history of Gujarat, and the places where they were made. As many as 108 objects have been examined, in the course of this comprehensive study.

6.3. Main constituents

COPPER being the main constituent of the objects under reference large number of them contain high percentage of copper which occurs rarely in low percentage (Graph no.1).

Tin: This metal is generally (but not always), one of the main constituents of the antiquities and works of art under reference, but the quantity found was highly variable. High percentage of tin (upto 22 per cent) occurs rarely, while comparatively large number of objects under reference frequently contain low percentage of tin (Graph no.2). In some bronze alloys, the frequent occurrence of zinc, along with tin, is rather remarkable; and such alloys are known as zinc-bronzes. Of the eight metal objects, belonging to the Chalcolithic proto-historic period of Rosdi, only one object (ring) was made of bronze alloy, the tin content being
11 per cent. Of the four objects belonging to pre-Gupta era discussed under section B of the Chapter III, two are of bronze alloy, the tin content being the same (15.8%) in both cases. None of the three Mahudi Images, are made of bronze alloy. Of the six images from Lilvadeva, only two are made of bronze, in which tin content varies from 5.9% to 7.5%. Of the 15 Akota images, two are made of bronze alloy, in which the tin content varies from 8.1% to 8.7%, while eight images are made of zinc-bronze alloy, with tin content varying from 3.2% to 8.1%. In the 20 copper plate grants, the tin content varied from 0.4% to 2.5%. But only one (Gadhia coin) of the 24 coins analysed, contains lead-bronze alloy having 21.9% tin. All the metallic art objects, of the Post-mediaeval period under reference, have tin content varying from 0.2% to 1.6%. It is worth noting, that as time passed, the tin content in these articles gradually decreased.

Zinc: The percentage of zinc varies from 2 per cent to 40 per cent in objects analysed. Zinc occurs rarely up to 40 per cent; while the greater number of objects under reference contain 9 per cent of zinc (Graph no.3). Zinc is the main constituent, of all the Post-mediaeval art objects; and it is one of the major constituents, of some of the Mediaeval metal figures. Of the six Lilvadeva metal figures analysed, three are made of lead-brass, in which the zinc content varies from 6.8% to 20.6%; and of the 15 Akota metal objects, 8 are made of
zinc-bronze, in which the zinc content varies from 2.6% to 12.8%. Of the Akota metal figures analysed, only two are made of lead-brass, and two are made of real brass alloy. In the lead-brass alloys of the Akota objects, zinc content varies from 10.4% to 10.7%; while in real brass alloys zinc content varies from 10.1% to 16.32%. The zinc content, in zinc-bronze images from Mahudi varies from 3.50% to 12.8%. There is practically no zinc, in objects made during the Protohistoric Chalcolithic period, and in those made during and before the age of the Imperial Guptas. It is also absent in composition of the plate grants under reference, and of the coins analysed. Here, it is necessary to make a special mention, of the Indo-parthian female figure, of the second century A.D.; which contains zinc as its main constituent. Being of foreign origin, it is possible, that the zinc found in it, was obtained from the mixed copper-zinc deposits, occurring in certain parts of the Roman Empire; and intentionally or unintentionally, it reached the melt, while copper was being made. There is, however no doubt, that it is a brass alloy of foreign origin. The analysis of the Post-mediaeval metal objects has shown, that of 7 objects analysed, 2 are made of lead-brass alloys, and the remaining 5 of real brass; and the copper-tin alloys, are totally absent, in this group of metal figures. The zinc content, in the lead-brass alloys of the post-mediaeval figures, varies from 13.8% to 18.5%; while the zinc content, of the real brass alloys, varies from 28.9% to 39.9%. Tin is
present, in the composition of this group of metal figures, only in very small quantity, which may be regarded as impurities. It is possible, that the price factor, must have played an important part, in the change which took place, from the use of antique copper to brass; and in this change, copper-tin alloys and zinc-bronze alloys, formed intermediate stages. At present, tin is 10 times costlier than zinc; and therefore, wherever possible, tin must have been replaced by zinc in copper alloys.

**Lead:** The distribution of lead is rather interesting. The large number of objects under reference contain very low percentage (1 to 2 per cent) of lead which occurs rarely in high percentage. Hardly one object contains lead more than 25 per cent (Graph no.4). The lead content, in Chalcolithic protohistoric metal objects discovered from Rosdi, varies from trace to 1.20%; while in the metal objects of the Pre-gupta Age, it varies from trace% 6.4%. The metal objects from Mahudi, contain lead ranging from 2% to 7.6%, while the Lilvadeva metal figures, contain lead ranging from 4.5% to 13.6%. The lead content of the Akota metal finds, vary from 2.2% 15.7%; while in the copper plate grants, it varies from 0.9% to 2.30%. On the other hand, the coins contain lead ranging from 0.1% to 20.8%. The lead content in one Gadhia coin, was 20.8%. In the Post-mediaeval metal figures, it varies from 0.5% to 9%; but in the bronze alloys of the Chalcolithic Proto-historic period, it is present only in the form of impurities. In the metallic objects made in historic
times, lead may have been added purposely, because it lowers the melting temperature of an alloy, and thus improves the rheological properties, and mould filling capacity of the melt. With the progress made in the field of metallurgy, and in the technique of furnace designs, the need for using higher lead content was not felt. For this reason, lead content is absolutely minimum, ranging from 3% to 0.5% in Post-mediaeval figures dated from 15th century A.D. to the 18th century A.D. In other words, the percentage of lead gradually diminishes, to the very minimum, from the 15th century A.D. onwards. The mediaeval objects, including coins, are conspicuous by the presence of high lead content. The maximum use of lead in copper alloys was made during the mediaeval period, in the history of Gujarat.

6.4. Secondary and trace elements

A qualitative, and quantitative determination of some secondary and trace elements, is rather instructive.

Iron: Among the secondary constituents, present in these alloys, in small quantities, iron content is not generally significant; because, this metal can easily reach the melt, in different ways, as uncontrollable impurity.

Nickel: The Nickel contents of objects examined, is generally small, and varies from trace to 1.6%. But one object, belonging to Lilvadeva, and one to Mahudi, contain Nickel upto 4.2% and 3.8% respectively. These are of course, exceptional cases.
Arsenic and antimony: As for arsenic and antimony, these are rarely present in the composition of early copper and bronze objects of Gujarat. In the spectrographic analysis, of the 15 objects, not a single spectrogram, revealed the presence of arsenic and antimony. A few (three) objects of the Chalcolithic proto-historic period, contained Arsenic in traces. Two objects belonging to Lilvadeva, and four to Akota, contain Antimony in traces. Out of 24 coins analysed, only two reveal the presence of antimony in traces. These two elements may be considered as unusual impurities.

Aluminium: This element, is present, in a majority of the objects under reference, as an impurity. Five out of the seven objects, of the Post-mediaeval period, contain Aluminium, ranging from trace to 0.6%. Of the 24 coins analysed, 20 contain Aluminium, ranging from trace to 1.1%. Of the 20 copper plate grants, all of them contained Aluminium, ranging from trace to 3.4%. 14 out of 15 of the metal finds from Akota, contain Aluminium, ranging from trace to 2.7%. While 5 out of 6 metal objects from Lilvadeva, contain Aluminium ranging from 0.7 to 2.6%. All the metal figures from Mahudi, contain Aluminium, ranging from trace to 5.7%. Of the 4 objects belonging to the pre-Gupta era, only one contains Aluminium, up to 0.5%. No aluminium whatever, has been found, in any of the objects belonging of Chalcolithic proto-historic period.

Gold: This element is rarely present, except in a very few cases. These few instances, were due to gilding, done purposely, for making offerings.
6.5. Near similarity with modern standardised alloys

This review, based on the results obtained so far, from the scientific analyses of antique metal objects from Gujarat, has yielded a good deal of interesting information, concerning the development of metallurgy, in Gujarat, in the course of more than 3000 years of its history. On the basis of an analysis of the main alloying elements, it could be shown, that some of the alloying types, found therein, are very similar to modern standardised non-ferrous alloys, in so far as their composition is concerned.

6.6. Early metal and early alloys

The investigations also showed, that the earliest metals used in making of artifacts, objects of self-adornment and worship, were more or less pure copper; and rarely copper-tin alloys. The metal, generally used, during the Gupta period, was a kind of impure copper; and in the Post-Gupta periods (7th to 8th centuries A.D.), it was copper-tin alloy. In the metal objects, of the latter mediaeval period (9th to 14th centuries A.D.), we find a transition from the use of copper-tin alloys, to copper-tin-zinc alloys, which are known as zinc-bronze, and thereafter, to copper-zinc-lead alloys known as lead-brass. In the Post-mediaeval period, particularly after 14th century A.D., we find a marked transition from lead-brass (copper-zinc-lead alloys) to real brass (copper-zinc-alloys). The use of zinc, instead of tin, in the copper alloys of the
the post-mediaeval period, was made probably, for reasons of economy in the cost involved, and the prevailing prices of zinc and tin.

6.7. Stages of development of copper technology in Gujarat

The Chalcolithic proto-historic objects, found in Gujarat, are mostly made, of more or less pure copper. In this particular period, objects made of bronze (an alloy of copper and tin) are very few and far between. When we turn to the Pre-Gupta period, we find the use of impure copper, and high tin bronze alloys, in making objects of art; and of imported brass alloy, in preparing foreign icons.

An analysis, of objects made during the classical Gupta age, shows, that they were made of impure copper, containing a little tin, as a deoxidising agent. In this copper, more of lead (hardly more than 8 percent) than of tin (hardly more than 4 percent) was used; and is a characteristic feature of that time (Graph no.5). The scarcity, and non-availability of tin, in India, during that period, may have been another reason for not using tin for purposes of alloy. The metal figures, of 5th and 6th centuries A.D.; from Mahudi, Akota, and Lilvadeva; revealed a composition of copper, devoid of major alloying elements. The Gupta style metal figures, of the Post-Gupta period, are mostly made of copper and tin alloy and in this alloy also more lead (hardly more than 13 percent) than of tin (hardly more than 9 percent) was used (Graph no.6). The metal figure (7th century A.D.) in the Cleveland Museum referred
to in Chapter IV, has also confirmed this. In all probability, by the 7th century A.D., trade relations had been established between India and Western Asia. Arab traders began to settle in parts of Western India, particularly Gujarat, during the 7th century A.D., and their presence, intensified trade and commerce, between India and Western Asia. This removed the scarcity of tin, in the Indian market. With the import of tin in India, copper-tin alloy began to be used in the making of objects of art and of worship. This continued from the 7th century A.D. onwards. But during the 8th century A.D.; a remarkable event occurred, in the history of Chemistry in Ancient India; viz. that copper could be converted into artificial gold, i.e. a gold-like metal by heating copper, along with Calamine (zinc ore). The extraction of zinc, from Calamine (Zinc ore) was probably carried out successfully in India, during 10th century A.D. and onwards. Zinc, was used as a metal, in India, during the period from 1000 to 1300 A.D.; and about the 14th century A.D., it was extracted commercially, from zinc ore in North India. The 'Rasaratnakara' of Nagarjuna (7th or 8th centuries A.D.) mentions, that copper could be converted into brass (which was regarded at that time as artificially prepared gold), by heating it with Calamine (a zinc ore), and Carbonaceous matter. Brass, prepared from copper and Calamine (zinc ore), was mistaken for gold. The method of preparation of brass, as mentioned in the 'Rasaratnakara' of Nagarjuna, has been repeated in 'Rasarnavatantra'
(12th century A.D.) which also mentions, the method of extraction of zinc, from calamine (zinc ore), and colouring of copper by means of Calamine, to turn it into gold /208/. Till that time, brass obtained from Calamine and copper, was regarded as gold. The 'Rasendrachudamani' of Somadeva (12th century A.D.), mentions a process for making a brass like alloy of copper, tin, zinc and lead /209/. This literary evidence shows, that during the period between 9th century and 10th, or early part of 11th century A.D., Indian chemists (Alchemists), were engaged in the production of an alloy made of copper, tin, and zinc, by roasting bronze alloy with Calamine; and such an alloy, is scientifically known as zinc-bronze, which is a transitional stage, between bronze and real brass. From the analytical data, shown in the Table no.11, under Metal objects from Akota; and Table No.8, under metal objects from Mahudi; it has been found, that there was an alloy known as 'Zinc-bronze' as stated above; and such an alloy (zinc-bronze), was used, for making objects of art and worship, during the period from 9th to 10th or early 11th century A.D. It is to be noted that, earlier zinc-bronze alloys, contain more tin than zinc; while later zinc-bronze alloys, have more zinc than tin, in their composition (Graph no.7). But during this transitional period, in the history of Indian Metallurgy, we find in the Lilvadeva objects, definite evidence, of the production of lead-brass alloys, in the making of objects of art and worship. Out of the seven post-mediaeval figures under reference only
two are made of lead-brass alloys; while of the fifteen
objects from Akota lead-bronze alloy occurs only in two cases.
Of the six Lilvadeva images analysed, three are made of lead-
brass alloys, and one of those has the date 1037 A.D. inscribed
on it. In this lead-brass alloy zinc occurs hardly more than
20 per cent and lead occurs hardly more than 13 per cent; while
tin occurs hardly 2 per cent (Graph no.8). This clearly shows,
that the metal workers of Lilvadeva, were successful in
evolving, and producing, a better alloy, made of copper-zinc-
lead, which is known as lead-brass, somewhere in the middle
of the 11th century A.D. This further indicates, that the
Lilvadeva metal working communities, were able to extract
zinc from Calamine, (zinc ore), and therefore, the credit
for preparing a kind brass, known as lead-brass alloy, goes
to the metal working communities of Gujarat, and particularly
of Lilvadeva, as early as the middle of 11th century A.D., a
time when the whole world was totally ignorant about such an
alloy. The metal workers of that time, however, did not know,
how to make real brass alloy viz., an alloy of copper and zinc.
This process was not known, until the 15th century A.D. when
we find the presence of real brass alloy, in all figures under
reference of the post-mediaeval period, dating back to the 15th
century A.D. onwards. Lead-brass alloys, were used right upto
the 14th century A.D., and as time passed, and with the improve-
ment of furnace design, and acquisition of greater skill, in
the use of metallurgical techniques, and realisation of the
composition of real brass as an alloy of copper and zinc, the importance of lead was minimised, and the percentage of zinc content was increased. From this, it is clear, that lead-brass alloys, were in use, much earlier than real brass alloys. Post-mediaeval brass objects, with dates inscribed on them under reference, further confirm, the lead and zinc relation in the preparation of brass alloys (Graph). If we compare the lead-brass alloys, of the mediaeval time with real-brass alloys of the Post-mediaeval time, we find the gradual decrease of lead content on the one hand, and the gradual increase of the zinc content, on the other. Real brass alloys of the period between 15th and 18th centuries A.D., have minute quantities of lead in their composition, while tin is present in negligible quantities; and the zinc content increases, with the considerable decrease of lead content (Graph no.9). From this study, it is reasonable to infer, that the Mediaeval Period in Gujarat, was the transitional period, in the history of Metallurgy, and it saw a gradual change in the use of alloys, from bronze to zinc-bronze, then to lead-brass alloys, and finally to real brass alloys. The advancement, in real brass metallurgy, was accompanied by the absence of lead, or by presence of negligible quantity of lead. The fact, that brass is an alloy of copper and zinc, is clear from the statement in Bhavamisra's Bhavaprakasa, that brass is a semi-metal (upadhatu) of zinc and copper; because, it is derived from those two metals. The
The renowned Bhavamisra, the author of Bhavaprakasa, lived about the time of the Emperor Akbar. Bhavamisra, in the first part of his treatise, "Bhavaprakasa", devoted one complete chapter on the subject of Dhatu-Ūpadhatu (i.e. metal and metal alloys). He states, that there are seven 'Ūpadhatu's', and included bronze and brass amongst them.

Bhavamisra mentions, several terms synonymous with Brass, and two different types of brass, are referred to in the couplet:

पितलं त्वादकूर्तं स्यादारी दीर्घशक्ष्यलि।
ग्राजरीलिंद्रारीलि: काम्प्तिना विज्ञायियि च। ॥ ८१ (६९)॥

In the 1st line, of the above couplet, Bhavamisra shows, that brass has four Sanskrit names viz. Pital, Arkuta, Aor, and Riti. In the same line, he explains, that, when the heated alloy in the crucible, turns Red in colour, this brass is known as "Rajariti"; and when it assumes a yellow colour, the metal is known as "Brahma Riti".

In the 1st line of couplet No.70, quoted below, Bhavmisra, explaining the properties of brass, states, that this metal, is only an alloy of copper and zinc.
These lines have been taken, from Bhavamisra's "Bhavapra-
kasa-Purba Khanda", translated by Shri Girija Sankar Maya
Sankar Sastri, published by Sastu Sahitya Vardhaka Karyalaya,
Ahmedabad and Bombay, 1955, pp.409 & 112.

These references, show very clearly, that real brass
was known to be an alloy, of zinc and copper, as early as
the 15th century A.D., and, during that period; this brass
was a popular metal, which was commercially produced.

As far as the metallic composition of Gujarat coins is
concerned, we find three types of alloys, used in making them.
They are (1) silver-copper alloys, (2) silver-copper-lead
alloys and (3) copper-tin-lead alloys. Apart from these alloys,
more or less pure copper and silver, were also used in ancient
Gujarat, for the purpose of making coins.

The composition, of copper plates analysed so far, revealed
no significant alloyed metal. They are all composed of impure
copper, which contain, appreciable quantities of tin and lead,
and such a metal, is suitable for the purpose of engraving
inscriptions. As far as the methods of extraction are concerned,
it may be said, that refining processes employed, in ancient
times, were very gradually developed, until the middle ages, and,
except for a few minor changes, it can be said, that even up to the beginning of the twentieth century, there was this same slow development directed towards obtaining, greater recovery of metal, from a given quantity of ore.

6.8. Different kinds of ores, and sources of obtaining them

The analytical data indicate, the kinds of ores employed, in the production of ancient metals of Gujarat. From the analytical data of 108 objects analysed so far, the author found, various kinds of ores, employed by the metal workers of ancient Gujarat, in the production of metal artifacts, objects of art, adoration and worship, for minting coins; and for fabricating plate grants. The metal objects of earlier dates, were made from oxidized ores, and native copper. Sulphide ores; were also used extensively, in ancient times. The most extensively used Sulphide ore, was chalcopyrite (Cu$_2$S$\cdot$Fe$_2$S$_3$), and the most frequently used oxidized ores, were malachite, azurite and chrysocolla. In only one case (fasting Sakyamuni), the use of native copper, was detected.

It is possible to infer, that the ancient artisans and metal workers of Gujarat, must have obtained their raw materials, such as copper, lead and zinc ores mostly from the Rajasthan copper belt, as well as from 'Ambamata' copper belt of North Gujarat, which are the richest, and nearest sources, for the people of Gujarat. But the possibility of using
'Ambaji' copper ores, by the ancient metal workers of Gujarat, is stronger than Rajasthan copper-ores-particularly in the Mediaeval period, and thereafter. So far as tin is concerned, it was imported from abroad, probably, from Northern Iran. Silver, was also imported more or less, from outside India; probably from the Roman empire, and middle eastern countries.

6.9. Evidence of trade and cultural relations with other countries

"If analyses show, that objects found in a given region, were made from a raw material that occurred only in some distant region, the existence of commerce or trade, in either the raw material or the objects, is thus indicated". As already mentioned, in the foregoing pages under section B of Chapter III, the composition of a copper image (Fasting Sakyamuni) found in Gujarat clearly shows, that it was fashioned, from a kind of native copper, which shows close similarity with the Zanskar valley (near Kashmir) - native copper. This native copper, could have been transported directly, or by successive stages of barter or trade, from the Zanskar Valley of ancient Taxila, and could have been fashioned, at or near the source of the raw materials; and then transported, in the same manner, to ancient Gujarat, from Taxila. The Mathura style Buddha figure, and the Amravati style bronze plaque, also stand as evidence of cultural and commercial relationship, between Gujarat, Mathura in the North, and Amravati in the South.

Further evidence of trade and commerce, is indicated by the
Indo-Parthian female figure described in the Section B of the Chapter III. This figure, is made of a brass alloy, of foreign origin, and this was brought to Gujarat, from Greece or Rome. Gujarat has been the field, of conquering and settling races, like Bactrians, Greeks, Hunas coming from West (Greece etc.), Western Asia, and Central Asia, from times before Christ, and after Christ. The contacts of Greeks and Romans, with the people of Gujarat, is evidenced, by numerous Greeco-Roman finds in Gujarat, as already stated in the Section B under Chapter III. It is therefore quite possible, that during the Pre-Gupta age, brass alloys were imported to places like Taxila and Gujarat, from Greek and Roman kingdoms.

The use of silver, for minting coins in Gujarat, from the time of early Punch-marked coins (about 500 B.C.) down to the Mediaeval age, provide further evidences, of strong cultural, commercial and trade relations, between ancient Gujarat and Roman kingdoms, and middle-eastern countries, where silver occurs plentifully. Silver ores, are extremely limited, in India. In fact, there is no silver ore as such in India. According to R.C.Majumdar, (the classical accounts of India, 1960, Calcutta, p.300) wine, porcelain, perfumes, and silver metal, were imported to Western India, from the Roman Empire. As already stated, R.N.Mehta, has found several evidences of such commercial relations, between the Roman Empire, and ancient Gujarat, during the Kshatrapa period, in his excavations at Devnimori and Samalaji. Besides, ancient Gujarat,
always cultivated close cultural, commercial and trade relations, with ancient Rajasthan, for various reasons, and particularly, for getting copper and other base metal ores. The analytical data, sufficiently demonstrated, that Rajasthan copper and other base metal ores, were employed in ancient Gujarat, for making various objects of art, worship and utility.

Gujarat also imported tin, which is scarcely available in India, from northern Iran. The occurrence of tin, in small quantities, in the Dharwar district, Palanpur State in Rewa Kantha (Narukot) and in the Hazaribagh district of Bihar, were quite insufficient, even if these tin deposits were worked in ancient days (which is not certain). Tin was definitely imported from abroad, particularly from the regions of Hindukush (Paropamisu), Khorassan and the Karadagh hills in the northern part of Iran, where tin occurs plentifully, and the tin ores, of these places, were the most likely source, wherefrom, ancient India, particularly ancient Gujarat, drew her main supply of tin, through trade and commerce.

6.10. Detection of Forgeries

Information, concerning the place and date of manufacture of an art object, is of great interest and importance, to archaeologists, and museum curators. But the problem of determining, the date of such objects, has become a complicated affair; because, modern copies or fakes of ancient metal
objects, are available plentifully. To ascertain, whether an ancient metal figure, is genuine or a fake, is, therefore, as difficult, as determining the correct date of its production. Both are puzzling problems, before Indologists and Museum curators, who not infrequently, seek the help of Chemists, for examination of doubtful objects. Some important features of fake objects or modern copies are:

1. The object may be an exact copy of the original,
2. it may be an object embodying features, very much like the genuine one, but having different workmanship and ageing effect,
3. it may be a genuine object, with spurious additions, such, for example, as engravings, inscriptions, and even inscribed date etc. to enhance its value,
4. two or more unrelated fragments, of genuine objects, may have been assembled, and joined together, with modern adhesives, or modern soldering materials, and the whole, covered with surface accumulations, giving ageing effects. Thus, a fake or a copy, may have one or more than one, of these features combined together. It must therefore be remembered, that stylistic aspects, motifs, and inscriptions or palaeographic study in themselves, cannot be the sole test for deciding matters like authenticity, and date of production, concerning these objects. It is very necessary, first of all, to find out, methods of detection of fakes or copies of original, before making any attempt to determine, the date of any ancient metallic object. To arrive at proper decisions, proto-types must be studied,
along with the suspected objects. A genuine object of art, expresses the spirit, of the period it belongs to, and therefore, the artistic expression, which is characteristic feature of that period, will be generally lacking in fakes and modern copies thereof. There are certain characteristic chemical indications, which are both useful, and reliable, for detection of copies or forgeries. These chemical indications, may be grouped into three categories: (1) Structure or composition of corrosion products; (2) the relationship of corrosion products to underlying metals and (3) composition of the metal itself. An object of antiquity, may not be genuine, if it bears a very thin layer of corrosion products. Similarly, objects not having heterogeneous layered structure of corrosion products of any thickness, may not be as old as they are claimed to be. A microscopic study, often reveals, a characteristic layered structure, when a polished cross-section is examined, under required magnification. Such layered structures, cannot be obtained, by rapid action of corrosive solutions, used for producing artificial patina. Even a genuine object of antiquity, cleaned drastically, will reveal internal grain boundary corrosion, when a polished cross-section, is examined under a microscope. In short, the absence of characteristic structures, and minerals, and the presence of modern materials, often indicate, that the corrosion products, on a given object, are not those of ancient
times. In genuine objects of antiquity, the dividing line between corrosion products, and the metal itself, is never well defined; but always irregular; whereas, in forgeries, it is always very sharply defined, and takes the form of ordinary coating. A distinction, between a genuine object, and a copied one, can also be made, in different ways, from the chemical composition of the metal. "The presence of some modern metal, such as aluminium, as a major component of an alloy, is of course a clear proof of forgery. But the presence of some metal, known in ancient times, may be suspicious, if it is present in some object, alleged to be from a period or a region, in which this metal, was not yet in use" /210/. For example, bronzes of certain periods in the history of Gujarat, are conspicuous by the absence of zinc; and if zinc, is found as a major ingredient, in alleged genuine 'bronze' figure of that period, the presence of zinc, may be considered to be an indication, of forgery. "Even if the major components are qualitatively correct, for an alloy made at a given period in a given region, the presence of these components in unusual proportion, may be a good reason for suspicion. Finally, another general indication of forgery, is the absence, and near absence, of certain impurities /211/. These special type of impurities, which form impurity patterns of ancient copper alloys or a copper, are usually absent in modern copies. Thus the role of trace elements, in the detection of forgery, is very great, indeed. Trace elements can
provide, a better clue, to solve the problem of fake or forgery, than any other means. For confirmation, a number of scientific examinations, with the help of chemical drop tests, chemical analysis, spectrographic analysis, metallographic examination, ultra-violet fluorescence, X-ray shadowgraph examination, and infra-red radiation, etc., should be carried out. All these, when applied, may reveal, hidden facts of significance, not available by other means; and which would have otherwise, remained concealed for ever.

6.11. Determination of the date of ancient metallic figures

In these days of fakes and forgeries, dating of metal figures made of copper, and copper alloys, is a difficult problem. There are many factors to be considered, for the determination of date of manufacture of such an object. If the region of its origin, is known, the date of its manufacture, may often be roughly estimated by comparing the results of an analysis of that object, with the results of analyses, of a series of objects, of known dates, from the given locality or region. "Very often, the composition of such a series of objects, will be found to fall, into two or three chronological groups, that are constitutently and widely different, from each other, in composition; but with no consistent, or significant, difference within these groups."/212/. In view of the analytical, and metallographical studies, of more than 100 metal objects from Gujarat, with dates ranging from Proto-historic
Chalcolithic to the post-mediaeval period, the author is able to follow, the entire development that took place in Gujarat in the realm of metallurgy of copper, and copper alloys.

Except South India, where metal figures are made invariably by solid casting, it is noticed, that the earliest metal figures dated up to Pre-Gupta age from North India, were made by solid casting. From the study, carried out by the author, it is evident, that the Chalcolithic proto-historic objects, the Pre-Gupta Gandhara style Sakyamuni figure, the Pre-Gupta Mathura style Buddha figure, Pre-Gupta Amravati style dancing girls figure—all these objects found in Gujarat, are made of solid cast. The Indus Valley Dancing girl figure, and the Gandhara Buddha figures, discovered at Taxila, are all made in solid cast. In Gujarat, the appearance of hollow cast figures, with clay core armature, began during the Gupta, and subsequent periods. Hollow casting, is an advanced method of casting, which suggests, a knowledge of economy in the use of metals. Hollow casting, is based on the technique of saving metal, from unnecessary wastage, and thus preventing the image from becoming unnecessarily heavy. The hollow casting technique, is undoubtedly, an advanced stage of metal casting, and hence a later technical development. The hollow casting technique, was persistently adopted, during the Gupta, Post-Gupta and Mediaeval periods in Gujarat. But during the Post-Mediaeval period, however, solid casting
technique, was practised, in making of the metal figures.

From a meticulous examination, of the chemical composition of metal figures from Pre-Gupta, to the Post-Mediaeval period of Gujarat, we find six or seven chronological groups. Proto-historic Chalcolithic objects, are mostly made of more or less pure copper; and objects made of copper-tin alloys, belonging to that period, are rarely found in Gujarat.

The Pre-Gupta Gandhara style Sakyamuni figure, is made of natural copper; while the Pre-Gupta Mathura style Buddha figure, and the Amravati style dancing girls figures, are made of copper-tin alloys, of almost identical composition. Barring the aforesaid chemical data, of the Pre-Gupta metal objects, the composition of the Gupta period metal figures, and those of the subsequent periods, are interesting, from the point of view of chronology.

The metal figures of Gupta period, as in the case of certain Gupta style figures from Akota (Sr.No.1 of Table No. 11), Lilvadeva (Sr.No.1 of Table No.9), Mahudi (Sr.No.1 of Table No.8), are composed of copper, which is more or less impure, and this type of copper, contains tin and lead, in small quantities, tin content being present below 5%, and lead content below 10%. The compositions, of the figures belonging to the period from 7th century A.D. to 14th century A.D., can be classed into three chronological groups:

1. Bronze alloy
2. Zinc-Bronze alloy
3. Lead-brass
alloy. The Gupta style figures, of the Post-Gupta age up to 8th century A.D., as in the case of two Lilvadeva figures (Fig. 2 and 3 of Table No. 9) and two Akota figures (Fig. 4 and 5 of Table No. 11), are composed of copper and tin alloy (i.e. bronze). The figures of the Mediaeval period between 9th and early 11th centuries A.D., as in the case of certain Mahudi figures (Sr. No. 2 & 3 of Table No. 8) and Akota figures of (Sr. No. 2, 3, 6, 7, 8, 9, 10 & 11 of Table No. 11), are composed of copper-tin-zinc alloys (Zinc-bronze). The earlier zinc-bronze alloys, however, contain more tin, than zinc; while the later, zinc-bronze alloys, contain more zinc than tin. The figures, of the still later periods i.e. the period between the middle of the 11th century A.D. and the 14th century A.D., as in the case of certain Lilvadeva figures (Sr. No. 4, 5, & 6 of Table No. 9), the Akota figures (Sr. No. 12 & 13 of Table No. 11) and certain Post-Mediaeval figures (Sr. No. 1 & 2 of Table No. 19) are composed of copper-zinc-lead alloys (i.e. the lead-brass alloys). Lead-brass alloy occurs in the figures having inscribed dates written on them. In these figures zinc is hardly present more than 18 per cent; lead is present below 10 per cent; while tin is present hardly more than 1 per cent (Graph no. 10).

The Post-Mediaeval figures, dating from the 15th to the 18th century A.D., are all of copper-zinc alloys, known as real or true brass. Earlier real brass alloys, contain
little lead (above 1% and below 3%), while the later real brass alloys, contain lead below 1%. The tin content of the earlier real brass alloys is hardly more than 1 per cent while in the later real brass alloys tin is present in negligible quantity i.e. below 1 per cent (Graph no.11). Thus in view of above facts, the real brass alloys, may be dated broadly to a period between the 15th and 18th century A.D. The lead-brass alloys, may be dated to a period, between the middle of the 11th and the 14th century A.D., and the zinc-bronze alloys, to a period, between 9th and 10th or at the most earlier part of the 11th century A.D. On the other hand, the bronze alloys may be dated to a period between the 7th and 8th centuries A.D. Metal figures containing impure copper, having tin and lead in appreciable quantities, may be dated to a period between the 4th and 6th centuries A.D. These conclusions are applicable, in so far as metal figures, from Gujarat, made of copper and copper alloys, are concerned.