BRITISH MUSEUM Occasional Paper No 15

Aspects of Tibetan Metallurgy

edited by
W. A. Oddy
and
W. Zwalf

Research Laboratory and Department of Oriental Antiquities 1981

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BRITISH MUSEUM OCCASIONAL PAPERS

British Museum, Great Russell Street,
London, WC1B 3DG.

Executive Editor: G.B. Morris, BA

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Occasional Paper No. 15, 1981:
Aspects of Tibetan Metallurgy.
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ISBN 0 86159 014 7

ISSN 0142 4815

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Preface

Metallurgical analysis and the study of metal technology as an aid to the fuller understanding of artefacts are nothing new, but their extension to the material cultures of south and south-east Asia has, for the most part, been a feature of more recent times. The attention paid to metal composition by Sir John Marshall during his Taxila excavations in the first quarter of this century was a significant contribution though the results did not become fully known until 1951. The consideration of metallurgy in the Indian and Far Eastern fields was not entirely neglected before the Second World War, but the provision of analyses and experimental evidence in any quantity still lay in the future.

The publication by Dr Otto Werner (1972) of 350 analyses, mainly from the Indian subcontinent and south-east Asia, may be said to have begun a new era, providing a model for comprehensive presentations of basic metallurgical data. Werner was able to draw on material in the Museum fuer Indische Kunst in Berlin and thus pointed to the part that could be played by museums having substantial collections and access to modern laboratory resources.

The editorial preface to Werner's book pointed out that an art historical and archaeological framework, even in relatively unstudied Oriental cultures, can usually group objects approximately in time and place. This permits the scientist to test the groups by means of analysis and if his results are consistent with the original groupings, or can improve on them, analyses may contribute towards establishing a provenance or attribution for problematic pieces.

On the whole, however, well defined groupings in time or place are not possible with Tibetan objects and the programme of analysis reported in this volume was initiated in an attempt to establish whether metallurgical studies could contribute towards an art historical classification.

The reasons for the exceptional difficulty in dating Tibetan art are many. Tibet has, from the standpoint of art history and archaeology, never been systematically explored - with the distinguished exception of the surveys undertaken by Giuseppe Tucci between 1927 and 1948. Tibetan donors, artists and craftsmen rarely dated their offerings and castings; when they did it was usually by the unsatisfactory Tibetan cyclical calendar which yields only a series of otherwise unsupported dates at fixed intervals. Inscribed objects rarely provide secure links with a datable historical personage or event and the testimony of Tibetan literature on styles and metallurgy can still not be brought into a satisfactory relationship with observed fact. Although Tibetan art depends on models and influences from China and the Indian world this fact does not often help to date it, for the stages by which Tibetan art developed from its sources are not clear. It is probable that the prestige of certain images and traditions resulted in antiquarianism and imitation and, in the absence of dated objects, it is particularly the combination of hybrid styles and antiquarianism that can inhibit the working out of an art historical sequence. The large numbers of usually undocumented Tibetan metal images in collections outside Tibet thus remain hard to date.

To help remedy this very unsatisfactory state of affairs 113 objects from the British Museum's collections, together with another eight items then in private hands, were submitted to analysis in the hope that certain patterns might emerge as an aid to the localisation of styles and establishing a chronology. The enterprise has several antecedents to which grateful acknowledgement must be paid. Werner's work (1972) provided a general model and stimulus as well as analyses of some objects from the Tibetan and culturally related regions of Nepal, Bhutan, Sikkim and Ladakh. Another stimulus lay in the sampling of Tibetan bronzes being undertaken for the Musée Guimet by the Laboratoire du Louvre. Some provisional results have been announced and fuller information promised (Béguin, 1977: 61). It is very much to be hoped that, even if the sampling may have proved in some respects inconclusive, a publication of analyses will appear in due course to add to the total number being made available. A further advance in this field has come from a contribution to an exhibition catalogue, *Das Bild des Buddha* (Uhlig, 1979), in which Dr Josef Riederer reported the results of some 37 analyses, by atomic absorption. A small number of these led him to distinguish between the composition of early western and south Tibetan metal images. Another contributor to that catalogue, Herr Ulrich von Schroeder, has also become known for his interest in the composition and production of metal images, and his (at the time of writing) forthcoming *Indo-Tibetan Bronzes* promises to be a remarkable publication, not only as a repertory of metal images containing basic information required for research, but also as a source of analyses. The editors had the good fortune of becoming aquainted with Herr von Schroeder's work ahead of publication and are indebted to him for his generous permission to incorporate some of his results in the various contributions to this Occasional Paper.

In addition, the editors had for some time been in close contact with the work of Dr Erberto Lo Bue, whose wide-ranging researches into all aspects of the production of Tibetan and Himālayan metal images will be evident from his contribution to the following pages. It is with particular pleasure and gratitude that the editors acknowledge his generosity and cooperation in making available chapters and material from his doctoral thesis which have been adapted to form a major part of the present publication. The opportunity to discuss all aspects of the present publication with Dr Lo Bue, whose interest in the subject is of long standing, has greatly benefited his fellow contributors.

The selection of images for analysis was made from a wide range of material. Preference was given to images known or believed to have come from Tibet - a recorded provenance was an inducment to include throughout; the so-called Sino-Tibetan group was given wide representation to the point of including an image believed to be of the enigmatic Sino-Arakanese type (Gutman, 1979); a few images in Nepalese and Indian styles were also chosen, particularly where it was though possible that they had been made in Tibet or for Tibetan use. Since the analyses were intended, if possible, to help define Tibetan bronzes, objects with uncertain attributions as well as some 'duplicates' were also sampled. The decision to illustrate all the pieces analysed is mainly due to the uncertainty, already explained, surrounding the dates and origins of Tibetan art. Readers will be in a better position to draw their own concusions from the analyses if they are not entirely dependent on the brief catalogue descriptions and attributions offered here.

The editors have at all stages of this enterprise been favoured with the advice, support and scholarly assistance of Mr John Lowry and they wish to express their deep sense of obligation to him.

They are also grateful to Mrs Anthony Aris who, as M-L de Labriffe, published a pioneering account of Nepalese metal casting and has generously provided photographic illustrations for the present volume. All otherwise unacknowledged photographs are the work of John Heffron and his colleagues, to whom warm thanks are due.

W. Zwalf
Department of Oriental Antiquities

W.A. Oddy
Research Laboratory

THE COPPER ALLOYS OF TIBET AND THEIR BACKGROUND

P.T. Craddock

Tibet has been closely governed by its geography and geology. Lying in the centre of Asia between the great civilizations of India and China it has nevertheless always been remote. Major trade routes such as the Old Silk Road ran well to the north but, even so, merchants, teachers and invaders from China and India have dominated its cultural and technical development. The inaccessibility of the country into modern times has precluded all but a little archaeological exploration. Traditional Tibetan technical literature is a little better known (see below, pp.37-67) but it is still meagre compared with the available wealth of early Indian, Chinese and Islamic works on metallurgy. However, Tibet was probably not an innovating centre of metallurgy in medieval times and any statement on early Tibetan metallurgy must rely on the careful study of the surviving texts of the surrounding cultures and the scientific examination and analysis of artifacts. All the objects described here are from the collections of the British Museum except eight modern Nepalese images included because their production is well recorded. (These modern statues are from two private collections which are, at present, on loan to the Victoria and Albert Museum). The new analyses are compared below with previous work by Riederer (1979), Werner (1972) and von Schroeder (1981) in an attempt to describe the purity and possible provenance of the copper, the range of alloys in use, and the technology by which they were produced in Tibet and its immediate neighbours.

By the time Tibet enters firmly recorded history in the 7th century A.D. all the principal non-ferrous alloys encountered in this study had been in use for many hundreds of years. Thus, before studying the Tibetan analyses in detail, it will be useful to summarise the history of non-ferrous metallurgy in the East generally.

Copper

Copper deposits occur widely throughout the mountainous regions of the East from Iran to China; for example, easily worked deposits of malachite and azurite (copper carbonates) occur just south-west of Lhasa (Jackson, 1976) (Fig. 1), and their exploitation was the subject of government supervision in the 18th century. The presence of workable deposits however, does not prove that they were exploited in the past, although many deposits do show signs of early, but as yet usually undateable, working. Instead one has to rely on the examination of copper artifacts for the prehistoric period, coupled with documentary evidence for the medieval and later periods. Thus copper is known to have been used from at least the seventh millennium B.C. in Iran, and both Iran and Afghanistan provide abundant archaeological evidence of early copper mining and smelting which were certainly carried on throughout the medieval period and later (Allan, 1979). For example al-Bīrūnī in the 11th century A.D. described varieties of Iranian copper ores including those especially useful for producing brass (Krenkow, 1936: esp. p.245), and Mactear (1894) described the primitive local copper production then practised in Iran (see below p. 6). The use of copper had spread into Afghanistan and Baluchistan by the fourth millennium B.C. (Muhly, 1973), as shown by material from Mundigak (Casal, 1961), and into the subcontinent around the end of the third millennium B.C. (Agrawal, 1971: 115). (See Bhardwaj, 1979: appendix II for a comprehensive list of ancient copper mining and smelting sites in India). There can be no doubt that copper production has been carried out there ever since, and descriptions of metallurgical processes are common from the 7th century A.D. onwards and detailed contemporary accounts of primitive mining and smelting exist for the 18th and 19th centuries (see below p.2ff) (Bose, 1971; Ray, 1956).

To the north, copper production spread through Trans-Oxiana by the early fourth millennium B.C. at the latest (Masson and Sarianidi, 1972), but apparently did not reach China before the beginning of the second millennium B.C. (Childe, 1953) or north-east Asia until later still (Chard, 1973). However, there is now good evidence for the independent discovery of metallurgy in South-east Asia in the very early copper and bronze castings found in burials at Non-Nok and Ban Chiang in Thailand (Solheim, 1972). The part played by South-east Asia in the dissemination of metal throughout the Far East has not yet been assessed, but already Agrawal (1971) has suggested that the origins of the Indian Copper Hoard Culture metallurgy may lie in South-east Asia. The spread of copper metallurgy here and elsewhere is largely documented by finds of stratified metal artifacts in excavations, but no archaeological investigation of early mines or smelters has yet been reported in the East on the scale of those recently undertaken in Europe and the Middle East (e.g. Craddock, 1980; Conrad and Rothenberg, 1980). We do, however, have quite detailed contemporary descriptions of primitive copper smelting in India and Iran as practised in the 19th century and we can safely assume that identical processes were employed to produce the copper of the Tibetan images.

Copper ores usually occur as the sulphide (chalcopyrite) or mixed with iron sulphides, commonly known as pyrites. Towards the surface these sulphides will have weathered to carbonates (malachite, azurite) or to oxide (cuprite); occasionally metallic copper occurs naturally in these surface deposits and was especially prized by the Tibetans (see below p. 22 and Lo Bue p.37). The oxide and carbonate ores can be relatively easily reduced to metal with charcoal at about 1200°C. However, when using sulphide ores it is first necessary to roast them in air (calcination) to get rid of the sulphur. If the sulphur content is high enough this may be achieved simply by setting fire to heaps of broken up ore and letting the sulphur burn itself out as was the practice at Rio Tinto in Spain until well into this century (Nash, 1904). The resulting copper oxides can then be smelted as for oxide and carbonates.

No matter how carefully the ore is sorted the copper minerals will contain appreciable quantities of other material (known as gangue), principally silica from oxide ores, or iron oxides from the calcinated sulphidic ores. This gangue must be removed if the smelt is to proceed, and this is accomplished by liquifying it with a flux to form a slag which can then be run off. Iron and silica form a relatively low melting glass, and thus iron oxide is added as a flux to remove the excess silica from oxide ores, and silica (clean sand) is added to remove the iron from the sulphide ores. (See Bachmann, 1980, for a full discussion of ancient slag.) If the reducing conditions in the furnace are extreme and an oxide flux is used, some of it will be reduced to metallic iron which dissolves in the forming copper (Tylecote and Boydell, 1978; Craddock, 1980). A high iron content is characteristic of much Indian and Tibetan copper from the time of the Copper Hoards onwards. Some cultures produced very iron-rich copper; up to 9% was reported in the Nalanda material analysed by Lal (1956) and the famous colossal Buddha from Sultanganj also has several percent of iron in the copper (personal communication from N.J. Seeley). As iron oxides are only added to oxide ores to remove the silica this suggests that malachite was the usual ore smelted in India. However, the 19th century descriptions of smelting in the East are all of sulphidic ores suggesting the malachite had been largely used up by then. The early 19th century description of copper smelting at Khetri in Rajasthan first published in *Gleanings in Science* (anon., 1831) is well known and has been repeated in both Ray (1956) and Bose (1971), although perhaps the best description and discussion are given by Percy (1861). (Figs. 2 and 3).

> An excellent account of the native method of copper-smelting at Singhana in India (lat. 28° 5' N and long. 75° 53' E) was published at

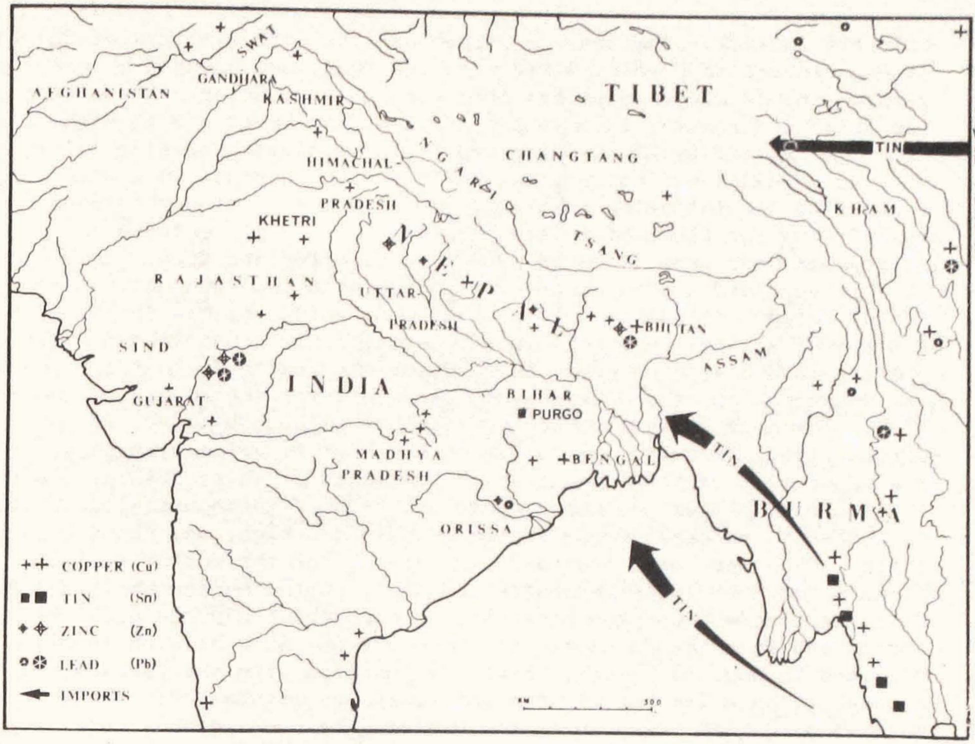

Figure 1 : Important metal deposits around Tibet. (Based with kind permission on U. von Schroeder, *Indo-Tibetan Bronzes*, 1981 with emendations and additions.)

Figure 2 : Copper smelting at Khetri (from Ball, 1881).

Calcutta in 1831. The ore was copper-pyrites with a matrix of quartz. It was reduced to powder, mixed with cow dung, and kneaded by hand into sausage-shaped pieces 5 inches long and 1¼ in diameter. These were sun-dried and roasted in circular heaps 4 feet broad and 1½ high. The fire was lighted in the evening and on the following morning the roasted ore, which had a red colour, was smelted with charcoal in a small blast-furnace of the following construction. A quantity of common sand was spread upon the floor of a circular hut, and in the centre a small hollow was made from 12 to 15 inches in diameter and from 2 to 3 deep. In this was laid a stratum of fine yellow sand and then another of ashes. A sand bottom, or hearth, was thus formed, which, by the action of heat and the alkali in the ashes, would become firmly consolidated. Two clay nozzles were placed on opposite sides of the hearth and a third one mid-way between them, the fourth side being left for the escape of the melted slag. The nozzles were connected together with moist clay, so as to form a little circular wall a few inches high to serve as a basement for the upper part of the furnace which consisted of three annular vessels of fire-clay placed one above another. Each of these vessels was about 15 inches in external diameter, 9 or 10 inches high, and about 3 inches thick. They were used over and over again, but the bottom of the furnace required to be reconstructed daily in the manner above described. Holes were made round the basement, through which a poker might be introduced into the furnace, and there was one such hole obliquely directed through each nozzle near its junction with the furnace, so that a clear passage for the blast might always be maintained. These holes were stopped with clay, which could easily be removed when necessary. The blast was produced by three ordinary goat-skin bellows, of which one was attached to each nozzle. They were worked by men, women and even children, all Mussulmans. Before the furnace was charged, a quantity of charcoal was burned in the hearth in order to dry it. It is reported that in the day (9 or 10 hours) a single furnace would consume 3 maunds of charcoal (1 mun or maund = 80lbs avoirdupois), during which time were added 2½ maunds of the sausage shaped pieces of ore and cow dung and 2 or 3 maunds of iron-slag, which was required as a flux, and was brought from a distance. Four persons were employed at each furnace - perhaps a man with his wife and two children - who received for their services 10 rupees per month. The head man prepared the furnace and occasionally relieved one of the party working the bellows of which all three were kept constantly in action. On the morning after the first melting, the mass of copper which had collected in the hearth was taken out and sent to the refining furnace. This is described as a small vessel which received the blast of a single bellows. The refined copper was cast into narrow, shallow, clay moulds, each about 1 foot in length. The ingots thus obtained weighed 2 or 3 seers each (1 seer = 2lbs avoirdupois). The copper was lilac-coloured and brittle. Copper smelting must have been carried on in this locality during a very long period, as the slag had accumulated to such an extent as to form a line of small hills several hundred feet in length and from 30 to 60 feet in height. There were four isolated stone bastions built on one of these artificial mounds.

(Anon, 1831)

Ball's description of the process 50 years later is almost identical except in the final stage of the process, of which he records:

It was then remelted and refined in an open furnace under a strong blast from bellows and cast into small bars or ingots which were subsequently removed to the Mint and cut up and fashioned into coins. The ore was said to yield only from 2½ to 7½% of metal. The quality of the metal

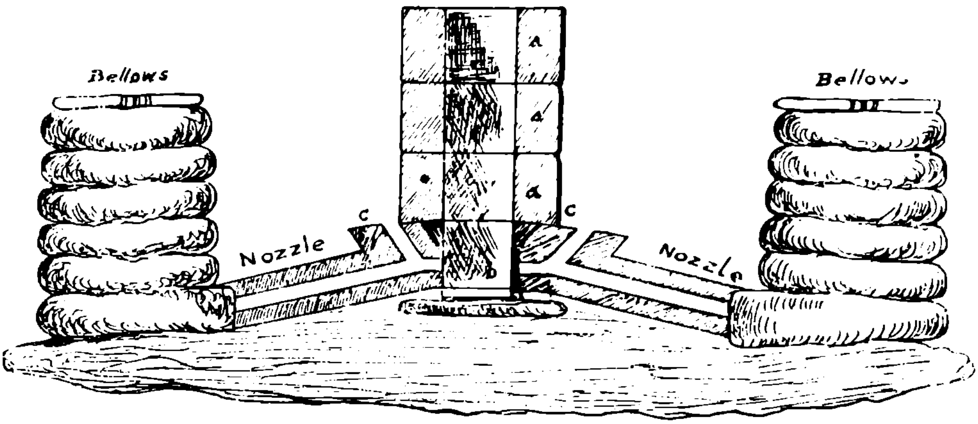

Figure 3 : Section through Khetri furnace (reproduced with kind permission from Bose, 1971).

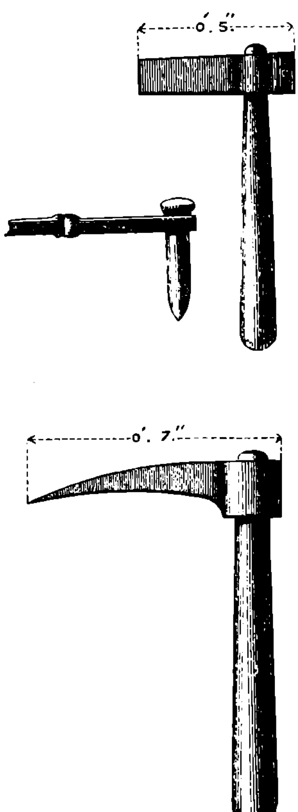

Figure 4 : 19th century copper mining implements used in Sikkim (from Percy, 1861).

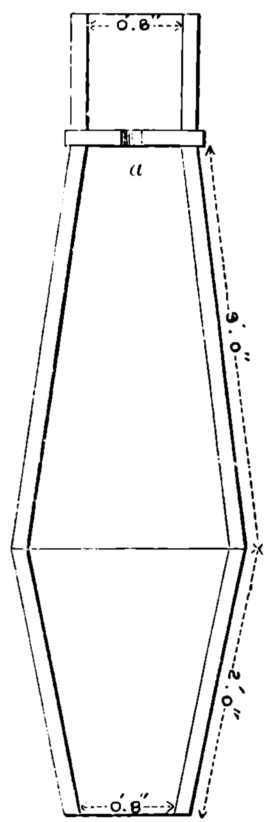

Figure 5 : Plan of tye used to launder Sikkim copper ores (from Percy, 1861).

is said to have been inferior to that of Basawar, this being attributed to the use of the iron slag as a flux...

The use of iron slag as a flux is explicable if it had a high iron oxide content. However most primitive iron slags also have a high free iron content and this would readily transfer itself to the metal, hence the inferior and brittle nature of the copper commented on by the authors. Mactear recorded a similar process still in operation at Abbasabad, Iran, in the 1890's.

In the case of the sulphide ores, after hand-dressing, the ore is roasted in a furnace built of mud, forming a cone about 7 feet in height, in which holes are pierced for the admission of air. At the bottom there is an opening closed with a door through which the roasted ore can be drawn and the draught regulated; about 35 per cent of fuel is required. The smelting is conducted in a small blast furnace, its dimensions being about 18 inches in depth and 9 inches in diameter. The blast is produced by the usual type of Eastern Bellows [presumably concertina bellows are meant here]; the chief peculiarity being that instead of the tuyere passing through the wall of the furnace near the base, it consists of a clay pipe led down the centre of the furnace; lasting for one operation. There are two tap-holes, one for the slag and the other for the copper. The copper produced is of poor quality and is not suitable for anything but the rougher classes of work

(Mactear, 1894)

A more sophisticated method of treating copper pyrites ore is *matte* smelting. The history of this process is obscure, but it was probably used in Bronze Age Europe (Tylecote, 1976: 29-30), although there is not much evidence until the post-medieval period. The process usually involves roasting in air to remove some sulphur, smelting with silica to remove some of the iron as a ferrous silicate slag and to produce a molten iron-copper sulphide *matte* which is run off and cooled. The broken-up *matte* is resmelted to remove most of the remaining iron and the purified copper sulphide is subsequently roasted in air to produce impure copper. Finally the excess oxygen is removed by 'poling', that is, stirring green saplings and twigs in the melt. A primitive version of this process was carefully observed and recorded in the 1850's in the Mahanuddi valley, Sikkim, by H.F. Blandford, a friend and pupil of Percy, and included in Percy's book (1861). This description is especially useful for its detailed information on mining and ore dressing. Of particular interest is the continued use of fire setting to break up the rocks.

I witnessed the process here described in one of the southern valleys of the Sikkim Himalya, a few miles from the Terai. The workmen were Nepalese, by one of whom the little mine from which the ore was obtained was rented from the government.

The rock of this part of Sikkim, to the north of the great fault which runs along the base of the hills, is a highly foliated quartz and hornblende schist, the folia of which dip at an angle of 30 or 40 degrees towards the north. The copper vein was small and, apparently, almost coincident with the foliation, dipping evidently at a very low angle. The ore was copper pyrites with a large admixture of mundic (iron pyrites). I was unable to visit the workings, which appeared to be carried on in the rudest and most irregular manner, owing to the fires being lighted at the time of my visit for the purpose of loosening the vein-stone, a mode of "winning" at one time extensively practised in Europe, and still to be seen in some important mines. The vein-stone loosened by the fire was afterwards detached and broken up by means of the hammer and gad, sketches of which I here append (Fig. 4). A small pick of the annexed form was also used.

The ore as brought from the mine, and which appeared to be very poor, was separated as much as possible with the hammer from the adhering rock, and was then pounded with a heavy stone mallet, another stone, with a slightly hollowed surface serving as a "knockstone", on the centre of which, after each blow, the ore was swept together by a woman. The ore thus pounded was next washed by women in small tyes, which in their general form much resembled those employed by the tin-streamers of Cornwall, but were smaller and of more simple construction. This type consisted of six planks about one foot in width fixed on edge in the ground, so as to form a partitioned trough of the form here shown (Fig. 5 The cavity above the head-board was nearly filled with clay, over which a stream of water, easily regulated in amount by a little clay placed in the feeding channel, was allowed to flow, and enter the lower trough through a notch (a, on Fig. 5) in the head-board.

The woman who sat, or rather squatted by the tye, with one hand divided and directed the stream while with the other she held to the aperture (a, Fig. 5) a handful of the pounded ore, which was thus washed down into the tye. When a considerable quantity of the ore had thus accumulated it was further washed by being raked up with the fingers towards the head-board, while a good stream of water was allowed to flow over the mass. This was continued until the ore was considered sufficiently "clean". The mass accumulated in the lower part of the tye was thrown away, and that in the upper part, occupying about one-third of its length, was removed to the furnace without being subjected to any further process. It consisted of a small quantity of copper pyrites mixed with a large proportion of mundic, and also much gangue, principally quartz and hornblende.

The furnace, formed of a sandy clay, was of the form and dimensions shown in the accompanying engravings (Fig. 6). It was built in a bank about two feet high, and consisted of a shallow square cavity, the bottom of which was slightly concave. The back wall of the furnace - which as a whole, may be well compared to an arm-chair - was carried up to the height of about eighteen inches, in the form of a truncated pyramid, the top being hollowed out for the purpose of receiving the slags as they were removed with pincers from the furnace. The front wall was very low, not more than about six inches above the bed, while the side walls were of intermediate height, being about one foot above the furnace bed six inches above the earthen platform on which rested the bellows.

These bellows were of simple construction, two in number, one being placed on each side of the furnace. They consisted of a seamless bag of goat-skin, formed of the skin and body and fore-limbs of the animal. The bottom, formerly covering the neck of the animal, now embrace in like manner the earthern nozzle of the bellows. The mouth of the bag was gathered in, so as to leave a small opening only, and it was grasped by a boy who squatted beside it and worked the bellows, alternately loosening and tightening his grasp as he raised or depressed the bag, thus producing an effectual, though intermittent, blast. The nozzle, moulded by hand, resembled in form the common mouth blowpipe, the end being bent at a right angle, so that, while the stem rested on the side wall of the furnace, the entrance aperture

> reached to within three or four inches of the furnace-bed, on which the blast impinged at a rather obtuse angle. Charcoal was the only fuel employed in the furnace.
>
> The first smelting operation was a single fusion. The furnace being heated with charcoal, a few handfuls of the washed ore, previously dried and mixed with charcoal, were thrown on, and the bellows worked by boys, as above described. More charcoal was added as required until a perfect fusion of the ore was effected. The fused "metal" (regulus) then formed a small pool at the bottom of the furnace, covered with a layer of fused slag, while the burning charcoal floated on the surface. The fusion being complete the charcoal was removed, water was sprinkled on the slag to solidify it, and it was then lifted off in successive cakes with a pair of pincers and placed to cool in the shallow basin at the back of the furnace. A fresh charge was then thrown on, and the same series of operations repeated, until a cake of "crude metal" weighing eight or ten pounds had accumulated in the bottom of the furnace. This was removed when cold, pounded, and kneaded with cow-dung into small balls which were dried in the sun and then roasted in a shallow furnace formed of a ring of slag-cake placed on edge. The roasted "metal" was afterwards refined in the same furnace in which the fusion of the ore had been effected, and in a precisely similar manner, the result being - 1st, refined copper, which collected in the bottom in a cake, weighing four or five pounds; and 2nd, slag, which was not, so far as I could learn, subjected to any further process, the probability being that the ash yielded by the very large amount of charcoal consumed in the process is sufficient to form a highly basic slag, and thus allow the whole of the copper to be reduced to the metallic state. Three pounds of "crude metal" were said to yield one pound of refined copper.
>
> (Percy, 1861)

Here 'metal' must be interpreted as *matte*. No additional flux was added as the smiths relied on the initial charge of ore having the right balance of iron and quartz. The first process produced copper iron sulphides with most of the iron and silica going into the slag. Then the *matte* was oxidised, and the iron oxides were removed by a final smelting. The furnace was of sandy clay and this must have produced the additional silica needed.

Note the extremely small furnace capacity in all these examples. This is quite usual (e.g. at Timna in Israel, Rothenberg, 1972). If the furnace was any larger it would prove impossible to maintain a sufficiently high temperture using primitive hand bellows. The large structures reported as furnaces from Italy (Coghlan, 1976) and Palestine (Gluek, 1965) were respectively a pottery kiln and store room.

Copper could also have been extracted from its ores by precipitation from aqueous solution with iron. The principle of this method is that of the familiar school chemistry experiment of plating an iron knife blade by immersing it in copper sulphate solution. On an industrial scale, loads of scrap iron are placed in water that has percolated through copper deposits, and the copper which then precipitates on the surface of the iron is removed at intervals. This is first described as an industrial process in Sung China (Needham, 1980: 201-3), and its products could have found their way to Tibet.

By the end of the second millennium B.C. tin bronze had everywhere replaced arsenical copper or unalloyed copper as the usual metal for tools and weapons. In India, however, and later in Nepal and Tibet, copper

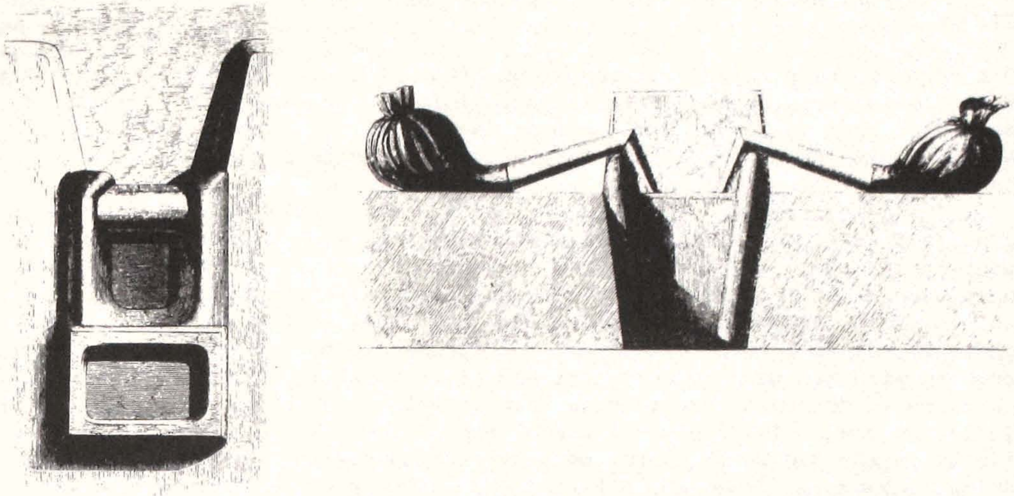

Figure 6 : Plan (a) and elevation (b) of Sikkim copper furnace (from Percy, 1861).

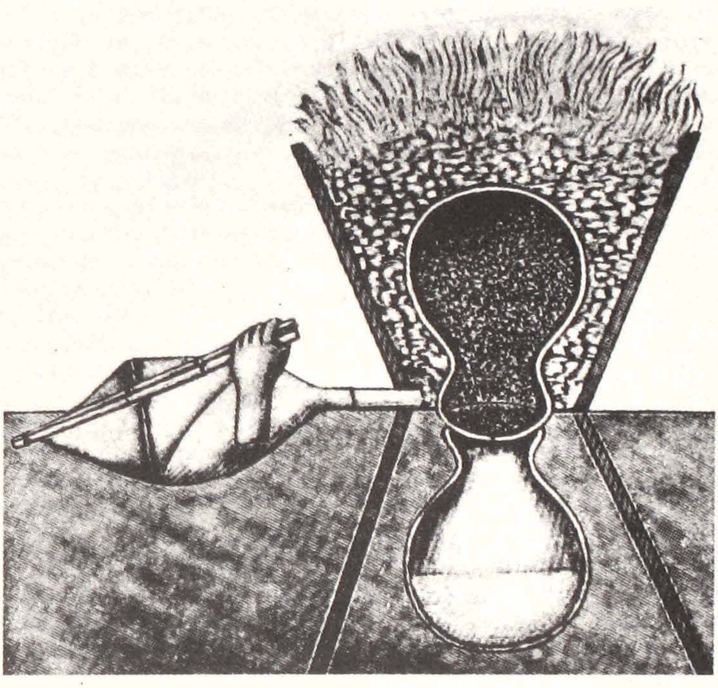

Figure 7 : Koshti apparatus for the process of zinc distillation (from Ray, 1903/9).

continued in use for casting images to the present day (Werner, 1972). The possible reasons for this are discussed below (see page 92).

Tin

Tin began to be alloyed with copper by about 2000 B.C. in India, but perhaps a little later in China. This is approximately the same date at which it becomes common in Europe and the Near East (McKerrell, 1977), although early bronzes from Non-Nok and Ban Chiang apparently predate this by at least a millennium (Solheim, 1972).

The principal ore of tin is the oxide (cassiterite) which is found in granite formations, although the most accessible source for early man was usually the small black pebbles or sands found in river gravels, having been washed out from the parent rock above. Cassiterite is easy to mine, and to smelt, either alone to give tin or by adding it to molten copper and charcoal to form bronze directly (Charles, 1975). For early man the problem with tin was its scarcity, and it is equally difficult for modern scholars to determine the sources used in antiquity (Franklin, 1978; Dayton, 1971). De Jesus (1978) gives a useful map of the main possible tin bearing strata in the Old World. Large well attested deposits occur in south-west Britain, Bohemia, Spain and Nigeria, and in the East in Yunnan province of China (the Mengtze district tin probably supplied the An-Yang smiths) (Draper, 1931), and from southern China through to Burma, Thailand and the Malay peninsula. In addition to these certain deposits, there are numerous reports of other supposedly ancient tin workings from Ireland to Japan. At some of these, e.g., in Ireland, Egypt and Italy, tin undoubtedly exists, but in concentrations too small to have been exploited. Other postulated sources, such as in the Troad, are said to exist for no better reason than that very early bronzes have been found there. The sources of tin available to the ancient civilizations of the Mediterranean, Middle East and India have long been a source of speculation (Agrawal, 1971; Hegde, 1978). Both these writers state that small uneconomic deposits exist at Bhilwara and Udaipur in Rajasthan and Dharwar in Karnataka with no evidence of early working, but, more significantly, at Purgo near Paharsingh in Bihar, tin was worked on a small scale at least until 1849 (Brown and Dey, 1955: 176). Deposits of tin in Iran are frequently quoted as the source of much of the tin used in Tibet (von Schroeder, 1981: map 2, and Agrawal, 1971: 150), but with no supporting evidence from Iran itself. Certainly no-one has yet been able to locate the tin deposits in the Middle East and in medieval times the Persian authors are unamimous that tin was found nowhere within their lands but was imported chiefly from Kalah (South-east Asia) (Allan, 1979: 27-8). In the early fourteenth century Abū'l Qāsim Kāshānī stated that tin was obtained from China, the Bulgars (Volga area) and Faragistan (Balkans ?). Allan (1979) has carefully reviewed the evidence for the presence of tin in Iran but could establish no proven sources.

Tin deposits are known to the south-east of Lake Baikal and elsewhere in North-east Asia, but there is no evidence for early working; in fact during the Second World War when tin supplies from South-east Asia were denied to the Allies, a very comprehensive survey of the USSR failed to locate any tin recoverable by modern technology (Itsikson, 1960). In the 19th and 20th centuries tin was imported into India and Tibet, and it would seem most likely that it was imported from the south-east in earlier periods (see below pp. 20-23).

Lead

The history of lead goes back at least to the sixth millennium B.C. at Çatal Hüyük in Anatolia (Mellaart, 1967). The metal itself is not found in nature so lead smelting must already have been known at that early date.

During the Bronze Age it seems to have been of minor importance, with only a few lead trinkets found in archaeological deposits until the end of the second millennium B.C. when it rapidly became much more common throughout the Old World, used by itself or in bronze alloys or as a constituent of ceramic glazes. The reason for this upsurge in the use of lead was probably that large amounts were available as by-products of silver extraction from lead ores by the cupellation process. Wagner *et al.* (1980) have excavated the remains of Early Bronze Age cupellation on Siphnos but, in general, silver did not become common before the Late Bronze Age.

The usual lead ore is the sulphide (galena) and this could be quite simply reduced by a continous roasting and reduction operation on a hearth. The medieval Persian author al-Hamdānī gives a description of the process, significantly as a precursor to obtaining silver. The galena and wood were stacked in alternative layers and fired. The fire was fanned by two bellows for 24 hours after which the molten lead was run into an ingot mould. The process seems to have changed little to this day, and in the late nineteenth century the process was observed at the Ghorband lead mines in central Afghanistan.

> The furnaces used resemble the Scotch hearth in principle, and are very simple in construction. A rubble wall, 5 feet long, 5 feet high and 18 inches thick, is built along the hillside, in a position best adapted for carrying off the fumes by the wind, and a rough roof is carried from the top of the wall back to the hillside to shelter the workmen producing the blast. The actual furnace is a rounded cavity in the bottom of the wall, lined with refractory steatite-clay, 18 inches by 14 inches by 7 inches.... and it is worked entirely from the front. There are two tuyeres of clay ¾ inch in diameter; the blowing apparatus being two sheeps' skins......
>
> (Collins, 1894)

Zinc and Brass

The usual copper alloy encountered in India and Tibet is brass, and therefore it will be discussed in more detail than the other alloys.

The early history of zinc and of brass, its alloy with copper, is at once fascinating and obscure, the latter despite the best endeavours of Caley (1964), Halleux (1973) and Craddock (1978). There is literary and archaeological evidence to show that brass (*oreichalkos*) was known in Anatolia in the first millennium B.C (Craddock, 1978), and from the beginning of the first century B.C. brass coins were regularly minted in Phrygia and later in Rome itself (Craddock *et al.*, 1980). Brass artifacts were also found at Taxila and those analysed by Ullah (Marshall, 1951) ranged in date from the 4th century B.C. to the 15th century A.D. These are the earliest brasses so far encountered in the East and are of great importance. One vessel in particular, ascribed to the 4th century B.C., has a composition which strongly suggests it was made from metallic zinc and copper; it is thus the earliest evidence of metallic zinc yet found anywhere (see below p. 16). Marshall considered that brass making had been brought to Taxila from the West, although the items of brass were locally made copies of Hellenistic originals. Elsewhere in the East brass is not attested so early, not apparently until almost half a millennium later. However, this gap may be more apparent than real and represents an analytical hiatus. The results published for India by Bhardwaj (1979) and by Prakash and Rawat (1961), and for China by Barnard (1961), cover the period to the 5th century A.D., but after this there is the gap until Werner's (1972) Indian analyses, which include a very few later first millennium A.D. pieces for India (all made of brass) but nothing earlier than the 14th century A.D. for China. Now von Schroeder's *Indo-Tibetan bronzes* (1981) gives the composition of ten pieces from the 6th to 10th Century A.D., of which six are brasses, and, in addition, two Gandhara Buddhas, one in the British Museum and the other from a private collection, are included in the table of analyses below. In China, the period between Chin bronze and Ming brass is represented only by analyses of mirrors, but they were always made of a special alloy, not of ordinary bronze or brass. Needham (1974: 212-220) claims that some Chinese texts suggest brass manufacture as early as the Han period, but, if this is so, no surviving brasses have yet been identified by chemical analyses. Wang Chin (1923) however, suggests the 7th century A.D. for the origin of brass in China and this seems more likely on the present meagre analytical evidence. Thus, despite the sparsity of analyses, it would seem that brass was known in India from at least the first centuries A.D. when it was still unknown in China, but that by the time of the earliest analysed Tibetan images it was known and widely used over most of the Far East.

The production of brass and zinc

Zinc minerals are quite common and there are important deposits in Iran, Afghanistan, Rajasthan, Bhutan and throughout China, especially in Hunan, all showing signs of early exploitation. Zinc and lead also occur in Tibet but it is not known how extensively they have been exploited in the past. Zinc, lead and silver are frequently associated together and the production of all three metals from one mine is quite common. The two commonest zinc ores are the sulphides (blende or sphalerite) and carbonate, called calamine in England or smithsonite in the USA. Zinc and its main alloy, brass, make a relatively late appearance because zinc smelting is so difficult. Zinc melts at only 432°C, and actually boils at 917°C, which is below the temperature at which it could be smelted. Thus it would not appear as a molten metal to be run off from the base of the furnace but as a vapour which would promptly reoxidise to give dense white clouds of zinc oxide, hence the Iranian term for zinc, *tūtīyā*, meaning literally 'smoke'.

The process of making an alloy of copper and zinc directly, by reducing zinc oxide in the presence of copper, was discovered in Anatolia in the 2nd century B.C. (Craddock *et al.*, 1980). Finely divided copper metal, zinc oxide and charcoal were packed into a crucible which was sealed and heated to about 1000°C. At this temperature zinc vapour is formed which dissolves into the copper. Note that the temperature is critical; if it is below 917°C then zinc will not form as a vapour, but if much above 1000°C the brass will melt as it forms and collect as a puddle at the base of the crucible, thus having a much reduced surface area in contact with the zinc vapour. This process formed the basis of the brass industry in Europe and the Middle East until the mid-nineteenth century (Percy, 1861).

The European process used calamine which occurs as an off-white material resembling clay (Day, 1972; Percy, 1861). It is normally fairly pure and in Europe was just calcined to convert the carbonate to oxide with no other pretreatment. There is abundant evidence to show that in Iran at least, much more complex treatments took place, probably both for calamine and also to enable sphalerite (zinc sulphide) to be used. As well as being converted to oxide, the sphalerite has to be separated from the lead and iron sulphides with which it is invariably found. Two medieval processes are described; in the first, recorded by Mustawfī and by al-Jawbarī (Allan, 1979: 40-1), the zinc ore was usually crushed, moistened and rolled in cylinders 'like sword sheaths' or wrapped around clay bars. These were roasted in a lidded earthenware box. This process would seem appropriate for the calcining of calamine, as the system was closed and unsuitable for oxidising sulphides. However, the second process, described by Kāshānī and al-Muqaddasī, and also by none other than Marco Polo, describes how the ore was roasted, sublimed, and the dense white smoke of zinc oxide was then collected on clay

(Polo says iron) pegs set in the furnace walls above. This process would have been eminently suitable for treating the low grade mixed sulphide ores, converting the sulphide into oxide and separating it from iron and lead in one operation. There is no proof that this process was used with sphalerite; al-Muqaddasī states that the process was a speciality of the Kirman area, where only sphalerites occur. Remains of the clay bars are still quite common in Iran at least, and Barnes (1973) investigated them rather inconclusively, but suggested they had been used for the latter process using sphalerite. There are very few contemporary references to the cementation process; Pliny and Dioscorides mention it obliquely, but the earliest detailed description occurs in the 12th century in the *On Divers Arts* of Theophilus (Hawthorne and Smith, 1963). The earliest reference in Indian literature is in the 7th or 8th century A.D. *Raṣaratnākara*, which states "what a wonder it is that calamine roasted thrice with copper converts the latter into gold" (Ray, 1956: 129), but significantly cementation is not mentioned by the succeeding Indian iatrochemists from the 14th century onwards. Possibly it was already superseded here by the production of brass from metallic zinc and copper.

The earliest contemporary Indian description of zinc metal production is in the *Rasārnava*, probably of the 12th century A.D. This states (Ray, 1956: 138) "extraction of zinc from calamine, *Rasaka* mixed with wool, lac, *Terminalia Chebula* and borax and roasted in a covered crucible yields an essence with the appearance of tin, of this there is no doubt (VII 37-38)". Better descriptions of methods for producing metallic zinc in India are given in the 14th century *Rasaratnasamuccaya:*

> Extraction of Zinc; Rub calamine with turmeric, the chebulic myrobalans, resins, the salts, soot, borax, and one-fourth its weight of *Semicarpus anacardium,* and the acid juices. Smear the inside of a tubular crucible with the above mixture and dry it in the sun and close its mouth with another inverted over it, and apply heat; when the flame issuing from the molten calamine changes from blue to white, the crucible is caught hold of by means of a pair of tongs and its mouth held downwards and it is thrown on the ground, care being taken not to break its tubular end. The essence possessing the lustre of tin, which is dropped, is collected for use.
>
> (Ray, 1956:171)

The chebulic myrobalan is a variety of cherry plum, and *semicarpus anacardium* is of the cashew nut family. Elsewhere (p.236) Ray defines this further as the 'marking nut' used for making ink. (I am indebted to my wife, B. Craddock, for this information.) These exotic and expensive organic ingredients would seem unnecessary except to produce the reducing agent,although good quality charcoal would have served as well. They are, however, amongst the favourite ingredients and reagents of the Indian alchemist, and were probably included to make the process appear more complex and impressive.

The mention of a blue flame shows that carbon monoxide was burning and the conditions were strongly reducing. Another description from the same sources states:

> Calamine is to be powdered with lac, treacle, white mustard, the myrobalans, natron and borax, and the mixture boiled with milk and clarified butter and made into balls. These are to be enclosed in a crucible and strongly heated. The contents are then poured on a slab of stone - the essence of calamine of the beautiful appearance of tin (thus obtained) is to be used.
>
> Or, a vessel filled with water is to be placed inside a *koshthi*

> apparatus and a perforated cup or saucer placed over it; a crucible charged as above is to be fixed in an inverted position over the saucer and strongly heated by means of the fire of jujube (*Zizyphus jujuba*) charcoal: the essence which drops into the water should be applied in medicine.
>
> (Ray, 1956:172)

The latter process includes a reference to the process of *tiryakpatana-yantra*, meaning 'distillation by descending', using a *koshthi* apparatus (Fig. 7). The process is described in the *Rasaratnasamuccaya* as follows:

> Place the chemicals in a vessel provided with a long tube, inserted in an inclined position, which enters the interior of another vessel arranged as receiver. The mouths of the vessels and the joints should be luted with clay. Now urge a strong fire at the bottom of the vessel containing the chemicals, whilst in the other vessel place cold water. This (process) is known as *tiryakpatanam*.
>
> (Ray, 1956:190)

Extensive remains of these processes for the distillation of zinc are still to be seen in India, in contrast to the cementation process of which nothing now survives. A good description of the remains at Zawar in Rajasthan is given by Carus in Mathewson (1960: 2). Two of these retorts are in the collections of the British Museum (Fig. 8).

> Large heaps of lead- and zinc-bearing residues, slags and clay retorts of furnace in the Zawar area bear testimony to an ancient smelting industry of impressive magnitude. There is no written record of it and inferences are based entirely on slags and other material left behind.
>
> The unbroken retorts found in the Zawar ruins have walls ⅓ to ½ inch thick, of vesicular fused clay containing numerous fragments of phyllite quartz and quartzite, which suggest that the retorts were made from the local soils of the area. These retorts are doubly tapered, cylindrical vessels, closed at one end, but having a hole at the other end marked by a thin-walled tube of baked clay with an internal diameter of ½ to ¾ inch. They clearly reveal construction in two parts, a cap with a tube being joined to the body, presumably having been added after the retort had been filled with ore and charcoal. All retorts bear evidence that they had been subjected to moderately high temperatures. Their interior surface is often partly glazed and blistered, and most of them are corrugated or wimpled as a result of fusion with subsequent partial collapse and flowage. The prolong[ed] end, which was apparently at a low temperature, does not show the same characteristics. The asymmetrical shape of the wrinkles or folds caused by flowage of the heat-softened clay walls indicates that the retorts had been in an inverted position when heated. They must have been closely spaced in the furnace, or in actual contact with each other, as many of them were found fused together.
>
> The quantity of zinc residues in the Zawar area is estimated to be 130 000 to 170 000 tons. From this quantity of residue, a very large tonnage of zinc must have been produced.

There is now a radiocarbon date showing that zinc ore was mined at Zawar at least 2000 years ago (Hindustan Zinc Ltd., n.d.). Fig. 9 shows rows of these retorts at Zawar, apparently fused together where they were

a

b

Figure 8 : Example of a complete (a) and sectioned (b) retort from Zawar for producing metallic zinc. (British Museum, Department of Oriental Antiquities, presented by S.W.K. Morgan, Esq.) Scale 1:2.

fired. The arrangement is strangely reminiscent of the 19th century Belgian process and one cannot help wondering if yet another Western 'invention' had its origin in the East.

Origins of Zinc and Brass

The traditional and popular view is that brass was produced by the cementation process from Imperial Roman times onwards, spreading to the East during the first millennium A.D. Metallic zinc was supposed to be unknown in the West and uncommon in the East until about the period of European contact (Forbes, 1971: 280-1) and for long periods no-one was aware that zinc was a component of brass (Ullah in Marshall, 1951). However, recent research and the evidence given above from sites such as Zawar suggest that metallic zinc was known much earlier and was far more plentiful than has hitherto been supposed. Most zinc was probably used for brass production and it has now proved possible to differentiate cementation brass from that made by mixing the two metals. Werner (1970) and Haedecke (1973) demonstrated experimentally that brass produced by the cementation process running efficiently at 1000°C could not contain more than 28% of zinc. Proof of the validity of this experimental conclusion comes from the records of brass founders themselves; thus William Champion wrote in 1760 that the maximum penetration of zinc into copper by the cementation process at his famous Baptist Works in Bristol was 28% (Day, 1972: 62). A further indication of the use of the cementation process is the iron content of the brass. The calamine ore always contained a small percentage of iron oxides and these would be reduced to iron during the process and dissolved in the forming brass. Several percent of iron is quite common in brass made by this process and, in 18th century Europe, brass was considered an unsuitable material for compass cases because of the interference of this iron with the free swinging of the compass needle (Day, 1972: 124). Thus the sudden appearance of coins containing about 25-28% of zinc and approximately 0.2-0.5% of iron in the reformed coinage of Augustus in 27 B.C documents the spread of the cementation process to Rome itself (Craddock *et al.*, 1980). However, in Iran at least, and perhaps elsewhere in the East, the use of the sublimation process described above to purify the ore would eliminate iron and all other impurities, except perhaps a little lead. Unfortunately, however, Eastern copper often contains a relatively high level of iron derived from the smelting process and thus the level of iron content of Eastern brass is not such a useful process-indicator as in the West. The graph of zinc against iron (Fig. 10) shows that the two are proportional to each other, even for the high zinc brasses which cannot have been made by the cementation process. These brasses have <u>more</u> iron than either the copper or low zinc brass. This is surprising and rather difficult to explain. The modern Nepalese statuettes collected by Lo Bue also show this puzzling trend; there is more iron in the brass than in the copper, yet we know that the brass was made by mixing modern commercial copper and zinc, both relatively iron-free. The iron must have been introduced at the mixing stage, and the only possible explanation is that iron rods were regularly used to mix the brass melt. Iron is quite soluble in molten copper and brass. However, the zinc content is still crucial; a brass containing less than 28% of zinc could be made by either process, but one containing much in excess could only have been produced by mixing copper and zinc metals. Hence the overriding importance of the vase (BM 215-284), excavated from the Bhir Mound at Taxila and dated to the 4th century B.C., which has been analysed by Ullah and shown to contain 34.34% of zinc together with 4.25% of tin, 3.00% of lead, 1.77% of iron and 0.4% of nickel (Marshall, 1951:568). This is very strong evidence for the availability of metallic zinc in the 4th century B.C. Nor is it alone, as there are contemporary documentary references to the metal, and finds of zinc objects have even been made farther to the West. The 4th century B.C. geographer

Figure 9 : Rows of used clay retorts at Zawar (reproduced with the kind permission of Dr. Ing. H.W.A. Sommerlatte).

Theopompus is quoted by Strabo in a passage which speaks of a certain mineral found near Andreida (an area of complex lead-zinc-silver deposits worked in antiquity) in north-west Anatolia, which "when smelted yielded iron, and then dripped down drops of fake silver which mixed with copper gave the metal which men call *oreichalkos* (brass)" (Jones, 1968). This sounds remarkably like the description of the *tiryakpatana-yantra* of the *Rasaratnasamuccaya*, written a millennium later. More direct evidence was the discovery in the excavations at the Athenian Agora of a small roll of zinc in a sealed deposit dated between the 4th and 2nd century B.C. (Farnsworth, 1949). Needham (1972: 198) condemns the piece as being beyond the contemporary technology, even though the apparatus needed to produce it was not sophisticated; Forbes (1971: 272) condemned it for existing at all! As there seems to be no evidence for knowledge or use of metallic zinc in the West during the Roman period or Middle Ages, we must conclude that the cementation process had completely supplanted brass made from metallic zinc and copper, at least as a commercial process. The next recorded European production of zinc as metal was in seventeenth century Germany at Goslar (Gibbs, 1957), although most zinc continued to be imported from the Far East by the Dutch. Zinc coins, said to date from 15th century China, have been reported by Leeds (1955); however, they are now known to be recent copies (personal communication from J.Cribb).

The date of zinc manufacture in India is uncertain. The earliest attribution is to one Nāgārjuna who flourished in the 7th century A.D. (Ray 1956: 49). Subsequently there are references to both the cementation process for brass and to metallic zinc manufacture in medieval Indian literature, but by the time of the iatrochemists (A.D. 1300-1550) there is no longer any mention of the cementation process, but only of metallic zinc production. This accords well with analytical data so far published. Brasses containing more than 30% of zinc are only very rarely found before the fifteenth century, but from then on become increasingly common.

Summary of the present state of knowledge on early Brass and Zinc

Brass, produced by the cementation process, was discovered in Anatolia at the end of the 2nd century B.C. and became rapidly diffused throughout the Roman Empire, but spread more slowly through India and then China, so that it was in use throughout the Old World only by the end of the first millennium A.D. Zinc is more problematic. By itself, or alloyed with copper in amounts greater than 30%, it is rare before the 15th century A.D., but not unknown. Classical literary sources and excavated finds from Athens and Taxilia all tangibly demonstrate its existence in the later first millennium B.C. Little is known yet of zinc in China, but that it was manufactured in medieval India is documented by literary sources and the remains of a production site at Zawar in Rajasthan. These extensive late and post-medieval remains suggest that the change from the cementation process to mixing zinc and copper metals was slow, but complete by the end of the 17th century (Ullah in Marshall, 1951: 570-571). By contrast, in Europe only the cementation process was used until the end of the 18th century. Even then William Champion, the first European to make zinc on a commercial scale, went bankrupt because his brass could not compete in price with the cementation product. Not until the second half of the 19th century did that process cease. By this time Indian zinc production had ceased, having been undercut by cheap imports of cementation brass from the West, a process abandoned, ironically enough, hundreds of years previously in the East.

Analysis of Metalwork

The objects which have been analysed are listed on pp.103-109 below These made by casting could all be sampled by drilling into the base or into some other

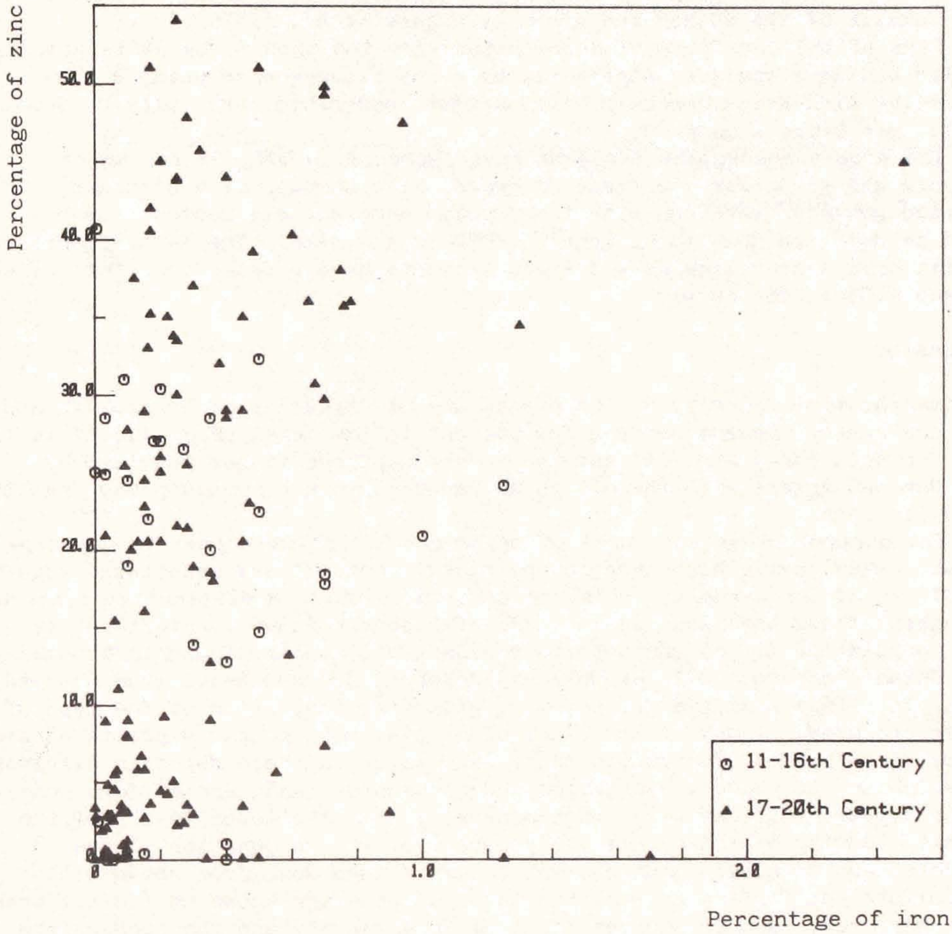

Figure 10 : Graph of zinc content plotted against iron content from the analyses of Tibetan and Himalayan metalwork listed on pp. 26-31

inconspicuous area. Gilt areas were avoided where possible and the surface drillings discarded to minimize the danger of contamination of the sample by gold or corrosion products on the surface. Yet the analyses show that an unusually high proportion of the samples contained gold in detectable quantities, compared with similar alloys from the West; furthermore the level of gold was independent of the presence of gilding. This indicates that the measured gold content is not just a surface contamination but is contained within the body metal. Its probable origin is discussed below. The samples were analysed using a Pye-Unicam SP 9 atomic absorption spectrophotometer for all elements except low concentrations of arsenic, antimony and bismuth for which a Perkin Elmer 306 atomic absorption spectrophotometer fitted with a heated graphite attachment was used for greater sensitivity. Full details of the method are given by Hughes *et al.* (1976).

Five of the artifacts of sheet metal were too thin to be satisfactorily drilled and were analysed separately by X-ray fluorescence using a non-dispersive Link-Kevex computer based system, described more fully by Cowell (1977). See table 2 on p. 31.

The atomic absorption analyses have a precision of ± 1% for major elements and ± 20% for the trace elements. Five samples of a standard analysed gunmetal were run with the Tibetan samples. All quoted elements could be detected down to at least 0.005% in the metal. The X-ray fluorescence results have a precision of ± 10% and elements have a detection limit between 0.1 and 0.5% in the metal.

Discussion

The overwhelming majority of the pieces are of copper or of brass. Tin and lead are rarely present above a few percent in the metal (Fig. 11). This is true for both early material and the modern Nepalese images provided by E.Lo Bue and agrees with the alloys as recorded in use by Alsop and Charlton (1973) in Patan.

The general range and level of trace metals in the copper is unexceptional. Occasionally high arsenic and nickel contents are associated together (p.107, no.84 for example); this correlation is quite a distinctive feature throughout these analyses, as in those of Riederer (1980). Unfortunately this correlation is not uncommon in the East and is also found in bronzes from China (Barnard, 1961) as well as Eastern India and Nepal (von Schroeder, 1981). The trace elements do, however, give some indication of the type of copper ore used, if not of its place of origin. Most copper deposits consist mainly of sulphides. The action of air and water on these deposits oxidises the sulphides to oxides, hydroxides and carbonates, and carries down some of the copper, together with trace minerals, into the lower levels of the deposit, leaving behind a relatively pure ore. At the junction of the weathered and unchanged minerals the metals washed down from above will precipitate out forming an enriched layer of what are known as *fahlerz* ores. These were very popular sources of metal in antiquity and the copper from them often contains up to several percent of trace elements and has a distinctive composition (Tylecote, 1962). Examples are the high arsenic/silver/antimony copper from the south-west of Ireland, exploited in the Early Bronze Age (Jackson, 1980), or the high arsenic/antimony/nickel copper from the Harz mountains in Germany, exploited in the Late Bronze Age and the Middle Ages. It should be pointed out here that nickel occurs naturally with the copper ore, and is not derived from the iron oxide flux (*contra* Forbes, 1972:36).

The general level of trace elements in the Tibetan metalwork is low, with the exception of iron, and this would suggest that the usual ore was an oxide or carbonate, such as cuprite, malachite or azurite (Tylecote *et al.*, 1977), with some primary sulphides. Probably only no.84 has a high enough trace content to be considered as possibly originating from a *fahlerz* ore.

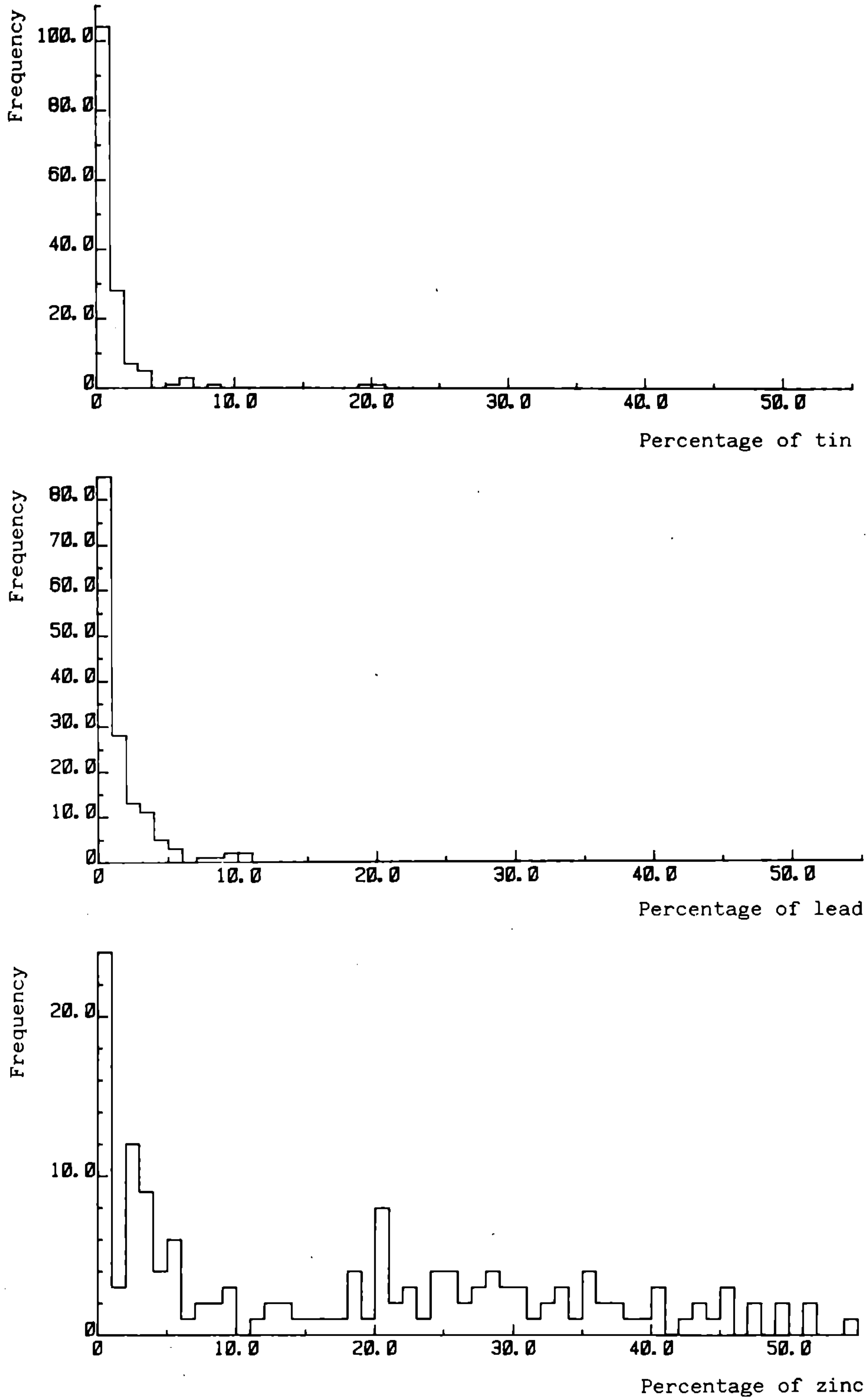

Figure 11 : Histograms of tin, lead and zinc contents

Many of the Indian and Tibetan treatises on art and technology attach great importance to the value and beauty of native copper found as a natural metal in the copper deposits (see Lo Bue, p.37 below). Native copper is rare and its use cannot have been widespread even for items so important as devotional images. Further, once it had been melted, any observable special qualities would have been lost. Native copper is almost always extremely pure (Maddin *et al.*, 1980); for example, a sample of native copper from Zanskar contained 99.48% copper and 0.08% iron with no other metals detectable (Ullah in Marshall, 1951: 570). None of the two hundred analyses published in this work, or by Riederer (1980), is sufficiently pure to be considered as native copper. The high iron content of most of the metals alone is indicative that they have been smelted using an iron based flux. However, it is not always certain that the Tibetans strictly meant native copper. Sometimes they undoubtedly did, as when 'Jam-dpal-rdo-rje (Chandra, 1971) defined it as "the ore which is dug out like gold is native copper". Elsewhere he states that "malachite and azurite appear in the earth which has malachite and azurite... by melting them there appears copper. It is the ore which is called native copper..." (Lo Bue, below pp. 37 & 40).

The brasses show a wide range of zinc content (Fig. 11). It has been shown above that brasses containing more than 28% of zinc were almost certainly made by adding zinc metal to copper. Of the thirteen pre-16th century brass pieces analysed here no.42 (p.105) which contains 30.4% of zinc, is too close to 28% to rule out the use of the cementation process, but the base of no.104 (p.108) which has 31% of zinc, is more likely to have been made by mixing the metals. The iron content of this base is low, but as we have seen there are many other factors controlling the iron content rather than just the use of the cementation process. Thus there is a strong possibility that the base of this 14th century image incorporates metallic zinc, but the composition stops short of proof. From the 16th century onwards, by contrast, many of the brasses have well in excess of 28%, the 16th century Maitreya (p.107,no.98) has 40.7% for example, with a very low iron content. This must incorporate zinc metal. The composition of these brasses then, provides strong, though indirect, evidence that the change from cementation brass to that produced by mixing the two metals was well advanced by the 16th century in the Tibet region, a date already suggested on textual grounds by Ullah (Marshall, 1951: 571) and on analytical grounds for India as a whole by Werner (1972).

Many of the copper images have a small but definite zinc content, normally in the 0.1 to 1.0% range. This is rather too high to come from the copper ore, but is too small to have any alloying effect. (Thus, in the catalogue, those with below 3% zinc are described as being made of copper.) Some of the modern Nepalese statues have between 1 and 4% of zinc and the modern craftsmen at Patan stated that a little zinc was added to improve the casting (personal communication from M.Bimson). This is true; molten copper dissolves air, some of which will oxidise the copper, causing unsightly blemishes on the casting. However, zinc has an even greater affinity for oxygen and so removes it from the copper to form zinc oxide which will sublime away. The addition of a little zinc or phosphorus is still standard practice in Western foundries for this purpose (Mills and Gillespie, 1964).

None of the alloys are what might be termed simple bronzes containing approximately 5-15% of tin and little else. Only six of the pieces contain several percent of tin, but these all also contain zinc, and are more accurately described as gun metals rather than bronze. There are the two high tin bronzes, the bell (p.107,no.80) and cymbals (p.105,no.47). Both of these are probably modern and the composition is the expected alloy for bells or cymbals the world over. Although brass largely replaced bronze during the first millennium A.D., bronze continued in use for a variety of specialised products, not only for bells and cymbals, but also for mirrors (Barnard, 1961). Bell metal and Chinese mirror metal were recognised as distinct alloys, although there is not much analytical evidence for their use in statuary. An exception is an 8th-9th century Buddha from Swat (von Schroeder, 1981: no.12D). The *khar sini* 'chinese iron' alloy of the Islamic alchemists has also been recently positively identified as being a high tin bronze (Craddock, 1979 and Allan, 1979: 48-51; but *contra* Needham, 1980: 429-32). There is also a long tradition of high tin bronze vessels in the East. These begin in the first millennium B.C., probably in South-east Asia, and were widely traded through India, being found at Taxila and elsewhere. This tradition continued into the medieval period with the famous *haft jush* vessels from Iran (Craddock, 1979). These all contain about 20% of tin which renders them extremely brittle and impossible to hammer at room temperature. However, if heated to approximately 550°C they can be easily beaten into any required shape. If the metal is water quenched from about 520°C a limited amount of cold work can be done, for example on the cymbals, to improve their tone (Rajpitak and Seeley, 1979).

Although the tin content is usually too low to be considered an alloying metal, between 0.5 and 3% is quite common in the copper. Tin is a rare impurity in copper ores, and so some of this tin must be derived from scrap bronze or tinned copper incorporated in the melt. Some may have been deliberately introduced to facilitate the melting of the copper. The presence of a few small pieces of tin (melting point 232°C) in the crucible promotes the melting of the copper by dissolving it to form a high tin bronze. This is still practised in small art-metal foundries.

The lead content of the metal is generally low (Fig. 11) and, wherever it exceeds trace-level, is accompanied by zinc. As lead and zinc ores are almost always associated together, there is a strong possibility that none of the lead found in this metalwork represents a deliberate addition. Traces of lead are also common in copper ores or even in the iron oxide flux (Craddock, 1980). This absence of deliberate additions of lead from the alloys, which is common in Nepalese and Indian practice, stands in total contrast to contemporary European, Islamic and possibly Chinese usage.

To understand the uses and limitations of lead in copper alloys it is necessary to know a little of the underlying metallurgy. Lead is practically insoluble in copper at room temperature and is usually present in the form of globules more or less evenly distributed throughout the metal. The presence of lead in molten copper, however, significantly lowers the melting point and increases the fluidity of the melt. Lead increases the fluidity only up to a maximum of 2% lead, beyond which there is no further increase (Brown and Blin-Stoyle, 1959), but the melting point is depressed by larger additions of lead. It is also a cheap metal and always has been, compared to tin or copper, and this must have been an important consideration for the medieval smiths who were regularly producing heavy mortars and other vessels from alloys containing 20% or more of lead, such as the *caldarium* of the *Mappae Clavicula* (Smith and Hawthorne, 1974).

However, there are serious drawbacks resulting from the presence of lead in copper alloys. The interface between the bronze or brass and the globules of lead is a potential source of great weakness, and cracks rapidly open up when any hammering or shaping work is performed. Thus sheet brass or copper can never contain more than traces of lead. Lead is most injurous to fire-gilding (see below p.92) and none of the fire-gilded pieces contains lead.

Before the section on alloys is concluded, the arsenical copper used for the base and attached lion relief of the 14th century figure of Mañjuśrī (p.105, no.42) must be described. Millennia earlier, arsenical copper was the first alloy to be used in the Bronze Age. In addition to forming a useful 'bronze' it was also used to give a pleasing silvery surface to copper. For example the third millennium B.C. copper bull from Horoztepe investigated by Smith (1973) had been selectively plated to give a striped effect. This decorative, or some might say deceptive, use of arsenical copper continued long after tin had replaced arsenic as the normal alloying element for bronze in the second millenium B.C. The silvery surface could be produced *in situ* by reducing arsenious oxide with charcoal on the surface of the copper, or by casting an alloy with a high arsenic content in such a way that the arsenic concentrated on the surface (Eaton and McKerrell, 1976). The two examples here have both been produced in the latter manner. X-ray fluorescence analysis of the surface showed them to contain 15% of arsenic. The Japanese swordmakers used a similar alloy (*shirome*) as an inlay in the 18th and 19th centuries A.D. The soft silver colour of *shirome* contrasted well with the steel of the blade.

Although no early examples were previously known, the alchemists and artificers all give recipes for the production of spagyrical or false silver from copper and arsenic salts, especially the two sulphides realgar and orpiment. For example the *Rasahṛdaya* speaks of copper heated with equal amounts of *tāla* (orpiment) and *vaṅga* (tin) to produce silver in one recipe; others speak of using orpiment or realgar with copper alone (Bose, 1971: 319-323).

Some *fahlerz* ores of copper are very rich in arsenic. However, in *fahlerz* copper ores the arsenic does not occur alone; in the East it seems to be typically accompanied by nickel, or by antimony, bismuth and silver. The other trace elements in the Mañjuśrī (p.105, no.42) are not noticeably higher, and the composition very strongly suggests that the arsenic is a deliberate addition. This is the only medieval example so far reported anywhere.

Several Tibetan sources describe some of the alloys used for statuary and decorative castings, and are discussed in greater detail by Lo Bue (below pp. 37-61). Unfortunately, although Tibetan authors name many different alloys, the terminology and description are very confused and often contradictory. They give little credible information on what the alloys actually contained; the colour is usually given and sometimes the sound produced when the metal is struck. However, some treatises, such as those of 'Jam-dpal-rdo-rje (Chandra, 1971), Klong-rdol (1973) and 'Jigs-med-gling-pa (Dagyab, 1977) do provide some data compatible with the analyses.

The general term for copper alloys is *li* (Lo Bue, below p.50). This is the Tibetan equivalent of the Greek *chalkos*, Latin *aes*, Chinese *jin* or even present day 'bronze', as a blanket term to cover copper or any of its alloys. Klong-rdol writes of 'female' and 'stone' brass which is yellow and 'male' brass which is light yellow (see below p. 47) 'Jam-dpal-rdo-rje writes of 'red' and 'yellow' types of brass in which respectively either three or one parts copper are mixed with one of zinc, and of 'bright' brass which is firmer (harder?) than silver (see below p.47). 'Jigs-med-gling-pa also writes of three main alloys, *li-dmar* which was red, *li-ser* with a touch of yellow, and *li-dkar* which was white. Now, these three alloys can be identified from the analytical tables, where the results show three quite distinct groups. 'Red' brass or *li-dmar* is clearly copper itself, perhaps with a little added zinc to deoxidise the copper (see above). 'Female' or 'stone brass' or 'yellow' or *li-dkar* with three parts copper to one zinc is clearly the common 25-30% brass, the successor to cementation brass. The name 'stone brass' is suggestive of adding calamine (stone) to the copper. 'Male', 'bright' brass and *li-dkar* with a 1:1 ratio of copper to zinc are clearly high zinc brasses. Metallurgically, brass falls into two main groups; those containing up to 36% zinc, known as α brasses which cold work easily, and those containing over 36% zinc, known as $\alpha + \beta$ or pure β brasses, which are light and harder than copper or α brass, and more suitable for casting. Brass containing more than 46% zinc is extremely brittle and is not widely used nowadays.

In addition to these brass alloys, 'Jam-dpal-rdo-rje speaks of bronze for bells and gongs *(mkhar-ba)*, made of copper with about 22% of tin (see below p.51) and the thirteenth century *Rasaratnasamuccaya* (Ray. 1956:

185) speaks of *kāmsya* made by melting eight parts copper to two parts tin. These are in good agreement with the bell and cymbal metal reported here.

One other alloy must be mentioned, *dzn̄e-ksim* which, according to 'Jigs-med-gling-pa, was composed of copper with gold and silver and other precious metals and nickel silver (Dagyab, 1977, I:51; Lo Bue, below p.41). This last component was the Chinese *baitong*, an alloy of copper, nickel and zinc, which has not yet been encountered in Tibetan metalwork. Alloys of copper with gold and silver, however, have been found; a Yama and Yamī (p.103,no.16) is of copper with 1% of silver and 1.5% of gold. These levels are too high to be from the copper ore and the presence of the silver rules out contamination from gilding. This is a deliberate alloy, and others are known, such as the *shakudo* alloys of Japan (Gowland, 1896 and 1915) and the Corinthian bronze of Rome which is described by Pliny (Rackham, 1968). a 2nd century A.D. plaque with a very similar composition to no.16 has recently been reported (Craddock, 1981). Alloys with this composition were surface-treated to produce a rich purple-black sheen, of which there is no trace on this particular Tibetan piece, but examples were seen by Turner (1800) in Tashilhunpo monastery of which he says: "some of those images were composed of that metallic mixture which in appearance resembles Wedgwood's black ware".

Substantial traces of gold were detected in a far higher proportion of the pieces than is usual with early metalwork. As stated above (p.20), contamination from the gilding is probably not the cause. Werner (1972: 146-9) also found substantial traces in his metalwork and suggested that small amounts of gold were deliberately added to images for ritual reasons (see p.83).

The medieval castings of Islam and China were usually of leaded brass. The absence of lead from Indian and Tibetan alloys is one of their most characteristic features. There is a whole tradition of statuary casting in copper alone. Technically copper is very difficult to cast satisfactorily; it melts at a much higher temperature than its alloys (1083°C); it is much more viscous and therefore only flows sluggishly within the mould, and is much more liable to contain unsightly gas holes on the surface than alloys of copper with tin or zinc. One can only assume that aesthetic considerations outweighed the technical, for many of the Indian, Nepalese and Tibetan copper statues are consummate works of technical skill and must command our admiration regardless of their undoubted artistic merit.

Acknowledgements

I should like to thank E Lo Bue for allowing me to read an early draft of his thesis, from which the above discussion had benefited, and to quote from his translations of original Tibetan material, and also Frances Winter, Anne Sheard and Gillian Dunn for assistance with the Atomic Absorption Analysis.

Table 1

Atomic Absorption Analyses of Tibetan and Himalayan Metalwork

Cat	Part	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Cd	Bi	Zn
1		90.5	2.20	1.00	.110	.060	.150	.130	.020	.006	.150	.001		4.50
2		89.0	.800		1.00	.030	.070	.050	.020		.070			8.90
3	BASE	95.5	.050	.800	.030	.400	.050	.260	.300		.200	.001		1.00
4	FIGURE	96.5	.040		.100	.003	.200	.058			.400	.001	.0040	2.75
4	BASE	78.5	.270		.200	.250	.100	.075	.010		.450	.003	.0010	21.5
4	SURROUND	74.5	.280	.280	.100	.200	.150	.085	.030		.300	.003		25.0
5		56.0	.950	.400	.040	.170	.100	.045			.700	.010		42.0
7	BASE	65.0	3.40	1.00	.040	.400	.150	.075	.005	.003	.500	.002		29.0
7		65.0	3.50	.900	.050	.450	.200	.075			.500	.005		29.0
7		62.5	3.90	1.00	.040	.380	.150	.070	.005	.003	.500	.006		32.0
8	BASE	98.6	.015		.080	.040	.100	.300		.010		.003		.500
8	FIGURE	96.5	.025	.300	.100	.040	.005	.200			.020	.010		2.90
9		90.5	3.35	3.30	.120	.250	.100	.110	.010	.010	1.00		.0030	2.20
10		96.5	.095	.200	.085	.050	.200	.050	.010		.300	.002		2.90
11	BASE	54.5	1.20	.400	.060	.250	.070	.080	.006	.003	.200	.005		43.8
11		65.5	1.00	.800	.030	.160	.076	.030	.005		.350	.006		33.0
12	BASE	93.0	.250	.150	.200	.130	.100	.120	.020		.750		.0010	5.80
12	BACKPCE.	90.5	1.30	.700	.150	.140	.150	.130	.040		.350		.0010	6.70
12	BODY	79.5	.400	.200	.120	.450	.100	.085	.020		.350	.001		20.5
13		97.5	.015	2.40	.050	.450	.100	.030			.100	.001	.0030	.030
14		91.0	5.95	2.40	.150	.035	.200	.030			.400			.850
15		92.5	.075	.200	.150	.060	.110	.180	.030		.500	.001	.0010	5.50
16		97.0	.400	.200	1.00	.095	.150	.045	1.50		.200	.003		.100
17		70.0	8.00	5.50	.075	.150	.200	.090	.010	.020	.300	.002	.0010	16.0
18		63.5	.630	.800	.020	.240	.100	.200		.020	.500	.010	.0100	33.8
19		98.5	.050		.010	.040	.140	.070		.008	.050			.050
21		60.0	1.65	.900	.030	.300	.150	.070		.007	.200	.010		37.0
22		47.0	1.13	.300	.036	.170	.060	.030	.030		.150	.010		51.0
23		93.5	.900	.400	.060	.150	.100	.180	.150	.004	.400	.001		2.65
24		94.5	.150	.150	.300	.100	.200	.080	.008	.006	.500		.0070	3.00
25		98.5	.150	.300	.060	.100	.150	.055	.050	.010	.200	.002		.300
26		85.5	2.32	1.50	.110	.210	.110	.120			.450		.0020	9.20

Table 1 continued

Cat	Part	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Cd	Bi	Zn
27		62.0	1.77	.600	.020	.170	.020	.030	.010		.450	.020		35.2
28		56.5	1.20	.400	.020	.170	.080	.025	.010		.200	.010		40.5
29		73.0	.950	3.30	.050	.350	.100	.200	.010	.008	.700	.002	.0040	20.0
30		2.80	.150		98.0		.060	.007	.200	.013	.020		.0060	.020
31		92.0	.110	.300	.300	.065	.090	.080		.005	1.00	.001	.0400	5.75
32		72.0	.750	3.70	.030	.470	.120	.200		.010	.430	.002		23.0
33		84.0	.100	.900	.047	.060	.020	.100	.400		.050	.002		15.4
34		71.0	4.40	1.80	.100	1.00	.700	.120		.020	.800	.001	.0270	20.9
35		67.0	1.75	.600	.017	.350	.070	.280	.010	.010	.800	.001	.0050	28.5
36		76.0	9.00	6.00	.070	.700	.160	.400	.010	.060			.0020	7.30
37		100.	.020	.300	.020	.070	.150	.120	.170	.020	.400		.0070	.070
38	BASE	79.5	.900	1.50	.027	.360	.060	.220	.040		.600			18.0
38	FIGURE	100.	.013	.200	.025	.340	.010	.070			.050	.001		.050
39		76.5	1.00	.500	.055	.160	.065	.120	.010	.005	.250			20.5
40		79.5	7.80	6.20	.078	.450	.200	.130	.020	.020	.600	.001	.0040	3.40
41		80.0	.090	.100	.005	.200	.130	.070			.050	.002	.0020	20.5
42	BODY	65.5	1.70	.300	.030	.200	.050	.160	.005	.002	.250		.0010	30.4
42	LION	76.0	1.00	1.00	.200	.300	.070	.040		.005	6.80	.008	.2000	13.9
42	BASE	90.1	.260	1.20	.230	.150	.070	.020	.010	.003	7.40		.2000	.400
43		65.5	.150	.200	.010	.250	.200	.030		.010	.080	.010		33.5
44	BELL	94.5	.010	.300	.007	1.25	.040	.750		.120	1.70			.030
45		62.5	1.56	1.50	.015	.500	.065	.300	.010	.010	.750			32.3
46		98.0	.030	.150	.030	.085	.070	.130	.020		.350		.0020	.900
47		77.0	.055	20.8	.025	.500	.150	.100		.050	.100	.001	.0010	.070
48		72.0	.520	.500	.030	.200	.015	.870	.010	.050	2.00	.001	.0100	26.0
49		60.0	1.77	.500	.065	.780	.100	.080			.300	.010	.0010	36.0
50		52.0	5.00	1.70	.045	.600	.200	.230	.010	.010	.200	.002	.0010	40.3
51		56.0	3.90	1.00	.040	.480	.120	.150	.050	.007	.200	.001	.0020	39.2
52		50.0	1.68	.200	.020	2.48	.150	.080		.040	.300	.002		45.0
53	FIGURE	97.5	.026	1.00	.020	.030	.050	.100	.200		.050			.600
53	BASE	98.0	.015	.250	.007		.010	.035	.020		.020			
54		97.5	.070	1.20	.015	.025	.060	.400	.007	.007	.080			.180
55	BASE	61.0	2.50	.550	.050	.450	.100	.100		.008	.200	.002	.0010	35.0
55	FIGURE	50.0	2.50	.400	.050	.320	.070	.080			.200	.002		45.7

Table 1 continued

Cat	Part	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Cd	Bi	Zn
56		78.0	.160	.200	.150	.110	.080	.050			2.10	.001	.0100	20.0
57		84.5	1.45	1.30	.087	.350	.090	.075	.010	.010	.500			12.7
58		74.5	1.57	1.80	.020	.130	.100	.080	.007		.300	.001	.0010	20.5
59	BASE	100.	.020	.300	.045	.035	.010	.039	.060		.150			
59	FIGURE	99.0	.010		.020	.055	.035	.040	.050		.020		5	
60	BASE	72.0	.055	.200	.150	.280	.050	.100		.020	.050	.020		25.5
60	FIGURE	97.0	.050		.250	.020	.500	.060			.300	.005	.0020	1.85
61		60.5	2.00	.700	.053	.760	.110	.070		.010	.150	.001		35.7
62		75.5	4.30		.100	.300	.200	.035	.020		.300	.002		18.9
63		77.5	4.90	2.60	.030	.500	.200	.070		.015	.200	.002		14.7
64	BASE	71.0	10.2	1.10	.030	.700	.070	.070		.010	.300		.0013	17.8
64	HEAD	70.0	9.95	1.10	.030	.700	.200	.070		.010	.230		.0010	18.4
66		63.5	.160	.100	.020	1.30	.150	.065		.070	.100	.010		34.5
67		57.5	3.50	.500	.030	.120	.200	.050			.350	.001	.0020	37.5
68		86.5	.400	1.10	.055	.070	.150	.120	.300	.010	.250			11.0
69		61.5	2.35	1.50	.020	.220	.050	.055	.010		.050	.010	5	35.0
70	HANDLE	60.0	2.30	.800	.030	.650	.050	.070	.005	.005	.200	.003	.0010	36.0
71	FIGURE	96.5	.380	1.00	.050	.100	.250	.080		.010	.050		.0010	.650
71	BASE	99.0	.018	.300	.005	.035	.050	.050	.020		.100		.0020	.100
72	HEADRESS	68.5	.090	.400	.010	.250	.030	.090			.050	.006		30.0
72	BASE	97.5	.050		.020	.045	.200	.060			.050	.002		.150
73		89.5	.370	.700	.040	.100	.150	.100	.010		.150		.0050	9.00
74		59.0	1.50	.900	.030	.750	.050	.050	.005	.007	.200	.005	5	38.0
75	FIGURE	94.5	.050	2.60	.010		.010	.045	.140			.002	.0010	3.30
76		95.5	.090	.400	.140	.080	.200	.110		.004	.200		.0055	3.50
77	BASE	68.0	1.00	.100	.050	.150	.070	.030			.020	.002		28.9
77	FIGURE	73.5	.250	.100	.030	.150	.100	.055			.050	.002		24.5
77	SURROUND	70.5	.580	.300	.020	.100	.090	.065			.030	.001		27.7
79		70.0	2.76	.400	.100	.090	.100	.050	.050		.100	.002	.0070	25.4
80	BELL	78.0	.850	19.8	.080	.030	.100	.040			.070		.0050	.200
80	HANDLE	87.0	2.45	.400	.100	.350	.100	.045	.010		.100	.002	.0200	9.00
81		98.0	.300	.300	.060	.030	.050	.090	.010		.200		.0100	.350
82		72.5	1.30		.010	1.25	.100	.100		.020	.350			24.2
83		72.0	2.00	1.20	.025	.500	.100	.320		.020	.800	.001	5	22.5

Table 1 continued

Cat	Part	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Cd	Bi	Zn
84		65.0	.600	.600	.030	.400	.150	1.13		.150	4.40	.003		28.5
85	BASE	46.5	3.30	.600	.040	.940	.100	.075		.040	.250	.005	.0020	47.5
85	NIMBUS	62.5	5.00	.900	.060	.670	.100	.070	.010	.020	.400	.001	.0020	30.7
85	FIGURE	44.0	4.50	.600	.080	.700	.200	.065	.007	.020	.500	.007	.0010	49.3
86	BULL	42.5	1.65	.400	.040	.250	.100	.050			.200	.006		54.0
86	FIGURE	52.5	1.75	.400	.025	.200	.100	.045			.150	.006		45.0
86	BASE	52.0	1.80	.400	.040	.250	.100	.050			.200	.004		43.9
87		65.0	3.64	1.00	.045	.700	.100	.085	.005	.005	.250	.001	5	29.7
88		91.0	.500	1.10	.010	.550	.100	.110	.020		.100	.002		5.60
89		72.0	1.35	2.70	.200	.150	.100	.110	.100		.150	.003		22.8
90		79.0	.085		.100	.030	.060	.100	.020	.003	.010	.001		20.9
91		83.5	2.00	1.00	.090	.400	.050	.037	.010		.100		.0040	12.8
92		95.0	.330	3.00	.120	1.70	.050	.110	.150	.003	.200		5	.150
93		92.0	2.00	2.90	.040	.100	.050	.200	.008	.005	.500	.001	.0010	1.20
94		91.5	1.65	1.90	.030	.280	.050	.300	.010	.020	.600	.001	.0010	3.50
95		98.0	.020	.400	.100	.400	.005	.005			.030			.015
96		96.0	.220	.300	.500	.170	.070	.130		.004	.350	.001	1	3.60
97		73.0	1.85	.600	.020	.280	.100	.450	.010	.030	1.40	.001		21.4
98		60.0	.300		.005	.006	.050	.045	.008		.020	.001		40.7
99		75.5	10.3	6.20	.140	.240	.300	.140	.020	.010	.400		.0080	5.00
100		75.5	3.10	2.00	.080	.350	.130	.150	.050	.006	.500		.0020	18.5
101		87.0	1.10	2.20	.150	.095	.200	.080	.010	.005	.200			8.00
102		68.5	3.00	.300	.032	.270	.100	.040		.010	1.20	.001		26.5
103		93.5	.770		.030	.040	.050	.110	.010	.005	.150			4.80
104		98.0	.040	.100	.095	.008	.080	.150	.020		.060	.001		2.50
104	BASE	67.5	.180	.200	.250	.088	.090	.100	.030		.300	.010		31.0
105		74.0	.150	.100	.100		.300	.100			.350	.003	.0010	25.0
105	REPAIR	74.0	.200	.200	.100	.100	.200	.100			.200	.001		24.5
105	SURROUND	74.0	.170	.300	.100	.030	.250	.060			.200	.003		24.9
106		70.5	.500	.300	.037	.030	.200	.035			.350	.001		28.5
107		72.0	.660	.100	.010	.200	.100	.035			.200			27.0
108		71.5	.860	.100	.015	.180	.100	.030			.200			27.0
109		75.5	.550	3.90	.020	.100	.100	.085			.300			19.0
110		77.0	1.30	.600	.070	.160	.070	.085	.300	.006	.400	.001		22.0

Table 1 continued

Cat	Part	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Cd	Bi	Zn
112		52.0	2.65	.450	.030	.400	.008	.075		.006	.200	.003		44.0
113		48.0	3.00	1.00	.040	.280	.200	.070		.008	.200	.002		47.8
114	BASE	42.5	4.30	1.80	.025	.700	.150	.190	.010	.005	.150	.002	5	49.8
115	BASE	72.5	5.40	8.20	.020	.590	.800	.150			.150	.001		13.2
116	BASE	95.0	.190	.300	.015	.220	.070	.100			.010	.001		4.20
116		94.0	.550	1.00	.015	.270	.050	.150	.010		.050	.002	5	2.30
117	BASE	94.5	.600	.600	.150	.040	.040	.180	.010		.070	.002	6	2.80
118	BASE	95.0	.220	.800	.015	.300	.060	.060	.030	.010	.055	.001	.0010	2.90
118	FIGURE	95.0	.200	.300	.005	.900	.030	.030	.020		.100			3.00
119	BASE	96.0	.400	.300	.025	.080	.050	.060	.010		.200	.003		3.10
119	FIGURE	96.0	.400	.300	.035	.080	.050	.060	.040		.100	.003	3	3.00
119	MAIN FIG	96.5	.100	.200	.020	.055	.050	.060	.010		.150	.001		2.50
119	HAT	98.5	.100	.400	.020	.035	.030	.065			.200	.002		2.00
119		93.5	.400	.300	.015	.150	.050	.050	.010		.100	.003		5.80
119	P.L.FIG.	97.5	.160	.150	.030	.050	.070	.060	.010		.100	.001	.0020	2.70
120	BASE	91.5	.430	.600	.015	.100	.015	.050	.030		.060	.003		7.90
120	FIGURE	94.0	.400	.400	.100	.200	.050	.070	.010		.050	.002		4.40
121	BASE	46.5	1.21	.600	.030	.500	.100	.110			.080	.003		51.0

Table 2

X-Ray Fluorescence Analyses of Tibetan
and Himalayan Metalwork

Cat	Cu	Pb	Sn	As	Zn
6	99	0.3	0.4		
20	99	0.8		0.3	
65	98	0.5	0.7	0.4	0.6
78	98	0.2	1	0.3	0.7
111	84		0.7	0.4	9

Table 3

Atomic Absorption Analyses of Buddhist Images
from Gandhara

Cat	Part	Cu	Pb	Sn	Ag	Fe	Sb	Ni	Au	Co	As	Cd	Bi	Zn
A		69.5	11.5	1.40	.095	.900	.500	.050		.030	.170		.0040	13.9
B	BACKPLATE	78.0	3.10	1.30	.010	1.20	.250	.015		.005	.030	.001	.0040	16.8
B	BODY	73.0	4.70	1.20	.010	1.20	.200	.015		.006	.050	.005	.0020	16.8
B	BASE	75.0	5.00	1.90	.010	1.30	.350	.005		.006	.060		.0070	16.9

Note : A is in the British Museum (Reg. No. O.A. 1958.7-14.1) and B is in a private collection.

STATUARY METALS IN TIBET AND THE HIMĀLAYAS: HISTORY, TRADITION AND MODERN USE

E Lo Bue

One fact which has emerged from six field-trips (1972-1978) which I devoted to the study of traditional Tibetan and Himālayan metal statuary (Lo Bue, 1978 and 1981) as carried out today in the workshops of Pātan, in the Nepal Valley, was that Newar sculptors use copper and brass for casting their images by the lost-wax process, almost to the exclusion of bronze. This observation prompted me to establish whether the term "bronze", as frequently used by Western art historians to describe Tibetan and Himālayan metal statues, is correct, and, if so, to ascertain the extent to which true bronze images were produced in the past, not only in Tibet and the Himālayas, but also in northern India. In November 1978 Jim Black kindly analysed for me a 20 cm. high Tibetan image of Ṣaḍakṣarī (Christie's sale catalogue of July 2nd, 1980, p.16, No.67 and Sotheby's sale catalogue of June 29th, 1981, p.10, no.13), attributed by von Schroeder to the 13th century, and this was found to be made of brass. Since then Uhlig (1979) has published a number of analyses of Tibetan and Himālayan images made by Josef Riederer[1] and this volume contains 121 new analyses by Paul Craddock of images and other ritual objects from the British Museum collection and elsewhere.

The following discussion serves as an introduction to the study of the various statuary metals in the context of the economic history of Tibet and Nepal (for a fuller treatment see Lo Bue, 1981, Ph.D. thesis).

There is a persistent myth among art historians that northern Indian statuary is cast in what has been termed "octo-alloy" (*aṣṭa-dhātu*), a compound containing copper, tin, lead, antimony, zinc, iron, gold and silver in varying proportions (Spooner, 1915: 157; Bhattasali, 1972 repr.: xx; Saraswati, 1962: 28; Sahai, 1977: 233; Bhattacharya, 1979: 146). This belief has not been supported by any serious study of the results of metallurgical analyses. Lee (1967: 47), commenting on the metallurgical analyses of one Kashmiri and one Indo-Tibetan image, notes that "the parts of the mix are radically at variance with those prescribed by various ancient holy texts for the guidance of artisans. In these, unfounded theory takes precedence and we are given imaginary formulae for particularly auspicious combinations of metals based on numerical magic but certainly incapable of producing the desired effect". The *aṣṭa-dhātu* is not the only instance of the Indian alchemical fascination with magical numbers. Majumdar (1926: 462) also mentions *navaloha*, *saptaloha* and *pañcaloha*.

One of the most striking features about Tibetan and Himālayan statuary, which becomes apparent when studying its materials and techniques, including the use of the lost-wax process and fire-gilding, is that descriptions of these processes appear to belong entirely to an oral tradition, as practised by the artisans and sculptors, as opposed to a religious and academic tradition of *literati*. The latter did not always have a clear picture of the technicalities faced by artists and wrote, as is the rule in Buddhist literature, in order to accumulate personal religious merit rather than to give precise instructions on technical problems. Thus no Tibetan or Newar manuals written in the vein of Cennino Cennini's *Il Libro dell'Arte*, have ever come to light. The suggested existence of a treatise allegedly used by Newar sculptors (Krishnan, 1976: 29 and Bhattacharya, 1979: 67) is without foundation and none of the leading Newar metal sculptors who were repeatedly interviewed during my fieldwork in Nepal had ever heard of such a manual. Attempts to trace Tibetan and Himālayan statuary traditions to literary sources are doomed to failure as the sculptors are sometimes illiterate and certainly ignorant of Sanskrit and do not need to refer to handbooks in order to carry out their work, any more than their western counterparts.

In the light of the above considerations, a study of Tibetan and Himālayan metal statuary has been attempted from a scientific angle, though without neglecting the literary and oral sources. This kind of interdisciplinary approach requires not only the study of the language and literature, but also fieldwork and close collaboration with scientists, so that the evolution of style and iconography in art can be related to the material culture and economic history of the people who produced it.

The traditional attitude of archaeologists and art historians towards the study of northern Indian metal statuary and its technology has not shed much light on the composition of the alloys used in the past. In his study on Taxila Marshall (1951, II: 564) uses the word "bronze" to include alloys other than those of copper and tin, and Goetz (1969: 139), while accepting the fiction of *aṣṭa-dhātu*, adds to the confusion by equating it with brass. The latter appears to regard brass as a "cheap metal", and his prejudice against the term "brass" is derived from the Western classical tradition which regards bronze as the statuary metal *par excellence* and brass as a cheap "substitute".

A detailed study of the metallurgical data reported by Spooner (1915: 157), Marshall (1951, II: 567-569), Lal (1956: 55-56), Lee (1967: 51, n.22), Sahai (1977: 234-236), Werner (1972: 184-187 and 190-191) and Uhlig (1979: 66-67) shows that in northern Indian metal statuary unalloyed copper was used from the times of Taxila, and that brass tends to replace bronze as one proceeds westward from Bengal (an area close to tin-producing countries such as Burma and Malacca) to Rajasthan (where zinc ores were exploited in ancient times: Brown and Dey, 1955: 163 and Werner, 1972: 161-2) and Kashmir. This is of great importance for the study of Tibetan and Himālayan statuary which was, and is, almost exclusively cast or embossed in copper or brass. Copper and zinc ores are found in both Tibet and Nepal, whereas tin is absent from both countries.

Indian statuary was introduced into Tibet from the west (Kashmir) and from the south (northern India via the Nepal Valley) concurrently with Buddhism. During the 10th and 11th centuries western Tibetan Buddhist kings were in contact with Kashmir and other Buddhist centres in India. At their request the Tibetan scholar Rin-chen-bzang-po (A.D. 958-1055) travelled three times to Kashmir and once to eastern India (Snellgrove and Skorupski, 1980: 90 and 99) and, having brought back to western Tibet thirty-two artists in c. A.D. 1019 (according to my calculations; see Snellgrove and Skorupski, 1980: 91, n.21 and 22; and Tucci, 1933, II: 67 and 12), he had chapels and temples built in twenty-one different places. In one of these temples, he erected forty-five metal images, some in copper and some in brass (Tucci, 1933, II: 69; *cf.* Snellgrove and Skorupski, 1980: 94 and 107). Previous to that, Rin-chen-bzang-po commissioned the Kashmiri artist Bhidhaka to make "an image of Avalokiteśvara to his father's size" with brass begged for in Kashmir (Snellgrove and Skorupski, 1980: 32). It is possible that, being an alloy commonly used in Kashmiri metal statuary, brass was preferred for casting statues in western Tibet, although another text unequivocally indicates that copper was also used there (Padma-dkar-po, 1973, I: 30-2; see below, p.42) at the turn of the 10th century to cast images meant for gilding. Copper and brass are also mentioned as the materials of a number of religious items listed in Rin-chen-bzang-po's biography (Snellgrove and Skorupski, 1980: 108). Thus both brass and copper were used in western Tibetan metal statuary from an early period.

A starting point for the discussion of western Tibetan metal statuary and statuary metals is the 98.1 cm high Cleveland Buddha, whose brass alloy was found to contain 68.3% copper, 20.2% zinc and 11.0% lead. It is inscribed as being a "vow of the prince-monk Nāgarāja", who lived in the 11th century and belonged to the lineage of western Tibetan kings. This image has been discussed at length elsewhere (Lo Bue, 1981 Ph.D.

thesis) and it is sufficient here to say that, in the light of genealogical evidence, the Cleveland Buddha should be attributed to the 11th (Karmay, 1975: 29) rather than the 10th (Pal, 1975: 100) century. This masterpiece proves once again the persistence and resurfacing of styles, which I find characteristic of Tibetan and Himālayan art, where copying is the rule, rather than the exception (Lo Bue, 1981: 115 and 126 n. 9). It is the earliest datable image from Tibet, for which metallurgical data have been published. Another early (11-12th century, see below p. 70) example of western Tibetan brass statuary is the 69.3 cm. standing Vajrapāṇi cast with the lost-wax process (Hours, 1980: 95-98), at the Musée Guimet (MA.3546). Western Tibetan statues belonging to the following period (12th-15th century, nos. 42, 63 and 64 on pp.105-6 and below) are cast in brass with small percentages of lead, tin and arsenic. An exception is the stand of no. 42, which has no zinc in its alloy.

Central Tibetan kings were in contact with India and the Nepal Valley from at least the reign of Srong-brtsan-sgam-po (A.D. 627-649), who married a Newar princess. Newar sculptors worked in Tibet from that period onwards, which may explain why central and southern Tibetan metal images are often cast in copper, a favourite metal for Newar statuary owing to the presence of copper ores in Nepal (see below, pp. 37 & 39) and because of its advantages for fire-gilding, which is traditional in the Nepal valley. However, brass was also used in central and southern Tibetan lost-wax metal statuary (see below, p.48), as well as in the Nepal Valley.

Whereas early Sino-Newar images made during the Mongol overlordship (A.D. 1207-1368) were cast in copper (*cf.* Uhlig, 1979: 168, fig. 95), eastern and Sino-Tibetan metal statuary from the Yung-lo period (A.D. 1403-1424) and Hsuan-te period (*cf.* Uhlig, 1979: 220, fig. 136) through to the Ch'ien-Lung period (A.D. 1736-1795) and afterwards was almost invariably cast in brass, even when it was destined for fire-gilding. (see nos. 91; and 5-7, 27-28, 49-52, 86-88, 111-112 in the list on pp.26-31).

Thus the geographical distribution of the use of metals in Tibetan statuary appears to reflect an increase in the use of copper at the expense of brass when proceeding from the west and east towards the centre and south of the country. In the Nepal Valley, where copper was the predominant alloy, there was a general increase in the use of brass from the 18th century onwards, probably in connection with the production of metallic zinc for brass-making and the availability of both zinc and brass from the East India Company (see below, p. 47).

In September and November 1980 I carried out a survey of Tibetan and Himālayan metal statuary in the major public collections of Britain with the aim of producing statistical data on the types of alloy and manufacturing techniques used in Tibetan metal statuary. In this connection I must acknowledge the help received from the British Academy in the form of a grant which enabled me to gather the following data and prepare them for publication in this paper. Of the 378 free-standing statues examined, 331 were of metal, the remaining ones being wood, stone, clay, *papier-mâché* and ivory. As it was not always possible to distinguish with certainty betwen Tibetan and Nepalese images, owing to the activities of Newar sculptors in all parts of Tibet for many centuries, some results in Table 1 on the following page are given as maximum and minimum, according to whether borderline cases are included or ignored. This table only refers to Tibetan metal statues, Newar icons having been left out when positively identified as such.

The general picture which emerges from this survey has been confirmed by the analyses of five Tibetan images at the Victoria and Albert Museum, which were made of brass or copper, by the analyses published by Uhlig (1979) and by those of Craddock (see above, pp.26-31). The results of the metallurgical analysis of one Gandhara and four Tibetan images carried out by A. Martin, of the Victoria and Albert Museum, in September 1980, confirm

Table 1

	Total	Brass	Copper	Silver	Fire-gilded brass	Fire-gilded copper	Cold-gilded	Repoussé	Inlaid
Ashmolean Museum	90-99	56-59	39-45	5	42	25	5	3	5
Liverpool County Museum	62-71	35-37	33-40	1	15	16-23	5	3-4	-
Gulbenkian Museum	2	2	-	2	-		-	-	-
Cambridge Museum of Anthropology	8-11	2	5-7	1	-	4-6	-	3	-
Royal Scottish Museum	29-36	18-24	8-9	3-4	6-9	6-7	0-1	1	1
Total	191-219	133-124	85-101	10-11	65-68	51-61	10-11	10-11	6

that brass was used throughout all periods in northern Indian metal statuary and that copper and brass must be regarded as the most common statuary metals in Tibet. I take here the opportunity to thank both Mr Martin and Mr John Lowry for allowing me to publish these results in Table 2.

It may be concluded, therefore, that copper and brass have been predominantly used in Tibetan and Himālayan metal statuary almost to the exclusion of bronze, although images were occasionally cast or embossed in other metals. The unusual composition of no.4 in Table 2 is discussed below (p.43).

Individual metals: the literary evidence

Copper

Zangs, *zangs-dmar*, and sometimes *li-dmar* and *zi-khyim* are the Tibetan terms generally used to define copper. Copper occupies a pre-eminent position in the metallurgy of India, Nepal and Tibet, where it has been traditionally employed for lost-wax and embossed statuary. *Li-dmar* (red *li*) is mentioned by Padma-dkar-po as being used in northern Indian statuary along with brass, in a passage in which he acknowledges the excellence of the Newar style (1973, 300, ll. 1-2). In view of the initial absence of bronze and white metal and the use of brass and copper in ancient northern Indian statuary it may be surmised that the term red *li* as used by Padma-dkar-po more often than not corresponds to "copper": "*li-dmar* is the same as *raṅ-byuṅ-ljon raṅ-byuṅ-zaṅs* - natural copper" (Dagyab, 1977, I: 52). Pure copper (see no. 37 on p.105), in particular, is very highly thought of (Padma-dkar-po, 1973, I: 294, l.2). The Mongol lay physician 'Jam-dpal-rdo-rje (early 19th century) explains that "native copper from under the earth is as precious as gold: it is rock copper. The native red copper from rock copper is called 'gold copper'. Black copper (cupric oxide ?) is called 'iron copper'" (Chandra, 1971: 41). 'Jam-dpal-rdo-rje's definition of "native copper" casts light on an otherwise obscure term used by the dGe-lugs-pa encyclopaedist Klong-rdol-bla-ma (A.D. 1719-1805; Smith, 1969: 26ff.) which recurs in Tibetan metallurgical literature (e.g. in Padma-dkar-po, I: 300, l.3): "the ore which is dug out like gold is native copper. It has the famous name of 'precious *dzhai kṣiṃ* stone" (Chandra 1973, 1462, ll. 1-2). Klong-rdol (Chandra, 1973: 1462, ll. 3-4) adds that "copper is dug out from parts of Nepal" and makes a distinction between pure Nepalese copper, soft without grooves, and a late poor quality copper of his day, harsh and with many grooves. Copper is found in small deposits in hilly areas of Nepal and has been extracted and also exported from that country to India [2] at least since the 11th century, for the use of Nepalese copper is mentioned in Cakrapāṇidatta's treatise, *Cakradatta*, written in A.D. 1050 (Ray 1956: 108 and 110). In Book V, vv. 42-4 of the late 13th century *Rasaratnasamuccaya* we read: "there are two varieties of copper: the one brought from Nepal is of superior quality" (Ray, 1956: 182).[3] Ray concludes: "on account of its purity Nepal copper was highly valued in old days" (1956: 93-4). According to Ray (1909: 222-3) the best quality copper is also said to come from Nepal in the *Rasāyanaśāstroddhṛti*, a short treatise included in the Tenjur. During his mission in 1793, Colonel Kirkpatrick (1975 repr.: 62) noticed the presence of copper mines in Nepal and reported that, though some of them were nearly exhausted, others were being exploited by a caste of miners. Three years later Abdul Kadir Khan also noted that the Nepalese were working some of their copper mines (Regmi, 1961: 247). The government profits from their annual revenue had been three to four lakhs of rupees, and in those days Nepal must still have been self-sufficient in copper, for the item does not appear in Kirkpatrick's list of principal metal commodities (1975 repr.: 209) exported from the East India Company's dominion to Nepal, either for use in that country or for the Tibetan market. Furthermore,

Table 2

	Inv No.	Description	Origin	Century	%Cu	%Zn	%Sn	%Pb
1)	IS 12-1948	Buddha	Gandhara	5th century	68.45	20.25	3.86	3.62
2)	IS 13-1971	Lama	Tibet	13th?	61.27	31.87	0.74	0.55
	This image is illustrated by Lowry (1973: 34, No. 12) and by Béguin (1977: 242, No. 283), who ascribes it to the 16th-17th century. Results of the analysis of its underside sealing copper sheet:							
					(98.14	—	1.61	0.02)
3)	IM 121-1910	Śākyamuni	Tibet	14th	83.67	0.04	—	0.01
	Illustrated by Lowry (1973: 14, no. 2)							
4)	IM 20-1929	Lama	Tibet	14th/15th	89.28	4.96	7.32	3.10
5)	IM 61-1929	Mahāsiddha	Tibet	18th	70.67	20.89	3.99	5.41
	Illustrated by Lowry (1973: 32). This fire-gilded Sino-Tibetan image was originally attributed by Lowry (1973: 33, no. 11) "possibly" to the 16th-17th century.							

copper was still being exported from Nepal into Tibet, in the late 18th century (Turner, 1800: 382).

Klong-rdol's indication of copper as a metal of Nepalese origin is also confirmed by Orazio della Penna (A.D. 1730, in Markham, 1879: 317) and supported by Buchanan's mention of about forty copper mines and sites in Nepal,[4] of the export of "large quantities" of copper to India (Buchanan, 1819: 272), and of the use of Nepalese copper both in Nepal and in Tibet. Again, Hodgson (1972 repr.: 119) noted that "Nepal is full of fine copper, and supplies copper currency to the whole tract" and that copper pots and the like were exported from Nepal to India. In the 18th century copper from the northern areas of Nepal was traded in the Terai (Regmi, 1971: 20) but by the end of the century, copper production in Nepal was barely enough for home consumption. From 1800 all existing mines in Nepal were brought under direct governmental management and arrangements were made to purchase copper on a monopoly basis. Indeed, Kirkpatrick had already noticed that "European copper was procurable in Calcutta" for one rupee the seer less than Nepalese copper. Kirkpatrick (1975 repr.: 176) had a poor opinion of Nepalese mining expertise and noticed the "backwardness of the natives in the arts of mineralogy and metallurgy". Buchanan (1819: 76-7) reports that "the ore is dug from trenches entirely open above, so that the workmen cannot act in the rainy season, as they have not even sense to make a drain". Nevertheless, the trade obviously continued in spite of the facts that not only the export of copper, but even private trading had been banned and stringent methods adopted by at least 1813 to stop it being smuggled out of the country (Regmi, 1971: 219). Tibetan merchants continued to buy copper utensils in Kathmandu (Buchanan, 1819: 213 and 232).

Copper appears as an import in Nepal only at the turn of the 19th century (Lévi, 1905, I: 312). By the early 20th century Nepal had to import "sheet copper and other metals" from British India (Imperial Gazetteer of India, 1908: 121) and there is reason to believe that by the end of the 19th century Nepalese copper mines were exhausted or uneconomical to work, and that very little copper is mined in Nepal nowadays.

Copper used by 20th century Newar artists is now bought in sheet form through the London metal exchange and is mixed with any scrap copper they may lay their hands on, such as old wire, faulty castings, sprues from previous images, and so forth. The vast majority of so-called Nepalese "bronzes" are in fact fire-gilt copper images, made by Newar artists, for the use of almost pure copper in Newar statuary is very ancient, as has been pointed out by Kramrisch (1964: 30). Copper is still very much in demand amongst Newar sculptors for the casting of good quality statues (nos. 116-119), in spite of the problems that its high melting point (1083°C) poses for the comparatively primitive Newar metallurgy. The soft surface of pure copper is easier to chase than the hard and brittle surface of brass, and it does not present any problems for fire-gilding.

Although Tibetan sculptors had alternative supplies of copper to those from Nepal, it is likely that Nepalese copper continued to reach Tibet in one way or another during the 19th century for, as a rule, Tibetans themselves did not get involved in mining on a large scale. They feared upsetting the local gods of the earth. and preferred to import metals from India,[5] China, Nepal, and East Turkestan. To that effect Hedin mentions Csoma de Körös's native source on the matter, dating from a few years before 1834:

> Mines are rarely excavated in Tibet. In the northern part of Nari (*sic*), and in Guge, some gold dust is gathered, as also in Zanskar and Beltistan (*sic*) it is washed from the rivers. If they knew how to work mines, they might find in many places gold, copper, iron and lead.
>
> (Hedin, 1922, VII: 185).

Ordinary Tibetans have religious and economic objections to the exploitation of mines. In Tibet

> there is an old-established objection to mining on religious grounds. 'If minerals be taken out of the ground', says the ordinary Tibetan, 'the fertility of the soil will be weakened'. Many think that the minerals were put into the ground by the 'Precious Teacher', Padma Saṁbhava, when he brought Buddhist teachings from India, and that, if they are removed, rain will cease and the crops will be ruined. The religious objection is intensified by an economic one. When a mine is found, the local peasants and others are expected to work it without pay. This work being for the Government, the system of *ula* (unpaid labour) is held to apply. So the villagers have every incentive to conceal the existence of mineral wealth, and will sometimes turn out and attack those who try to exploit the mine.
>
> (Bell, 1968 repr.: 110-111).

The Tibetan administration, on the contrary, was interested in developing the mineral wealth of the country (Bell, 1927: 158-9; *cf*. below, p.55). The presence of copper ores in Tibet was first reported by the Italian Capuchin, Father Orazio della Penna di Billi (A.D. 1730, in Markham, 1879: 317) who spent twenty years in Tibet and later, in A.D. 1783, by Saunders, who accompanied Captain Turner to Tashilhunpo, near Shigatse (Turner, 1800: 405). Turner (1800: 296) himself mentions "mines of lead, copper, cinnabar and gold" on the roads to Ladakh and Kashmir and specifies that "copper mines furnish materials for the manufactory (*sic*) of idols, and all the ornaments disposed about the monasteries, on which gilding is bestowed" (Turner, 1800: 372). Copper mines, as well as silver and gold mines, were mentioned also by Hedin's informants (Hedin, 1922, IV: 99), and copper is found in Ladakh (Hassnain, 1977: 43) and in Zangskar (Marshall, 1951, II: 565 and 570). Deposits of malachite and azurite (basic copper carbonate) are known to exist in sNye-mo-thang, a site probably in the hills south-west of Lhaṣa (*cf*. Pal, 1969: 30), though arbitrarily placed by Ronge (1978: map) somewhere between Gyantse and Rin-spungs. Because of their importance, "the Lhasa government strictly controlled" their "mining and distribution", which supplied most of the green and blue pigments used by Tibetan painters (Jackson, 1976: 274). The central Tibetan administration mined the colourful minerals only once a year, apparently so as not to exhaust the supply, but the people of sNye-mo also picked up loose bits on the mining site in order to sell them for their own gain (Ronge, 1978: 148). 'Jam-dpal-rdo-rje specifically mentions "malachite" (Tib.:*spang*) and "azurite" (Tib.:*mthing*) in his section dedicated to copper ores (Chandra, 1971: 57): "they appear in the earth which has malachite and azurite (...) By melting them there appears copper. It is the one which is called 'naṭive copper'".

The existence of copper, besides iron, zinc, lead and a wealth of other minerals, was also reported during the surveys carried out by investigation teams despatched to Tibet by the Geological Section of the Chinese Academy of Science in 1957 and 1964-1965. Copper also occurs in the northern foothills of the Kunlun between Yarkand and Khotan, and bronze and brass items from east Turkestan dating from the 7th century (Werner, 1972: 190-3, table 7.1) are known. Copper mines in eastern Tibet are mentioned by Cooper (1871: 463-4, *cf*. Pranavānanda, 1939: 37). For a long time, copper has been extracted to the south of Li-thang (Gong-kha-gling; Coales, 1919: 246 spells this place name "Kungkaling") and near 'Ba-thang (Le'), in eastern Tibet (Ronge, 1978: 145). It is worth noting that "one of the most important areas for metal casting is the province of Kham in eastern Tibet. Three well-known centres in the province are Derge, Chamdo, and Reo-Chi" (Pal, 1969: 29). The coppersmiths of sDe-dge, famous throughout Tibet (Rockhill, 1894: 358), also got their raw material from Gong-kha-gling, south of Li-thang, (Coales, 1919: 246) and so probably did those of Li-thang (Rockhill, 1891: 207). Copper ore was also found in the area of sDe-dge itself (*cf.* Duncan, 1964: 19). At Va-ra-dgon-pa, a copper "mine was opened in 1910 or thereabouts, but has since been closed" (Coales, 1919: 246). Although copper ore was worked in the neighbourhood of Zi-ling, on the Sino-Tibetan border, most of the copper objects in eastern Tibet and Amdo were imported from China. For example, at Lhamdun, south of 'Ba-thang, Rockhill (1894: 340) "noticed in use (...) a good many Chinese utensils, especially of iron and copper". As the most important copper deposits lie in eastern Tibet, and those in lower sPo-bo (on this district, see Waddell, 1906: 440 and 502-3) played no great rôle, central Tibetans occasionally obtained their copper from Khams (Ronge, 1978: 146). Sometime between 1851 and 1853, rDo-rje-don-grub of sKyid-stod "was sent to Khams to procure the copper necessary for the repairs at bSam-yas" (Petech, 1973: 91). However, it is certain (see above p.39) that the metal continued to be imported into Tibet through its southern borders (Ronge, 1978: 145), sometimes for minting purposes (McGovern, 1924: 342). Although copper ores were apparently worked in Bhutan for the manufacture of large copper cauldrons (Pemberton, 1961 repr.: 75), that country too had to import the metal (Pemberton, 1961 repr. : 77).

In Tibet, copper has been used either pure, or to form the various alloys which go under the general terms of *li*, *'khar-ba* and *khro*. The 'Brug-pa bKa'-rgyud-pa scholar and artist Padma-dkar-po (A.D. 1526-1592) informs us that during the reign of Srong-brtsan-sgam-po native copper, *li-dkar* (white *li*) and *li-dmar* (red *li*) were used "pure", and also in composite metalwork (inlaid patchwork; Padma-dkar-po, 1973, I: 300, 1.3), and that during the reign of Ral-pa-can (A.D. 815-836) copper was used not only to inlay the lips of metal images, but also in their alloys, whereby "they gradually turned darker than the early ones" (Padma-dkar-po, 1973, I: 301-2). From the early 11th century, native copper was used in western Tibet either pure (Tucci, 1959: 186) or alloyed with zinc to cast metal images (see above, p.34). Finally, mention should be made of the use of copper in Tibet from at least the 11th century (see above, p.34) to cast various ceremonial articles, including reliquary *stūpas* (no. 46 on p.105 below).

Zi-khyim

Sarat Chandra Das's *A Tibetan-English Dictionary with Sanskrit Synonyms*, (1976 repr.: 1090) contains the following translation and explanation under the Tibetan word *zangs:* "copper - pure unalloyed copper being considered very valuable, images of Buddha and *Bodhisattva* made of pure copper are called *nor-bu dzha-kṣiṃ* (*sic*); also a compound of gold, silver, copper, zinc, or of mica, quicksilver, tin and lead (....)". The most famous statue in Tibet, the Jo-bo (Lord) of Lhasa, portraying a more than life-size (Walsh, 1938: 538) Śākyamuni, is said to be made of such an alloy (Tucci, 1959: 181-2; Dagyab, 1977, I: 52). Although the image is said to have been brought from China by Srong-brtsan-sgam-po's Chinese wife, the statue is supposed to have been originally made in India from "gold, silver, zinc, iron, and copper". (Das reported by Walsh, 1938: 539. See also Landon, 1905, II: 310). On these and stylistic grounds, Walsh (1938: 539) concludes that "the image is Indian". It is to enshrine this image that king Srong-brtsan-sgam-po built the Jo-khang during the second quarter of the 7th century. It may be interesting to contrast Walsh's statement with the tradition that the Jo-khang itself was built by Newar craftsmen to house "several valuable Buddhist images" brought to Tibet by Srong-brtsan-sgam-po's Newar queen as part of her dowry (Norbu and Turnbull, 1972: 143) and that its gilt copper "screen was, perhaps, the work of the famous Nepalese artist and craftsmen, Anika (or Aniko) who worked also in China in the latter half of the 13th century "(Richardson, 1977: 169; Richardson does not give any reason to justify his attribution).

On the other hand Padma-dkar-po (1973, I: 300, 1.3) states that *zi-khyim* was used in Tibetan statuary at the time of Srong-brtsan-sgam-po, along with "pure" red and white *li* for composite inlaid metalwork (Tib.: *sho-bsgrigs*, translated by Dagyab (1977, I: 55 and 57) as: "square patches" and "square pieces". This type of inlay work may perhaps be exemplified by a 17th century brass Ṣaḍakṣarī in the British Museum (registration no. 1905.5-19.7). The anonymous text translated by Tucci (1959: 186) confirms that *zi-khyim* was used to manufacture statues which were subsequently gilded during a period corresponding to the 10th-11th century in western Tibet, and Padma-dkar-po (1973, I: 301-2) confirms that:

> Regarding the varieties (of early Tibetan images) at the time of the two monk-princes, uncle and nephew (Ye-shes-'od and Byang-chub-'od).
>
> They were mixtures of red copper (Tib.: *zangs-dmar*, i.e.) *zi-khyim* thickly coated with gold from Zhang-zhung (western Tibet. On Zhang-zhung and its extension see Tucci, 1956: 71ff.).
>
> Their nose is beautiful and the shape of their body sturdy.
>
> Their *déhanchement* has a graceful manner. Those which resemble the images of Nepal are called *mthon-mthing-ma*. ("azurite blue ones", with reference to the pigment used to paint their raised up hair. *Cf.* Tucci, 1959: 186 and Karmay, 1975: 7).

How do the two Tibetan words, *dzhai-kṣiṃ* and *zi-khyim* relate to each other, and in which context do they appear in Tibetan literature? In view of the facts that the Jo-bo itself is said to be made of *dzhai-kṣiṃ* and that *zi-kyim* was used in western Tibet in connection with gilding at the time of the second introduction of Buddhism into the country, an attempt to translate and interpret these two words appears to be useful for the purpose of shedding more light on the use of statuary metals in early Tibetan sculpture.

Das (1976 repr.: 1090) identifies the Tibetan transliteration "*dshai-kṣiṃ*" (*dzhai-ksim* in the standard system of transliteration followed by me), with the Sanskrit *yaukṣiṃ*, a term which I cannot find in any Sanskrit dictionary, and he does not include the word *zi-khyim* in his dictionary. In his work on Tibetan loan-words, Laufer (1918: 55) only mentions *zi-khyim* and postulates a Sanskrit etymology with a question mark, but Tucci (1959: 180, n.2) suggests a Chinese derivation, from the Chinese *ch'ih chin* (Mathew, 1969: 145, 1048: "deep coloured gold; copper") and gives the spellings "*ji k'yim*" (*ji-khyim*, in the transliteration system I follow) and "*dsai kṣiṃ*" (from Klong-rdol who, however, has *dzhai-kṣiṃ* in the standard transliteration system I follow). Dagyab (1977, I: 51-2) only uses the form *dzñē-kṣiṃ* to the exclusion of any other, perhaps following his source, 'Jigs-med-gling-pa (A.D. 1729-1798). As will appear below, each of these words is used to the exclusion of all the others in Tibetan texts dealing with metals, and they should be regarded as various spellings for the same term. I have chosen to follow the spelling *zi-khyim* as consistently used by Padma-dkar-po (A.D. 1526-1592), not only on the grounds that he is the earliest and more detailed of my Tibetan sources, but also because he was a well-known artist himself besides being a *literatus*, and 'Jig-med-gling-pa's account used by Dagyab is in fact largely drawn from Padma-dkar-po's.

According to Padma-dkar-po (1973, I: 264, ll. 5-6) *zi-khyim* "appears like the gold on the banks of the Sin-dhu river; it is therefore called 'red gold'" and it is recognized precisely by its red colour. It emits the light of a rainbow: when touched by acid, it shows the very bow of Indra", i.e. it becomes iridescent. Klong-rdol (Chandra, 1973: 1462, ll. 1-2) distinguishes two types of *zi-khyim: li-khra* ("iridescent *li*"), whose ingredients, "gold, silver, copper, and white iron, and rock crystal, lead, black and white (*zha-nye dkar nag*), and mercury, the eight of them, when melted and ground, are known as 'artificial *dzhai-kṣiṃ*'"; and the "precious *dzhai-kṣiṃ*" (Tib.: *nor-bu dzhai-kṣiṃ*), which is "native copper dug out like gold underneath the earth". The composition of the *li-khra* type of *zi-khyim* as described by Klong-rdol differs from that given by Das, for Klong-rdol does not mention the presence of zinc and tin in the alloy. Elsewhere, in the same dictionary, Das (1976 repr.: 1212) maintains that *li-khra* is "a compound made of gold, silver, zinc and iron cast together", a most unlikely mixture in which copper is not mentioned, and which again is in disagreement with the definition given by Klong-rdol, whose text Das generally follows.

Following 'Jigs-med-gling-pa, Dagyab (1977, I: 51-2) states that pure *zi-khyim* "is obtained from the earth and greatly resembles natural copper" and that it turns iridescent when touched by a poisonous "water" (i.e. acid). He distinguishes it from "artificial" *zi-khyim*, "an alloy composed mainly of copper mixed with gold, silver or other precious metals, and nickel silver". He confirms that *li-khra* is nothing else than artificial *zi-khyim* and that the Jo-bo in the Jo-khang is made of this alloy. Dagyab (1977, I: 51) goes as far as identifying one particular image as being made of pure *zi-khyim* and even illustrates it. Unfortunately, throughout his work, Dagyab never supports his descriptions with metallurgical analysis, thus adding very little to our knowledge of Tibetan statuary metals.

Neither native nor artificial *zi-khyim* is mentioned in 'Jam-dpal-rdo-rje's comprehensive *Materia Medica of Āyurveda*, thus making it difficult to postulate a Sanskrit origin for the word and suggesting that Tucci's etymology is more satisfactory. However, it may be interesting to investigate a possible connection between this word (pronounced: Sikhim) and the place name Sikkim, where copper mines are known to exist (see below, n. 2; Waddell, 1906: 72 and 491; and Marshall, 1951, II: 571).

Although it may be assumed that Tibetan scholars writing on the subject of *zi-khyim* and *li-khra* did not know their chemical composition and were merely following either hearsay information or a mixed academic tradition partially traceable to Chinese and Indian sources, all Tibetan authors so far reviewed appear to agree at least in one respect, that both pure and artificial *zi-khyim* are copper alloys. None of them mentions zinc (Tib.: *ti-tsha*) or tin (Tib.: *gsha'-dkar*) among the ingredients of artificial *zi-khyim*. It should be mentioned, however, that Jäschke (1972 repr.: 471) equates the Tibetan term *zha-nye dkar-po* "white lead", with *gsha'-dkar*, "tin", thus allowing another interpretation of Klong-rdol's formula.

Tibetan metal (*li*) statues showing an iridescent (*khra*) surface are rare. I have come across only one statue with this appearance which has been analysed, a late 14th or early 15th century portrait of the Pan-chen Phyogs-las-rnam-rgyal from Bo-dong (A.D. 1306-1386). Its metallurgical analysis (see above, p.38,no. IM 20-1929) shows that copper, tin, zinc and lead are present in significant proportions in the alloy. In fact this is a very rare instance of a Tibetan image actually cast in a kind of bronze alloy. It might be suggested that the Tibetan expressions "artificial *zi-khyim*" and *li-khra* cover some unusual or seldom used Tibetan copper alloys, or else that they are the Tibetan equivalent of the Indian *aṣṭa-dhātu*, as suggested by Tucci (1959: 180), and thus a mythical alloy (see above, p. 33). The fact that the Jo-bo of Lhasa is said to be made of this alloy by Tibetan sources and the circumstance that no Western visitor has ever been able to have a proper look at the material of the image, which is heavily covered with clothes and bedecked with jewellery, should make us cautious, if not suspicious, with regard to the alloy as described by

Tibetan writers. However, it is more likely that *li-khra*, or artificial *zi-khyim*, is just a kind of leaded brass. This suggestion is reinforced by Dagyab's statement that at the time of Ye-shes-'od and Byang-chub-'od (see p. 42) many statues were cast in that material. We know (see p. 34) that western Tibetan statuary of the 10th-11th centuries was cast in brass, besides copper, which is also mentioned by Dagyab as being used at that time. When Dagyab (1977, I: 56) adds that "the *li-khra* statues of this period were of such fine quality and resembled so closely the Indian statues as to be easily mistaken for them", I cannot help thinking of the Cleveland Buddha, which was cast in leaded brass (see above p. 34) in Kashmiri style, perhaps by Kashmiri sculptors working in western Tibet or by their Tibetan pupils, during the 11th century.

With regard to the "pure" or "precious" i.e. native type of *zi-khyim*, we know that Padma-dkar-po equates it with *li-dmar*, red *li*, which I have suggested to be copper (see above, p. 37) and which Dagyab (1977, I: 52) also describes as "natural copper". The anonymous text translated by Tucci equates it with "red copper, *ji k'yim*" (Tucci, 1959: 186); Klong-rdol defines it as "native copper"; 'Jigs-med-gling-pa states that it "is obtained from the earth and greatly resembles natural copper" (Dagyab, 1977, I: 51); and Das (1976 repr.: 1090) specifies that Buddhist images made of pure unalloyed copper are called precious *zi-khyim*. In this connection it may be interesting to note that there is an important copper ore, bornite or erubescite ($Cu_5 Fe S_4$ or $Cu_3 Fe S_3$) which, on account of its peculiar colour and iridescence, is known as "peacock ore", "pure copper ore", and "horseflesh ore". The colour of a freshly cut surface of bornite is coppery, but in moist air this rapidly tarnishes to iridescent blue and red colours. According to Holland "it occurs in several parts of India" (Ray, 1903, I: 76), and the presence of sulphur in some of the copper objects found at Taxila was noticed by Ullah (Marshall, 1951, II: 570). In the light of the above literary and metallurgical evidence, there is strong indication that pure *zi-khyim* is nothing other than native copper, and that red *li* is yet another one of the many Tibetan expressions used to indicate copper. In connection with the use of these three terms by Tibetan authors to define one western Tibetan statuary metal, it is important to note that Ullah (Marshall, 1951, II: 570) reported the existence of a native copper of a very high degree of purity in Zangskar (literally: "White Copper") a culturally western Tibetan area. The analysis of a specimen of Zangskar copper made by Ullah gave the following result: 99.4% Cu, 0.081% Fe and 0.34% insol. (SiO, etc.). It is very likely that similar ores of native copper of very great purity (*nor-bu zi-khyim*) were used by the western Tibetan kings for casting the images mentioned by Padma-dkar-po, by the text studied by Tucci, and by Dagyab's sources, and that they were also used in alloy with zinc to cast at least some of the early brass images from western Tibet, at the time of Rin-chen-bzang-po. We have already seen (above p.40) that copper ores are also found in Ladakh, where Rin-chen-bzang-po was active during the first half of the 11th century.

Zinc

Zinc (Tib.: *ti-tsha*), like tin, is not used as a statuary metal on its own, but is always alloyed with copper. The history of zinc metallurgy is dominated by the fact that its oxide is not reduced by carbon below the boiling point of the metal. If zinc oxide ore is heated to boiling point (above 906°C) without special precautions, it simply evaporates into the atmosphere. In England, it was not until A.D. 1738 that William Champion first obtained patent protection for a furnace fitted with an external condenser for the production of metallic zinc. However, Ray (1956: 138 and 171) provides sufficient literary evidence to conjecture that zinc had been isolated by Indian alchemists from at least the 12th century (see below,

p. 46 and nn. 8 and 9).

The problem of tackling the time and place of the recognition and production of metallic zinc is directly connected with the manufacture of brass. Until zinc was isolated and produced on an industrial scale, brass was manufactured by heating zinc ore (calamine) with thin plates of copper, which would absorb the zinc metal *in statu nascendi*. Champion's experiments in the 18th century and Werner's in the 20th showed that brass manufactured by this method could contain no more than 28% zinc. Hence, a zinc content above 30% is a sure indication that the brass in question has been obtained from metallic zinc and copper.

This circumstance is important, for ascertaining the period and area of the first production of zinc metal would help to establish a *terminus post quem* for those brass images with a zinc percentage exceeding 30%. Conversely, a dated image with more than 30% zinc in the alloy would cast more light on the history of the metallurgy of zinc. Since metallurgical analysis reveals that brass was used traditionally in northern Indian and Kashmiri statuary and was adopted from at least the 11th century in western Tibet for casting images, it may be useful to look for historical evidence of the production of zinc and brass not only towards India but also towards the "brass country" (Needham, 1974, V/2: 220), Iran, with which Tibetans traded from at least the 8th century (Beckwith, 1980: 35 and al Ya'ḳūbī, 1937: 4 and 234-6).

During his stay in Iran, Marco Polo (A.D. 1254-1324) witnessed the process of making "tuzia" (tutty, impure zinc oxide) from an ore which he describes as *andànico* [6] and which we can reasonably assume was calamine. *Tūtiyā* is the Middle Persian word for calamine, which spread into Arabic and most Western Languages (Needham, 1974, V/2: 203).

> They take the crude ore from a vein that is known to yield such as is fit for the purpose, and put it into a heated furnace. Over the furnace they place an iron grating formed of small bars set close together. The smoke of vapour ascending from the ore in burning attaches itself to the bars, and as it cools it becomes hard. This is the tutty; whilst the gross and heavy part, which does not ascend, but remains as a cinder in the furnace, becomes the spodium.
>
> (Masefield, 1936: 71).

In his *Cosmography* (c.1200) the Persian al Kazvini describes the scraping of tutty from the sides of the furnace (Dawkins, 1950: 5). Again, Marco Polo mentions "a mountain where the mines produce steel and also andanico" in the district of "Chingitalas" (Ponchiroli, ed., 1979: 49) in Turkestan.[7] Zinc deposits have been located in the Khotan district, and references "found in sixth century texts" as well as "archaeological finds at Kucha in Khotan show the way" by which knowledge of brass-making with zinc ore "penetrated from Persia" (Forbes, 1971, VIII: 281). We have seen (above, p.40) that copper ores exist between Khotan and Yarkand. It is quite significant that Needham (1974, V/2: 220, n.c) should conclude his section "The origins of zinc" by stating that Chinese mention of

> brass as a Persian export would point to the Iranian culture-area as the place where we ought to look, but unfortunately the early history of science and technology in that region is still (...) poorly documented (...) All in all, nevertheless, we are disposed to favour the view that brass-making began in the Persian culture-area and spread both west to Europe and east China
>
> (Needham, 1974, V/2: 220 and n.c.).

In any case, it would seem that the recognition and production of metallic zinc had started in India by the 13th[8] and in China by the 15th centuries (Needham, 1974, V/2: 213 and 211, table 98).

In 1597 Libavius (c. A.D. 1545–1616) received Indian zinc, which he called "Indian or Malabar lead" or "Malabar tin" from Holland. He was uncertain what it was but ancient lead-zinc deposits "which according to the information of Carus must have already been exploited around 1382" (Werner, 1972: 127) exist near Jawar (or Zawar) "15 miles due south of Udaipur, Rajasthan" (Brown and Dey, 1955: 163). There are also remains of zinc furnaces at Sojat in Jodhpur and in connection with the manufacture of brass alloys it is interesting to note that important ancient copper mines existed in Jaipur (*Imperial Gazetteer of India*, 1908, XXI: 128). The zinc mines at Jawar were active through the 18th century until 1812. According to Somerlatte, "very many small clay retorts are found in the ruins of Zawar, which may possibly have been used for zinc production in ancient times" (Werner, 1972: 127). Indeed, it has been suggested that the term "calamine" may derive "from its place of exportation, Calamina, at the mouth of the Indus" (Beal, *Si-yu-ki*, 1884, II: 174, n. 103). Small zinc deposits also exist in Kashmir. In this connection, it may be interesting to note that Ponchiroli (1979: 299) explains *andànico* as (*ferrum*) *indianicum*, "Indian iron", though he translates the term as "antimony" instead of calamine.

Details of the extraction of metallic zinc from calamine are to be found in the *Rasaratnasamuccya*, as translated by Ray (1956: 171). That treatise, which starts with a Buddhist invocation, and is attributed by Ray (1903: 223) and Kala to "about 1300 A.D." merely borrowed the description of calamine and the couplets concerning the extraction of zinc almost word for word from the *Rasaprakāśasudhākara*, a comprehensive work by Yaśodhara who, according to Ray, lived in the 13th century and used as one of his authorities Nāgārjuna.[9] It is interesting to note that by the 15th century, perhaps in connection with the Muslim conquest, alchemy had become so neglected in India that one alchemist, Govindācārya, declared that for the knowledge of certain processes he was indebted to the Buddhists of Tibet (Ray, 1909: lxvii). In this connection, and on the basis of the attribution to the 15th and 16th century of two Tibetan metal images at the British Museum (nos.110 and 98 on pp.108 and 107) it may be tempting to surmise that by the 15th century Tibetans had the knowledge of the need of an external condenser for the extraction of metallic zinc, whether derived from Iran, from Indian alchemical treatises, or from China. However, their very poor mining and technological ability strongly suggests that they either imported the unalloyed metal already smelted (Kirkpatrick, 1975 repr.: 209), or else used local zinc ores, and alloyed them with copper, to manufacture brass. In fact we know from della Penna (A.D. 1730, in Markham, 1879: 317, *cf.* Giorgi, 1762: 456) that Tibetans used the cementation process to manufacture brass from local zinc ores. Della Penna wrote in 1730, at a time when zinc metal had not yet been isolated in Europe, and although he could only recognize its ores, it is quite clear that he refers to zinc when describing a "mineral, of a white colour, like tin, which is called *tikzà*, and is worked into a sort of brass by being mixed with copper". As we know, *ti-tsha* is the Tibetan word for zinc. Also 'Jam-dpal-rdo-rje describes the ores used to make brass: "the one having bluish-white lustre or the cloudy one, with specks (Tib.: *skya-sob*, not in the dictionaries, as translated by Phuntshogs Wangyal) is like *a-rag*. It has hair-clefts. After having been finely ground, it is thrown into molten copper and there appears light-coloured brass. Brass is not produced (from the ore alone)" (Chandra, 1971: 57). In that passage, not only is calamine (smithsonite, sometimes blue but white when pure) recognized as zinc ore, but the cementation process is mentioned too.

The presence of lead and zinc deposits in Tibet was also reported by investigation teams of the Chinese Academy of Science (see above, p. 40)

and zinc oxide is mentioned by 'Jam-dpal-rdo-rje as *ti-tsha dkar-po* ("white zinc") in his description of brass manufacture (Chandra, 1971: 43). In the same *Materia Medica*, 'Jam-dpal-rdo-rje describes metallic zinc in the following terms: "as for zinc, it is blue and is like the Tibetan silver appearing from both red and green stones. If you rub it with fodder barley it produces a sharp sound. If you break it, its edge is like *cong-zhi*[10] If it is mixed with copper it turns into brass" (Chandra, 1971: 44). Zinc ores, probably sphalerite and calamine of various colours, are described by 'Jam-dpal-rdo-rje (Chandra, 1971: 58) under the title of "yellow zinc"[11] and associated with lead and silver. The ophthalmic use of tutty from melting of zinc ores is mentioned by 'Jam-dpal-rdo-rje.

The presence of zinc ores and mines in Nepal was reported by Buchanan (1819: 76, 94, 195, 264, 272) and Hodgson (1874: 109): "Nepal produces plenty of zinc, but no skill to work the mines". Furthermore, "little is known of the deposits near Tiplin in Nepal" (Brown and Dey, 1955: 614). Ullah follows Latouche in mentioning that "copper ore associated with that of zinc is common in Sikkim" (Marshall, 1951, I: 571). Hodgson (1874: 119) specifies that there are lead and "Zinc mines in Nepal, but no skills to work them profitably. A deal of each is imported from the plains, and also of Tin, with which last, and with the Zinc got from us, the Nepalese mix their own Copper, and make a great variety of mixed metals in a superior style". Kirkpatrick (1975 repr.: 209) mentions zinc in his list of principal commodities exported by the East India Company to Nepal either for use in that country or for the Tibetan market in the late 18th century and the circumstance is not surprising when we know that by then Europe had started to produce metallic zinc as a separate commodity in commercial quantities.

Brass

Brass (Tib.: *rag*, *ra-gan*, and some types of *li*) is described in a number of Indian and Tibetan texts for its external properties. Different proportions of copper and zinc give rise to alloys of varying ductility and brittleness and having a range of colours, of which the most notable is that with about 80% copper which resembles gold. Klong-rdol (Chandra, 1973: 1462, ll. 4-5) distinguishes various types of brass: "'female brass' and 'stone brass', which are yellow, (and) have a good ductility; 'male brass' is the brass which makes the 'light yellow' type of brass and is poor." 'Jam-dpal-rdo-rje (Chandra, 1971: 43) tells us that "red, yellow and bright types of brass come from China, one or three parts of copper having been admixed to (one of) zinc. Also, the white one is firmer than silver". Padma-dkar-po (1973, I: 300, l.1) mentions that in northern India images were made of "white *li*, brass, and, being mixed, it was like the light yellow types of brass".[12] Regarding the materials of the "new" images, by which he means the statues cast from the advent of the Ming dynasty (A.D. 1368), "those which are known as *sku-rim-ma* and appear in Chinese brass or in light yellow brass are superior on inspection "(Padma-dkar-po, 1973, I: 304, ll. 5-6).[13] In Tibet itself the images of the period of the first religious king Srong-brtsan-sgam-po when made from brass or *khro* are similar (Padma-dkar-po, 1973, I: 304, l.1), and the composite ones, made with different metals (Tib.: *zangs-thang-ma*),[14] during the reign of Khri(-gtsug-lde-brtsan) Ral(-pa-can) (see above, p. 41) "were not as good as those made of brass" (Padma-dkar-po, 1973, I: 301, l.5).[15] From the 11th century onwards, brass was consistently used in Tibetan statuary, though described by Western scholars as "bronze". A passage in Padma-dkar-po (see below p.50) suggests that the metal images made by Indian artists in central Tibet during the early 9th century were cast in brass and inlaid with copper and silver. In the context of the Indo-Tibetan derivative style which may have resulted from the imitation of

Pāla models in central and southern Tibet, one should perhaps situate nos. 82, 108 and 105-108 which were all cast in brass with 68.5–74.0% Cu and 24.2-28.5% Zn. Their alloys show copper and zinc percentages very close to the proportions in one of the types of brass described by 'Jam-dpal-rdo-rje (see above, p.47) and nos. 106-108 are inlaid with silver and copper. We have also seen (above, pp.34-5), how brass was used in western Tibetan statuary from the 11th century.

The first names of Tibetan artists known to have used brass and mentioned as "most accomplished in the art of sculpting" images in Tibet, are those of the *sprul-sku* Padma-mkhar-pa and Sle'u-chung-pa (Kong-sprul,in Chandra, 1970: 572, 1.5; and Tucci, 1959: 186). Dagyab (1977, I: 38-39) regards them as contemporaries of Tsong-kha-pa (A.D. 1357-1419), but gZhon-nu-dpal (A.D. 1392-1481; Roerich, 1976 repr.: 829) mentions one Sle'u-chung-pa as a disciple of the great translator bSod-nams-rgya-mtsho (A.D. 1424-1482) in western lHo-brag, a southern Tibetan area bordering with north-western Bhutan. Both sculptors were probably active in the mid-15th century. According to Dagyab (1977, I: 56) or his sources, the statues made by Sle'u-chung-pa closely resembled the "new" Chinese (Ming, A.D. 1368-1644) ones, a remark which can be traced also to the anonymous author of the text studied by Tucci, who tells us that the images made of brass or the gilded images[16] by Padma-mkhar-do and Sle'u-chung and other clever artists may be mistaken for the Chinese ones (Tucci, 1959: 186). Both Tucci's and Dagyab's sources describe the style specific to Sle'u-chung-pa, and mention that the "cushion-seat was formed from a double row of lotus flowers completely encircling the seat" (Dagyab, 1977, I: 56), a characteristic to be found , for example on a gilded seated Sa-skya lama published in Christie's sale (catalogue of July 2nd, 1980, p.16, no. 69), which may be attributed to the 15th century.[17]

Brass continued to be widely used in Tibetan statuary until the present century and Turner (1800: 274) was well aware of the types of metals used in the workshops and in the collection of images studied by him in a "gallery" of Tashilhunpo monastery. After mentioning the manufacture of a brass portrait of a deceased *dge-slong*, he goes on to say that "some of those images were composed of that metallic mixture, which in appearance resembles Wedgwood's black ware, but the greater part were of brass or copper gilt." He concludes: "the manufacture of images, is an art for which they are famous in this country. Theshoo Lomboo has an extensive board of works, established under the direction of the monastery, and constantly employed in this manufacture." Some of the images shown to Turner had been brought from China, Lhasa and Nepal. Although we know from della Penna that brass was manufactured in Tibet with local zinc ores, from at least the 18th century brass and brass ware were also imported into central Tibet from Nepal (della Penna, 1730, in Markham, 1879: 317; Regmi, 1961: 247; Buchanan, 1819: 213 and 232; and Sandberg, 1904: 160), whereas eastern Tibet was supplied by merchants bringing in brass ware from Kansu (Teichman, 1922: 86).

In Nepal, brass must have been known and used for various purposes from a very early date. During the administrative organisation of Tibet under Khri-srong-lde-brtsan (A.D. 754-797), one of the four kings paying tribute was the king of Nepal, with the appellation of "king of brass" (Stein, 1962: 20, from dPa'-bo gTsug-lag-phreng-ba's chronicle, written between A.D. 1545 and 1565). However, the preference for copper in early Newar statuary may be explained by its relative abundance until the 19th century, by its prestige, and by its advantages for mercury gilding. The production of brass statuary seems to have flourished particularly after the Gorkha conquest, perhaps for economic reasons following the diminished wealth of the Buddhist monasteries and lack of royal patronage, and certainly in connection with the availability of zinc metal from British India (see above, p.47) coupled with the progressive exhaustion of local copper mines. Hodgson (1972, repr.: 118-119, see also Regmi, 1971: 20) mentions the manufacture of brass with zinc imported from India and, in his day, not only copper but also brass vessels were exported from Nepal. The composition of Indian brass ("yellow metal") exported to Nepal seems to have a high zinc percentage: 62% copper and 36% zinc (Brown and Dey, 1955: 150). The late Newar brass image analysed by Bhowmik (1964: 395) reflects similar percentages: 60.5% copper and 35.3% zinc. The increased use of brass in 19th and 20th century Newar statuary is witnessed by a number of dated images of deities and devotees with zinc percentage sometimes higher than 40% (nos. 114 and 121 on pp.108 and 109 below), but lower (no. 125) when associated with fire-gilding (see below, p. 83).

Finally mention should be made of the use of brass for the casting of metal reliquary *stūpas* (Tib.: *mchod-rten*) from at least the 13th century (see Hatt, 1980: 210 and 214, *cf.* nos. 29 and 45 on p.104 and 105 below) in Tibet, where brass was commonly used to manufacture all kinds of ceremonial articles from at least the 11th century (see above, p.34 and below, nos. 22, 70, 79).

Tin

Like zinc and lead, tin (Tib.: *gsha'-dkar*) has been imported into Nepal since at least the 18th century (Kirkpatrick, 1975 repr.: 209 and Hodgson, 1972 repr.: 109) and is only used alloyed with copper in Tibetan and Himālayan statuary. The general absence of tin ores from the Himālayas, India and Tibet partially accounts for the rarity of its use in Newar and Tibetan statuary. 'Jam-dpal-rdo-rje (Chandra, 1971: 43) regards "upper, Indian"[18] and "lower, Chinese" tin as the best. His mention of average and poor quality Tibetan tin is not supported by geological evidence. Tin is apparently not even found in eastern Tibet, "for no mention of it is ever made. The white alloy of tin used in Dege for metalwork is imported from China". (Coales, 1919: 246). Although Tibetans did use bronze scrap, it appears that they seldom manufactured bronze for statuary purposes. The analytical data provided by Craddock on pp.26-31 indicate that tin was almost never used in Tibetan statuary alloys, a fact which may be explained by the virtual absence of tin ores from Tibet as opposed to the presence of zinc ores. The low tin percentages to be found in many Tibetan metal images analysed by Craddock only betray the use by Tibetan artists of bronze scraps from bells or other bronze items.

Bronze

Brass and bell metal are both mentioned in Book V of the late 13th century *Rasaratnasamuccaya*, and the latter is described as being made by melting together eight parts of copper and two parts of tin (Ray, 1903: 114). 'Jam-dpal-rdo-rje states that "upper" (Western or Burmese) tin from India was mixed with six or eight parts of copper to produce respectively red and white *li*,[19] the only two types of alloy accurately described in his section on *li* (Chandra, 1971: 41) which may be regarded as bronze (Tib.: *'khar-ba*, *mkhar-ba*, some types of *li*, and perhaps *khro*). However, he mentions those two types of bronze only in connection with the manufacture of certain items, including religious musical instruments, and we know, indeed, that bronze is traditionally used by Tibetans to cast bells (Ronge, 1980: 269-276).[20] The only two types of *li* which 'Jam-dpal-rdo-rje recognizes as being used specifically for statuary purposes are of foreign origin and he does not give us their composition: "as for Chinese *li*, which appears from the smelting of Khotanese ores, there are two: white *li*, of white brilliancy, slightly yellow; and red *li*, of red brilliancy, slightly yellow. The images of the gods are made with them" (Chandra, 1971: 41). Padma-dkar-po (1973, I: 295, 1.1) describes statuary white and red *li* in identical terms and according to him too, both were "obtained in the mountains of Khotan".[21] As for these two types of Chinese statuary *li* obtained from Khotanese ores, it is doubtful what Padma-dkar-po and 'Jam-dpal-rdo-rje had in mind. It is interesting to note, however, that copper occurs in the northern foothills of the Kunlun, between Yarkand and Khotan, and that zinc deposits have been located in the Khotan district, but no tin. Although the manufacture of bronze objects in East Turkestan is demonstrated by Werner's analyses (1972: 190-1),[22] the same author (1972: 141) ventures to say that for the period from the 12th to the 16th centuries the zinc content among the analysed objects from Chinese Turkestan and China "rises sharply to 30% Zn": indeed one standing goddess from Turfan "dated to the 8th century, yielded a zinc content of 27% Zn" (Werner, 1972: 139). These circumstances (see also Marco Polo's information on p.45 and n.7) suggests that brass manufactured from Khotanese ores was exported to Tibet.

It is unlikely that Padma-dkar-po and 'Jam-dpal-rdo-rje had first-hand knowledge of the components of the two *li* statuary metals whose exterior aspect they describe in identical terms, a circumstance which may be due to the fact that both white and red *li* were often of foreign provenance. Since metallographic analysis and careful inspection of Tibetan and Himalayan metal images show that the vast majority are cast either in brass or copper - and the same goes for northern Indian and Kashmiri statuary, whose alloys are again often described by Padma-dkar-po in terms of *li* - it may be concluded that Tibetan writers used the term *li* in the same loose and incorrect manner in which the term "bronze" is used nowadays in the West when referring to objects made of copper or its alloys. It may be further suggested that the terms "white" and "red" *li* used by Tibetan writers in connection with Tibetan and Indian statuary more often than not indicate in fact brass and copper, which are indeed by and large the most common statuary metals used in the area with which we are concerned. The general confusion among Tibetan writers about the term *li* and its composition may be explained by the fact that they were virtually unacquainted with the manufacture of bronze for statuary purposes and were rather out of their depth with the word, which betrays foreign origin. This contrasts with the relative precision of the words they use for copper, gold, silver, lead, tin, zinc, iron and, significantly, brass. This suggestion is strongly supported by the metallographic analysis of an Indo-Tibetan metal image of Pāla-Sena style (p.108, no.105) and inscribed: *De-mo li-ma*,"*li* object of the De-mo"[23]. That statuette was cast in brass and no tin is detectable in the alloy. It is described by Béguin (1977: 70) as a northern Indian "replica of an original of the 12th century" and included in a group of Tibetan images betraying very strong Indian stylistic features (Béguin, 1977: 11-12). It shows Umā sitting on Śiva's left leg, with the latter caressing her chin. The donor at the bottom of the pedestal wears a seemingly Tibetan garment and chignon. In connection with the group of Indo-Tibetan images in which Béguin includes this statuette, it is quite interesting to report Padma-dkar-po's verses on statuary in Tibet during the kingdom of *mnga'-bdag* (king) Khri-ral (Ral-pa-can; see above, p. 41). He explains that as for

> The images manufactured by Indian artists (in Tibet),
> Their kind is similar to the images of Magadha,[24] made out of white *li* (of the quality called) 'indisputable'.
> As for the dissimilarities setting them at variance,
> Their face is a little plump
> Their *déhanchement* has a great share of grace,
> And the silver and copper openings of their eyes are perfect.
> *Zangs-thang-ma*[25] (images also) occur; they are (with) copper lips and silver eyes.

Padma-dkar-po, 1973, I: 301, ll. 3-6.

The description given by Padma-dkar-po in the first four verses above fits remarkably well the group of images studied by Béguin (see above, p.48), which are often inlaid with copper and silver. Is it possible that this kind of statuary was produced by Pāla and Sena artists in Tibet perhaps as early as the 9th century[26] and that the type of white *li* mentioned by Padma-dkar-po was in fact brass? The latter suggestion is confirmed by the metallurgical analysis of the Umāmaheśvara mentioned above, and also by the circumstance that a Tibetan inscription was found inside the base of an 11th-12th century silver inlaid brass Maitreya in Pāla style (Uhlig, 1979: 114-115, fig. 46). Although Neven (1975: 35, no. 67) has implied that white *li* is to be understood as a kind of silver,[27] there would have been little point in inlaying silver statues with silver. All the images belonging to this group are cast in brass and most of them inlaid with silver and copper.

The fact that the term *li* has to be understood in a loose manner as merely indicating any copper alloy is again suggested by the several kinds of uses attributed by 'Jam-dpal-rdo-rje to the various types of *li* which he describes in the same passage (Chandra, 1971: 41). After specifying that white *li*, slightly yellow with white brilliancy, and red *li*, slightly yellow with red brilliancy, are both made from Khotanese ores and used to manufacture metal images (which we know to be cast almost exclusively in copper and brass), he mentions "coloured *li*" (or "coloured *lis*") as the metal used for fashioning the metal circles for *mandals*,[28] although copper is a metal often employed for these. He then states that the "resonant" *li* alloy is used for the manufacture of various musical instruments, such as cymbals, but the term must here indicate "bronze" or "bell metal" (see no. 47 on p. 105). For all these reasons, dictionary translations of the term *li* as "bell metal" or "bronze" and of *li-ma* as "a metalic (*sic*) compound containing more gold and silver with which images are generally made" (Das, 1976 repr.: 1212, from *'Jigs-rten lugs-kyi bstan-bcos*) are either as inadequate or fantastic as the *aṣṭa-dhātu* alloy mentioned above (p. 33).

mKhar-ba (or *'khar-ba*) is another term which has been variously translated as "bronze" and "bell metal". Klong-rdol (1973: 1462, ll. 5-6) explains that:

> apart from black *khro*,[29] (which is) iron, the alloys (known as) 'thousand lotus', like silver, 'poor', like *mkhar-ba*, 'red paradise', like copper, 'clear white', like white iron, are called *mkhar-ba*. lately, all these were made with *dong-rtse* ('copper coins',*cf.* Laufer, 1918: 106). After being perforated in the middle it is easy to carry them. It is reckoned that China and India enjoy (the use of copper coins as) extensive trading currency.

The fact that copper enters into the composition of *mkhar-ba* alloys is confirmed by 'Jam-dpal-rdo-rje (Chandra, 1971: 43), who by the same token gives us a positive definition of it as "bronze": "as for *'khar-ba*, by mixing seven parts of copper to (one of) tin from Khams and (one of) tin from 'Jus (in eastern Tibet;[31] *cf.* Dagyab, 1977, I: 50); it turns into white[30] and red *'khar*, which is used to make mirrors and gongs.". 'Jam-dpal-rdo-rje's proportion of tin to copper corresponds to the mean values of tin percentages found in the Chinese mirrors analysed by Chikashige (1920: 919), or suggested by Craddock (1979:77) in his discussion of *khar-sini* ("Chinese bronze"), an alloy used in Islamic metalwork (see also Allan, 1959: 50ff.). *Khar-sini* may have been a bronze alloy manufactured not only in China, but also in eastern Tibet, perhaps with Chinese or Burmese tin.

Since bell metal varies considerably in composition from about three to five parts of copper to one of tin, and the composition given by 'Jam-dpal-rdo-rje falls within such percentages, we may well accept "bell metal" as a suitable term for translating *'khar-ba*, at least when supported by metallurgical analysis.

In Nepal, according to my Newar informant, the owner of a metalwork atelier at Pātan, tin is present in three types of bronze used in the casting of various domestic and ritual items:

i) Newar "bell metal" with two parts of copper to one of tin, used for example, in the manufacture of water-pots and wine jars;

ii) Newar "bell metal" with three parts of copper to two of tin used, for example, in the manufacture of traditional plates. Neither appellation of "bell metal" by my informant,[32] corresponds to the use of the word in Western metallurgy, where it may indicate any type of bronze in which the parts of copper may vary from three to five, to one of tin (75% to 83% in the alloy);

iii) "bronze", made with two parts of white metal to one of tin, mostly imported from India. The very low percentage of copper from the melt makes it preferable to regard it as a variety of white metal;

iv) white metal, imported from India. In Western metallurgy the term white metal designates three different alloys with high (more than 83%) tin, lead and cadmium percentages respectively.

Images cast in white metal are rare and, because of their weight, I tend to believe that they are made of lead-based alloys, which are cheaper than tin and cadmium alloys. The low melting point of lead and its relative freedom from contraction when solidifying makes it particularly suitable for casting. Alloys i), ii) and iii) have not been mentioned as being used for common statuary purposes by any of my Newar informants. This circumstance confirms my suggestion that the terms "bell metal" and "bronze" as translations of names of Tibetan and Himālayan metal alloys and compounds may be used only in a rather vague and approximate way with regard to ritual and domestic implements and should be used hardly at all in connection with the metal statuary from that part of the world. Buchanan's following remarks also seem to confirm that in the past too the use of bronze by Newar craftsmen was limited to the manufacture of domestic or ritual implements (Buchanan, 1819: 232): "in Lalita Patan and Bhatgang there is a very considerable manufacture of copper, brass, and Phul, which is a kind of bell-metal.[33] The bells of Thibet are superior to those of Nepal; but a great many vessels of Phul are made by the Newars, and exported to Thibet, along with those of brass and copper. Iron vessels and lamps are also manufactured for the same market." (*cf*. Buchanan, 1819: 213).

Silver

The earliest known silver (Tib.: *dngul*) item from Tibet was apparently manufactured in Bactriana and has been studied at some length by Denwood (1973: 121-7). Authentic survivals of silver metalwork from the monarchic period are extremely rare and no serious archaeological or metallographic research has been carried out on the silver jug kept in the Jo-khang at Lhasa and "said to be a recent outer covering, made in replica and containing an original piece dating from the time of *Khri-srong-lde-brtsan* " (lived A.D. 742-797. Snellgrove and Richardson, 1968: 50).[34] It is possible that Iranian silverwork was known in Tibet from a very early period and that its reputation lasted until the 19th century. In fact 'Jam-dpal-rdo-rje mentions that silver, if "roasted in the *ru-ba-da* wood of the country of Khurasan, flowed" (Chandra, 1971: 41), and Das (1976 repr.: 358) maintains that "the kind of silver called *mchog-can* is imported into Tibet from Khorasan". Whereas no silver mining occurs in Khorasan and during the Islamic period silver was used mostly for inlay or for jewellery and coinage, it is a fact that the zenith of the old Iranian silverwork tradition was reached during the Sassanian period (A.D. 224-651) and that Tibet came into contact with

Iranian civilisation by at least the 7th century A.D., and with Khurasan in particular by the beginning of the following century (see al Ya'ḳūbī, 1937: 124). The Tibetan tradition associating silver with the Iranian world is contrasted by 'Jam-dpal-rdo-rje (Chandra, 1971: 41) with the types of silver available in his day, which included Indian *taṅkas*, Chinese ingots and Tibetan coins.[35] Klong-rdol (Chandra, 1973: 1461, 1.3) also mentions silver from Hor (Turkestan?) and from Khams. The presence of silver ores in eastern Tibet was first reported by the famous Italian Jesuit Ippolito Desideri (De Filippi, 1937: 121) and by della Penna (1730, in Markham, 1879: 316). In the end of the 18th century silver continued to be worked in eastern Tibet (*cf.* Cooper, 1871: 463) in small quantities at Dar-rtse-mdo (Coales, 1919: 246) and the trend continued in the following centuries. Pranavānanda (1939: 37) mentions that silver is obtained in eastern Tibet and Waddell (1906: 475) specifies that it came from Li-thang and 'Ba-thang. Giorgi (1762: 456) refers to the presence of silver ores in gTsang and Waddell (1906: 475) reports that small quantities of silver were said to be found in the valley west of Se-ra "one day's journey off the Pemba Pass" north of Lhasa. Ronge (1978: 145) mentions the presence of silver ores in lower sPo-bo. However, the output of these deposits was negligible and Tibet continued to import silver from China (Rhodes, 1980: 261; Sperling, 1980: 281; Olson, 1975 repr.: 54; *cf.* Turner, 1800: 381), Mongolia (Bell, 1968 repr.: 122; Rhodes, 1980: 261), and from Siberia (Bogle, in Markham, 1879: 125-6). Chinese silver bullion was available in Dar-rtse-mdo in 1889 (Rockhill, 1891: 208). Tibet imported its silver requirements for minting from China (Rhodes, 1980: 264) and from India (Ronge, 1978: 145). In the 16th century the latter was in turn supplied with large quantities of Mexican silver by the Portuguese, who used to trade it for spices. The great Moghul emperor Akbar (who even had a Tibetan wife in his harem) used surplus silver to trade with Tibet (Rhodes, 1980: 261).

Silver was seldom used to cast images by Tibetan and Newar sculptors (but see no. 30), though its use in statuary does survive even to this day (Alsop and Charlton, 1973: 43).[36] Like copper and brass, silver has been widely employed for *repoussé* work by Newars in Nepal and Tibet and by Tibetans themselves. Three ancient gilded silver images made by a Newar and a Kashmiri sculptor at Kojarnāth, in western Tibet, are mentioned by Tucci (1937: 40 and 1956: 61-2, *cf.* Pranavānanda, 1939: 52 and 161). A good example of a 20th century *repoussé* silver Tibetan statue is the 13 ft. high image of an eleven-headed Avalokiteśvara erected in 1970 in the main chapel of the newly built Tibetan Cathedral in Dharamsala (Dalai Lama, 1970: 14). This image includes faces from the eleven-headed Thugs-rje-chen-po from the Jo-khang in Lhasa, which was destroyed by the Cultural Revolution in 1966. Parts of the heads were somehow rescued by Tibetans and conveyed to India in 1967 and 1968 (Dalai Lama, 1970: 13, and Richardson, 1977: 174).

The use of silver inlay in white *li* and in composite copper and white *li* Tibetan statuary is attested by Padma-dkar-po from the reign of Ral-pa-can (see also above, p.50). Silver has been consistently used for inlay work in brass and copper statuary in Tibet, and the same tradition, traceable to Pāla, Sena and Kashmiri origins, is still followed by leading Newar sculptors such as Nhuche Raj Sakya and Jagat Man Sakya. However, nowadays in the Nepal Valley silver inlay is more often applied to copper than to brass images. Although, according to Abdul Kadir's report of January 6th, 1979, silver mines existed in Nepal and "the natives do not understand working them" (Regmi, 1961: 247), his suggestion is not supported by geological evidence and the yield of silver from lead ores in Nepal must have been negligible. Bhutan imported silver from Tibet and exported it to Bengal (Pemberton, 1961 repr.: 8, 76-7 and 79), but it is likely that the item did not originate from Tibetan ores and was ultimately of Chinese origin.

Gold

Deposits of alluvial gold (Tib.: *gser*) in Nepal are mentioned by Buchanan (1819: 76 and 298, *cf.* Regmi, 1971: 18), but their importance is minor and greatly contrasts with the reputation of Tibet as a gold-bearing country. Della Penna (1730, in Markham, 1879: 316) reports the presence of gold mines in the provinces of dBus, Kong-po (central Tibet), gTsang, Dvags-po (southern Tibet), Byang-thang (northern Tibet) and Khams (eastern Tibet, *cf.* Giorgi, 1762: 456). Saunders (Turner, 1800: 404-5) mentions "large quantities" of gold in the form of gold dust, lumps and veins in Tibet. In 1867 the Indian Pandit Nain Singh explored the gold mines of Thok-ja-lung, in western Tibet, reaching the main gold-field at 16,330 feet, in N. lat. 32° 24'26" and E. long. 81° 37'38", "where the camp of the Tibetan gold diggers was placed. The master of gold diggings was a native of Lhasa, a shrewd and well-informed man. The Pundit describes the method of working of the gold and the habits of the diggers". (Markham, 1879: cxiv and xxiv (see also Trotter, 1877: 102-3). Extensive goldfields in the district of Sankora, western Tibet, were discovered by Swami Pranavānanda, an Indian who made surveys in the 1930s and 1940s in the Mount Kailāśa and Lake Mānasarovar districts. Pranavānanda (1939: 36) mentions the existence of a vein of gold deposits running about a mile south of the Ganga Chu, a discharge stream connecting the Mānasarovar to the Rākṣas Tal. Mining had been abandoned there around 1935, because an outbreak of smallpox "was attributed by the Tibetans to the wrath of the presiding deity of the mines and consequently the mining was stopped by the Government". Besides the goldfields at Thok-ja-lung, Pranavānanda mentions those at Munakthok and Rungmar "some 20 days' march northwards from the shores of the Manas". Those and other extensive and rich deposits were then mined by primitive methods. The mineral specimens collected by Pranavānanda were analysed at Benares Hindu University. Gold mines were also mentioned by Hedin's informants (Hedin, 1922, IV: 99) and gold was used by the 11th century kings of western Tibet not only to gild statues, but also to pay Atīśa for his visit to Tibet in A.D. 1042. In central Tibet, Atīśa was presented by a nun "with the image of a horse made of gold on which a small boy made of turquoise was riding" (Roerich, 1976 repr.: 256).

The gold mines at Thok-ja-lung are again mentioned by Waddell (1906: 474), McGovern (1924: 25), and Tucci (1935: 114-5) and illustrated by a picture of a pit in the Byi'u gSer-ka-kyi Ro area (Tucci, 1937: opp. p. 65) where, by order of the Lhasa Government, it was then forbidden to mine gold, "perhaps because the mines are too close to the border (...). People obey because they are convinced that by extracting from the earth the treasures contained in it, its fecundating power is made barren and its crops impoverished" (Tucci, 1937: 61-2). However, besides the use of common placer techniques, digging occurred in western Tibet: "there are left the traces of the ancient excavation works: deep and narrow pits, like many ant-hills" (Tucci, 1937: 62). Commenting upon Pliny's and other historians' mention of the presence of gold in the area, Petech (1977: 6) states that the "most detailed treatment of the question is still that of Herrmann, who brings arguments to show that the tale" of the "Dards'" gold-digging ants "goes back to a hazy knowledge of gold-washings in Ladakh and Baltistan, and chiefly at Kargyil" (see also Waddell, 1906: 474), Although "gold is found in the sandy banks of the Indus and its tributaries right from Saspolo to Chilas on Dardi Stan" (Francke, 1977: 5) and "was found from the sand of the river Shyok" (Hassnain, 1977: 43), it is more likely that Herodotus's tale is connected with the western Tibetan areas visited by Tucci (1937: 62), than with Ladakh or Baltistan. As for the Dards, Clarke (1977), in Philip Denwood's words, "has relegated them to the status of a ghost people invented by academics."

Gold excavations "in the La-shung country" are mentioned by Hedin (1910, I: 174 and 179), who spotted many trails of gold-diggers in western

Tibet. Most of the Tibetans digging gold in western Tibet came from Shigatse and Lhasa (Hedin, 1910, I: 194) for a period of two or three months and combined their mining activities with the trade of various goods carried during their journeys (Hedin, 1910, I: 171 and 174). On the other hand, in the 19th century, western Tibetans were brought in by the governor of lHa-khang-rdzong, near Bhutan, to dig gold from an old river bed in that area (White, 1971: 201). During the early 18th century Desideri reported that more gold is found in E "than in other parts of Thibet, and in rather larger nuggets." (De Filippi, 1937: 140, see also Karsten, 1980: 163). In parts of central Tibet gold seekers had to buy the rights to prospect for gold (Ronge, 1978: 144; Bailey, 1957: 188; and Karsten, 1980: 165). Gold is found in lower sPo-bo (Ronge, 1978: 145) and Dvags-po (Waddell, 1906: 437 and Bell, 1968 repr.: 110) and Bailey (1957: 188, see also *ibid.* 193) describes the placing techniques used by labourers in the latter district:

> "The way they did it was this. They dug a channel beside the stream about a yard and a half wide. With what they removed they made a dam across the exit of the channel. On this dam they placed five pieces of very short turf about 15 x 8 x 1 inches. These made a weir-top, when the stream was diverted into the channel. Then they dug the mud from the stream-bed up stream and placed it on top of the turf, letting the top get gradually washed away. The mud in this way was removed and the gold dust fell and was caught in the turf. As they worked, they moved slowly down stream, repeating the process over and over again. Twice a day, at noon and in the evening, the sods were removed and the dust washed out of them. The dust went through three stages, being washed first in a wooden pan three feet by one with a hollow in the middle. The contents of the hollow were washed finer in a small wooden bowl and finally these were washed more finely still in a tin. By the second stage I could detect grains of gold. But the deposits were obviously not very rich (....) and (....) if a nugget was ever found, it was replaced because the people believed that the nuggets would breed more dust".

However, gold mines existed in Dvags-po at Mani Serkha and Michung (Waddell, 1906: 437 and map) and the monastery of bSam-yas contained "the State treasure and gold" from those mines (Waddell, 1906: 440, n. 1). South of the gTsang-po river, the nomads of Mus mined gold because they were required to pay their taxes in gold dust (Ekvall, 1968: 55). An episode illustrating the Tibetans' ambiguous attitude towards mining is reported by Macdonald (1932: 220-1): wishing to be self-sufficient in gold supplies, the Tibetan administration sent a monk who had been trained in England as a mining engineer to prospect for gold to the north of Lhasa; however, the reaction of the local monastery towards such irreligious activities was such that, although the prospecting had been successful, the monk was "recalled to Lhasa, and placed on duty as a police officer, with the title of Khenchung, of the fourth rank of monk officials" (see also Thomas, 1951: 130). According to the Nepalese consul in Lhasa in 1904, the best gold came from a reef "a few days' journey due east of Lhasa" (Waddell, 1906: 474).

The presence of gold in eastern Tibet did not escape the notice of Desideri, who first described the placer technique used by Tibetans as observed by him in the early 18th century:

> Gold and silver of good quality exist in the province of Kham, indeed gold is to be found everywhere in Thibet, but there are no mines as in other countries, the people simply separate it from the earth and sand in the following manner. Near the rivers, with great labour, Thibettans move large blocks of stone and dig

> out the earth and sand underneath, which they throw into a trough. Into this, after placing therein large square sods, they pour much water, which running down carried off the earth, the coarser sand and the small stones. The gold and fine sand is caught in the rough grass of the sods, which are washed over and over again until none remains. The gold is generally like sand and not in nuggets. It is usually found in flat land at the foot of mountains, because the rain washes the earth and with it the gold. It is therefore manifest that if the Thibettans knew how to tunnel mines in these sterile, bare mountains they would find much gold.
>
> (De Filippi, 1937: 121-2).

Rockhill (1894: 360-1) left a brief description of an extremely simple method of extraction used in eastern Tibet, as he observed it in 1892. Alluvial gold is widely distributed in the sands of the great eastern Tibetan rivers (Ronge, 1978: 143), where "the usual method of cradle washing is employed, the concentrates being finished off with quicksilver" (Coales, 1919: 246). Similar mining techniques were used in eastern and western Tibet (Ronge, 1978: 144). It is possible that placer mining was favoured because "it can be operated without undue damage to prejudice against digging", which arose from the religious belief that delving into the earth was "to disturb the subterranean demons and destroy the crops and the people" (McGovern, 1924: 343). Centres of gold exploitation in Khams were at some distance from Li-thang (Waddell, 1906: 474), for gold washing was forbidden by the monks in the neighbourhood of the town, although its trade was allowed in Dar-rtse-mdo (Ronge, 1978: 143). Gold dust was traded also at Jyekundo (Rockhill, 1891: 206). An indication of the relative abundance of gold in eastern Tibet is provided by Rockhill (1891: 208), who mentions that the same gold purchased by him in Peking for 20 taels an ounce was worth only 12.5 to 13 taels in Dar-rtse-mdo. He notes that "gold-washing is one of the commonest occupations throughout the country, as every stream seems to contain in its sands particles of the precious metals; and, though the quantity collected by any individual washer is undoubtedly small, the total amount procured annually cannot fail to be of great value." Rockhill (1891: 208-9) was probably one of the first western travellers in Tibet to report that "mining is not allowed in Tibet, as there exists a deep-rooted superstition, carefully fostered by the lamas, that if nuggets of gold are removed from the earth no more gold will be found in the river gravels, the nuggets being the roots of plants whereof the gold dust is the grains of flowers." Taining, a locality north of Dar-rtse-mdo was an active gold-mining centre in 1908 (see Fergusson, 1911: 222) but the goldfields in its neighbourhood had been worked out by 1919 and everywhere "abandoned workings, in the shape of pits in the gravelly soil by the streams" were noticed by Teichman (1922: 61). The most productive gold mines on the frontier in 1918 were in Erkhai, in rGyal-rong and Nyag-rong (Teichman, 1922: 65-6 and 70). Information on gold deposits in eastern Tibet brought "large parties of Chinese" into the country (Fergusson, 1911: 214 and Duncan, 1964: 19), but the Chinese prospectors who appeared in the 1940s could operate only under military authorization and protection (*cf.* Guibaut, 1949: 59 and 174-5).

Gold mines in eastern Tibet are also mentioned by Goré (1923: 324) and Cooper (1871: 474). The eastern Tibetan gold deposits were controlled by natives and could only be exploited by the local rulers, "to whom a small quantity of the gold found in due" (Desideri, in De Filippi, 1937: 122). Although "the yield of gold" was "generally poor", in 1916-17 "several thousands" of Chinese labourers were engaged in exploiting the goldfields 50 miles north-east of Tre-'o, in Hor (Coales, 1919: 246). This gold reached the market of Yunnan (Ronge,1978: 143).

Mining gold by placer techniques is a subsidiary activity of northern and north-eastern Tibetan pastoral nomads (*cf.* Olson, 1975 repr.: 54).[37] However, it "is contrary to nomadic prejudice concerning disturbing the soil and robbing the soil lords. It appears to derive from the proximity of historically worked mines (...) and tax policies which require taxes paid in gold dust (...). A number of pastoral communities prohibit mining altogether and enforce heavy penalties", even death, "for any violation " (Ekvall, 1968: 55). The exploitation of gold in north-eastern Tibet was also made difficult by nomads. Two thousand Chinese Muslims who washed gold in the sands of the Kokonor area had to be protected by soldiers against such incursions (Ronge, 1978: 143-4).

Tibet exported gold from an early time. During the monarchic period (7th-9th centuries A.D.) Tibetan gold found its way to the West *via* the Arab Caliphate (Beckwith, 1980: 35) and to T'ang China, in the form of "bullion or dust" (Beckwith, 1977: 99). Although "gold in dust, grains and small lumps" was produced and exported from Tibet in Kirkpatrick's days (Kirkpatrick, 1975 repr.: 206) and gold was exported from Tibet into Nepal (Turner, 1800: 370 and 372; Buchanan, 1819: 212; and Lévi, 1905, I: 315), Bhutan (Turner, 1800: 383; and Pemberton, 1961 repr.: 76 and 70), China (Turner, 1800: 373 and 381; Bogle, in Markham, 1879: 125; Goré, 1923: 324; and Bell, 1968 repr.: 122), Kashmir, Siberia, and Bengal (Bogle in Markham, 1879: 126 and 128; *cf.* Turner, 1800: 370 and 382), for generations Newar traders exported gold into Tibet, sometimes from India (Ronge, 1978: 145). Thanks to the efficiency of the British mail system, bars of gold packed in wooden crates of the weight of ten pounds could be mailed by one Newar trader from India to Lhasa for minting purposes (Ronge, 1978: 145) early this century. It is likely that the Tibetan administration found it difficult to be self-sufficient in gold as is shown by the episode of the prospecting monk mentioned above. Chinese gold imported from Mongolia (Bell, 1968 repr.: 122) did much to enable Tibet "to keep the balance of her trade" (Kawaguchi, 1909: 456).

Statues cast in solid gold are extremely rare in Tibetan and Himālayan statuary and, as a rule, textual reference to gold images should be interpreted as "gilded". Solid gold has been used to cast or hammer ritual objects and jewellery by Newars and Tibetans, and Landon (1905, II: 309) mentions "rows and rows of great butter-lamps of solid gold" in front of the Jo-bo's altar in the Jo-khang at Lhasa (see also Walsh, 1938: 536 and 538; and 1946: 30), whereas Tucci (1952: 80) mentions solid gold lamps in the chapel of the XIIIth Dalai Lama (A.D. 1876-1934) in the Potala. Gilded silver offerings are mentioned in the same context, thus reminding us that gilding is by no means limited to copper and brass only. Solid gold items in a chapel in the Potala are illustrated by Waddell (1906: opp. p. 400) and Thomas (1951: opp. p. 192). A 20th century golden butter lamp is illustrated and described by Pal (1969: 128 and 160, no. 117). Gold, sometimes solid, was commonly used in jewellery and Gill (1883: 136) was struck by the circumstance that even poor people in Lhasa wore gold jewellery.

The T'ang Annals refer to all kinds of golden presents which the Chinese received from the Tibetans:

> a suit of gold armour, a golden goose seven feet high and holding ten gallons of wine, a miniature city decorated with gold lions, elephants and other animals, a gold wine vase, a gold bowl and agate wine-cup, a gold duck, plate and bowl. Gold animals are also mentioned as decorating the camp of the Tibetan king (*Ral-pa-can*) on the occasion of the visit of a Chinese envoy in 821.
>
> (Snellgrove and Richardson, 1968: 51).

> The king sits in a tent which is decorated with gold ornaments in the form of dragons, tigers and leopards (....). He bears a sword inlaid with gold.
>
> (Snellgrove and Richardson, 1968: 64-5).

Padma-dkar-po (1973, I: 300, 1.3) mentions that gold was used for statuary purposes during the reign of the first "religious" king, Srong-brtsan-sgam-po. It is very difficult to ascertain whether what the Chinese envoys saw in Tibet were gilded rather than golden images. Significantly, Padma-dkar-po (1973, I: 300, 1.6 and 301, 1.6) mentions that gold was used during the first and third period of the religious kings (7th and 9th centuries) for the fire-gilding process (Tib.: *tsha-gser*), which consists in applying a gold amalgam to the metal and driving off the mercury with heat, leaving a coating of gold on the metal surface (see p. 87). Further confirmation of the gilding of metal images during the 9th century is provided by dPa'-bo gTsug-lag-phreng-ba (see Karmay, 1975: 5). By the 9th century it appears that Tibetans had also started to inlay stones in their statuary, since we know from al Ya'kūbī that the Tibetan governor of Turkestan presented "a statue made of gold and precious stones" to al Ma-'mun (Petech, as reported by Shakabpa, 1967: 48) during the reign of the Tibetan king Khri-lde-srong-brtsan (c. A.D. 800-815). It is likely that the Tibetans derived the idea of inlaying statues with precious stones from the Newars, whose statues were decorated with stones and pearls at the time when the Chinese missions visited the Nepal Valley in the 7th century (see below, p. 80).

Iron

Though thought to be a component of the artificial alloy *zi-khyim*, iron (Tib.: *lcags*, though in other contexts *lcags* merely means "metal" and, *khro-nag*) hardly appears in any significant amount in Tibetan and Himalayan statuary alloys (nos. 44, 66, 82 on pp.105-7).

I understand that the Newar artist Jagat Man Sakya has cast a few images in iron. Alsop and Charlton (1973: 43) confirm the use of iron by sculptors for occasional casting in Pātan. Iron statues are comparatively rare in Tibetan and Himālayan statuary, notwithstanding the presence of ores in Tibet and Nepal (*cf.* Hodgson, 1972 repr.: 109, and Regmi, 1961: 247). Tibet is "full of iron ore" (McGovern, 1924: 343) and della Penna (A.D. 1730, in Markham, 1879: 316; *cf.* Giorgi, 1762: 456) first noticed the presence of "mines of iron" in the country. 'Jam-dpal-rdo-rje dwells extensively on the subject and Klong-rdol (Chandra, 1973: 1461-2) mentions that "the soft Tibetan white iron is a good material for the begging bowls" of monks, into which edibles are thrown by alms-givers; whereas in China "'poor' iron, not tempered, is ideal for various arts and crafts (....). Farming tools are of 'poor' iron from Khams and Kong(-po)". Klong-rdol must have been aware of the fact that, besides its more traditional uses, iron sometimes replaced bronze in Chinese statuary, and that it was used in China not only for temple furniture (braziers, censers, cauldrons and even bells), but also to build pagodas. Though many iron items were imported from China to eastern Tibet (Rockhill, 1894: 340), we know from Rockhill (1891: 207) that "the few pieces of ironware required in Tibet" came from Dar-rtse-mdo and that iron deposits existed at Chab-mdo, in Khams (Rockhill, 1894: 302-4). The existence of iron mines in eastern Tibet is also reported by Cooper (1871: 463-4), Pranavānanda (1939: 37) and Duncan (1964: 19). The existence of iron deposits in Chab-mdo was confirmed by the findings of the geological section of the Chinese Academy of Science (see above, p. 40). Bonvalot (1891, II: 149-151) mentions a forge at Lagong, which was probably supplied by local iron ores (*cf.* Rockhill, 1894: 303-4). Rockhill (1894: 330 and 353) reports the presence of blacksmiths at Nyewa and Li-thang but none of the work he saw was "of a high order, all is very inferior to that of Dérgé". Iron deposits were also located in the Thang-lha Range on the border of Tibet and the province of Tsinghai. Iron mines in the Nag-chu-ka area were reported in production by the late 1950s. Iron is to be found also in western Tibet, where Pranavānanda discovered it on the eastern shores of the lakes Mānasarovar and Rākṣas Tal. It is very likely that Tibet was self-sufficient in iron and the item does not appear in Kirkpatrick's list of exports from India to Nepal and Tibet. Some wrought iron was exported to Tibet from Bhutan (Pemberton, 1961 repr.: 76), where iron was "procured in the hills" during the first half of the 19th century (Pemberton, 1961 repr.: 75). Kirkpatrick (1975 repr.: 176) maintains that "the iron of Nepal is not, perhaps, surpassed by that of any other country" and in A.D. 1795 Abdul Kadir noted that Nepalese worked some of their iron mines (Regmi, 1961: 247). Iron utensils were exported from Nepal to Tibet (Buchanan, 1819: 213 and 232).

Lead

Lead (Tib.: *zha-nye*) is not used on its own for Tibetan and Himālayan statuary, but it is often found in brass and sometimes in copper statues, where it is added to improve the fluidity of the alloy. Lead deposits were located in Tibet by the Chinese Academy of Science after the Chinese occupation of the country (see above, p. 40) and the existence of a lead mine two days' journey from Tashilhunpo is reported by Saunders (Turner, 1800: 405; see above, p. 40) who adds that the ore was "mineralized by sulphur, and the metal obtained by the very simple operation of fusion alone". The lead mines mentioned by Bailey (1957: 167) at Kyimdong Dzong, in Dvags-po, were nearly exhausted at the time of his expedition in 1913. The lead was extracted there "by heating the ore with charcoal". Lead is found in eastern Tibet, between 'Ba-thang and dMar-khams (Cooper, 1871: 463) and in Yu-t'ong (Goré, 1923: 324). 'Jam-dpal-rdo-rje (Chandra, 1971: 43) was aware of the circumstance that lead can be associated with silver ores (*cf.* Saunders in Turner, 1800: 405) and observes that: "it flows out of the place of the ashes (residuum) of silver." He also mentions Indian, Chinese and Nepalese red lead (Chandra, 1971: 61) and explains that: "if you roast it, lead will flow.". We know from Hodgson that there were lead "mines" in Nepal, but there was "no skill to work them profitably" (see also Kadir's report in Regmi, 1961: 247) and the metal was "imported from the plains" (Hodgson, 1972 repr.: 119. *cf. ibid:* 109). Lead, "China red lead" and white lead were imported into Nepal from India (Hodgson, 1972 repr.: 109). According to Jackson (1976: 282) the red lead used by Tibetan painters was imported "as an already powdered pigment from Nepal, India and China".

From the study of Werner's data (Werner, 1972: 184-7, table 4.1) and the analytical data reported by Riederer(Uhlig, 1979: 64-67), it may be seen that lead is present in many Tibetan brass statues, but virtually absent from most copper ones. The same applies to the Tibetan metal images analysed by Craddock (pp.26-31 above). The presence of lead in Tibetan and Himālayan statuary brass dates from at least the 11th century and the Cleveland Buddha (see above, p.34) contains as much as 11% in its brass alloy. It is very likely that western Tibetans learnt of the advantages of adding lead to brass for casting purposes (nos. 42, 63 and 64 on pp.105-6) in amounts even higher than 10%. These varying percentages reflect the inconsistent proportions to be found in Kashmiri statuary: 2.75% lead in the brass Sūrya studied by Lee (1967) containing 78.1% copper and 18.7% zinc (personal communication from Stanislaw Czuma, September 5th, 1970) and 10.37% lead in the brass Buddha illustrated by Uhlig (1979: 122, fig.56) containing 73.106% copper and 13.18% zinc. Newar sculptors only add lead in small amounts when casting brass images (nos. 114, 115 and 121 on pp.108-9). Although the addition of lead reduces the strength of brass, it makes it easier to cast and more suitable for engraving.

Mercury

The importance of mercury in metal statuary is connected with its role in the traditional fire-gilding process (see pp.80-83 and 87-101).

Mercury (Tib.: *dngul-chu*) enjoys a great reputation in Indian and Tibetan medical and alchemical literature and occupies the first place in the list of precious substances which can be melted, as examined by 'Jam-dpal-rdo-rje (Chandra, 1971: 40), thus preceding gold, silver and copper. 'Jam-dpal-rdo-rje (Chandra, 1971: 40, 1.3) quotes the "Phyi-rgyud", the fourth book in the medical *tantras*, the *rGyud-gzhi*, to say that mercury "is manufactured by roasting cinnabar". He further distinguishes vermilion (*mtshal*) from cinnabar (*cog-la-ma*) and agains mentions that if one roasts the former "quicksilver flows" (Chandra, 1971: ll. 2-3). As to the latter, "it is called *mtshal-rgod* ('wild vermilion') and also *rgya-mtshal* on account of its appearing in India (Tib.: *rGya-gar*) and China (Tib.: *rGya-nag*). In the native red stone there is a great deal of purple. It is like an arrangement of wide needles. By melting it there appears mercury" (Chandra, 1971: 59, ll. 1-3). The Tibetan *rGya* is an adjectival prefix which may indicate India or China. Chinese vermilion was occasionally exported to Europe during the first half of the eighteenth century and its reputation for high quality became firmly established from the second half of that century (Harley, 1970: 116). Vermilion, a synthetic mercury sulphide, was probably imported into Tibet "from India or China, both of which had the technology for synthesizing it since ancient times" (Jackson, 1976: 277). There is evidence that both "singraf or vermillion (*sic*) cinnabar" and mercury were exported from India to Nepal and Tibet (Kirkpatrick, 1975 repr.: 209 and Hodgson, 1972 repr.: 109) during the 18th and 19th centuries and it seems unlikely that either country had the technology to manufacture vermilion before then. Cinnabar, the native mercury sulphide, "occurs naturally in some parts of South-East Tibet. It is easily recognizable by its reddish metallic appearance and extremely heavy weight" (Jackson, 1976: 277). However, vermilion made by the sublimation method is pretty well indistinguishable from the best native ores (personal communication from Mavis Bimson). Native Tibetan cinnabar ores "exported to the low country for sale" are mentioned by Turner (1800: 78 and 296) and "cinnabar, containing a large portion of quicksilver" by Saunders (Turner, 1800: 405) who travelled through southern Tibet to Tashilhunpo. Saunders, who was a surgeon, only mentions mercury in connection with its preparation for medical uses (Turner, 1800: 410-11). Mercury ores are found in lower sPo-bo (Ronge, 1978: 145) and according to a Tibetan informant (Berglie, 1980: 41 and 40) cinnabar is found at Mount Targo, in central Tibet, and in a place near Mount Kailāsa. Tibetans knew how to extract mercury from the cinnabar deposits near 'Ba-thang and used it specifically for fire-gilding purposes (Ronge, 1978: 145). The earliest reference to cinnabar ores in Khams (eastern Tibet) is to be found in della Penna (A.D. 1730, in Markham, 1879: 317, *cf.* Giorgi, 1762: 456). Also Cooper (1871: 463-4) and Pranavānanda (1939: 37) mention the existence of mercury ores in eastern Tibet. However, both quicksilver and cinnabar appear in Turner's list of Chinese exports to Tibet. Turner (1800: 372) maintains that Tibetans did not know how to extract mercury from cinnabar, though he mentions the existence of mines of cinnabar, containing a great proportion of mercury and used "for colouring, in paint". In the same work, however, Saunders (Turner, 1800: 410-11) observes:

> Nor could I allow myself to think that they were acquainted with the method of preparing quicksilver, so as to render it a safe and efficacious medicine. In this, however, I was mistaken (...). There is one preparation of mercury in common use with them, and made after the following manner. A portion of alum, nitre, vermilion, and quicksilver, are placed at the bottom of an earthen pot, with a smaller one inverted, put over the materials, and well luted to the bottom of the larger pot. Over the small one, and within the large one the fuel is placed and the fire continued for about forty minutes. A certain quantity of fuel, carefully weighed out, is what regulates

them with respect to the degree of heat, as they cannot see the materials during the operation. When the vessel is cool, the small inverted pot is taken off, and the materials are collected for use. I attended the whole of the process, and afterwards examined the materials. The quicksilver had been acted on, by the other ingredients, deprived of its metallic form, and rendered a safe and efficacious remedy.

This passage, along with 'Jam-dpal-rdo-rje's observation, suggests that Tibetans were aware of the property of heated mercury and cinnabar to evaporate and knew techniques of collecting mercury during the heating process.

According to Nadkarni (1954, II: 72), cinnabar was also "found in Nepal", and Buchanan (1819: 264 and 272) confirms the existence of cinnabar mines in Nepal. Such mines were "worked to some extent" (Regmi, 1971: 18). However, as we know from Buchanan (1819: 212; see also Imperial Gazetteer of India, 1908: 121) that Chinese quicksilver found its way to Nepal and as cinnabar appears in Kirkpatrick and Hodgson's lists of Indian exports to the country, it is very unlikely that Nepal was self-sufficient in mercury in the 18th and 19th century. The metal was much needed in the fire-gilding technique commonly used in Newar metal statuary. It is possible that the Newars were also acquainted with the technology necessary to synthesize mercury and that vermilion was manufactured in both Kathmandu and Pātan (*cf.* Regmi, 1971: 23 and 67). However, it is not clear whether Regmi, who mentions the castes manufacturing "vermilion", distinguishes between red lead and vermilion, when using the latter term: the Nepalese word *sindur* translates both "vermilion" and "red lead". It may be noted here that all the mercury and cinnabar exported from India to Nepal and Tibet was not of Indian origin, since there is no evidence for the existence of either in India (Brown and Dey, 1955: 299).

Notes

1. The brass statuettes described by Uhlig (1979) as "western Tibetan" often include a floating scarf, the shape of which conjures up the outline of a *stūpa* dome. However, this characteristic, as well as their general stylistic features, is not to be found in any statue or statuette, whether Kashmiri, Ladakhi or actually western Tibetan, to be seen in the shrines illustrated in relevant books by Tucci (1935, III), Snellgrove and Skorupski (1977 and 1980) and Govinda (1979, II: 153-181 and 183). Because the above mentioned scarf motif is conspicuous by its absence from all western Tibetan images, whether made of clay or of metal, to be found *in situ* and because of stylistic differences, there is in fact no evidence to support the description of that group of brass statuettes as "western Tibetan", of which I have never come across one single example during my visits to various monasteries in Ladakh. Thus the attribution by Uhlig (1979) of a large number of brass images to western Tibet should be treated with caution. An interesting technical feature of this group of images is that they often have a very thin cast (*cf.* Howes, 1980: 95).

2. On the location and mining from ancient times of copper ores in northern India, see Brown and Dey (1955: 146-154): "there are many occurrences of copper ores in the outer ranges of the Himalayas at intervals from Sikkim in the east to Kashmir in the west. In Sikkim they were worked extensively in the past by Nepalese miners". A copper mine in Kamraz (Kashmir) is mentioned in Kalhana's *Rājataraṅgiṇī* (Book IV, vv. 616, in Stein, 1900, I: 176). Ray (1956: 210) states that "mining of copper ores and the extraction of the metal had been carried out on a large scale in the various states of Rajputana

(Rajasthan) from a very early time till towards the end of the 19th century". On copper ores from the Darjeeling area see Piddington (1854: 447-9).

3. Again, the land of the Kirātas (western Himālaya) is mentioned in connection with the production of oopper pyrites in Book II, v. 77. The same verse occurs in Nāgārjuna's *Rasaratnākara*, vv. 25-30 (*cf.* Ray, 1956: 130 and 168). Nepal is mentioned as a copper-bearing country also in the *Dhātukriyā* (couplets 143-5 in Ray, 1956: 210). The earliest mention of Nepalese copper in Chinese literature is probably that by Hiuen Tsiang, who travelled to India from A.D. 629 to 645 and reports that Nepal "produces red copper (...). In commerce they use coins made of red copper" (Beal, 1884, II: 80, *cf.* Watters, 1905, II: 83). Since Hiuen Tsiang obtained his information in India, it appears that by the 7th century India already looked on Nepal as a copper-bearing country.

4. Buchanan, 1819: 76-7, 203, 242, 264, 267, 269, 272, 275, 297 and 301. In Parbat (or Malebum) alone "the mines of copper are said to be twenty-five in number and produce a great revenue." (*ibid.*: 272).

5. See, for example, the "Customs House Returns, Yatung" and the mention of metal imports in Chandler (1905: 65). *Cf.* Chandra, 1971: *passim.*

6. For the term *andànico*, see Olivieri, ed., *Il Milione*, Bari (1912: 28 and 34). The same word appears also in C. Steiner, ed., Cecco Angiolieri, *Il Canzoniere*, Torino, 1928, comp. no. 105, v. 2. Cecco Angiolieri (1260-1311/13) uses the term in connection with the word "steel" and Marco Polo with the words "iron" and "steel". From Marco Polo's description of the process, I should think that the translation of *andànico* as "zinc carbonate" or "zinc ore" would be more appropriate than the current Italian dictionary definitions of it as "very hard metal, akin to iron and steel", for I do not regard the leading Italian comic poet of the Middle Ages as an authority in mineralogy. On the same process, see the reference given by Craddock (1979: 69). *Cf.* also Forbes (1964, VIII: 265ff). Zinc oxide has a pigmentary strength somewhat superior to white lead, and having the added advantage of being non-poisonous, is used in cosmetics. Marco Polo says that "excellent collyrium" was made from the tutty by the inhabitants of Kobiam. However, Ponchiroli (1979: 299) translates *andànico* as "antimony" (*ferrum indianicum*, "Indian iron"). Antimony is highly toxic to the human body and irritates it both internally and externally.

7. Amongst the objects from east Turkestan analysed by Werner, there is one from Ko-cho (Turfan oasis) with 31% zinc (Werner, 1972: 190-1, no. 24). If its dating is correct, it would seem that the manufacture of metallic zinc in that area began in the 13th/14th century, since a zinc percentage in excess of 28 is evidence of the use of the complicated method to extract zinc from its ore by means of an external condenser.

8. *Cf.* Forbes (1971, VIII: 281): "Though the value of the old Indian alchemists and their modern commentators is very doubtful it seems that zinc was prepared by Indian chemists since the twelfth century, but that this remained a laboratory experiment and was never applied to industrial production. This zinc or 'the essence of tin' as it is sometimes called was prepared by distilling calamine with organic substances in an apparatus suitable for *destillatio per descensum*, where a substance could be heated in an upper flask and the drippings could be collected in a lower one."

9. *Cf.* Ray (1956: 122). Ray (1909: lvii) uses a copy of the *ms.* preserved in the Runbir Library, Kashmir, of which the "readings are on the whole accurate" (*ib.* footnote). A fuller discussion of the use of metallic zinc in medieval India is contained in vol. I, pp. 156ff., where Ray concludes: "In the medical Lexicon ascribed to king Madanapala and written about the year 1374 A.D., zinc is (...) distinctly recognised as a metal under the designation of *Jasada*". The extraction of zinc is also mentioned in the 12th century *Rasārṇava* which is believed to be a Tantric work of the 12th century A.D. (Ray, 1956: 119). Section VII, vv. 37–8, states that calamine mixed with various ingredients and "roasted in a covered crucible yields an essence of the appearance of tin" (Ray, 1956: 138).

10. Also: *cung-zho*. This word has been inadequately translated as "a kind of white stone" (Jäschke, 1972 repr.: 141), "a medicinal white stone alleged to cure diarrhoea" (Das, 1976: 383), and "calcite" (Hübotter. 1957: 125). 'Jam-dpal-rdo-rje (Chandra, 1971: 46) lists five types of *cong-zhi*, with colours varying from that of rock-salt, to white, bright purple, yellow and even blue and black, and says that the first two are found in hot springs. It may be suggested that the word indicates a range of minerals from sodium carbonate to calcium carbonate (calcite, calcareous spar).

11. Sphalerite, a sulphide of zinc, is the chief ore of that metal. The colour varies widely. Generally, it is a shade of reddish-brown to black, but some sphalerite is green, yellow or, in crystals of high purity, almost colourless transparent to translucent. Calamine is usually coloured green, blue, yellow, grey or brown by impurities (*cf.* Forbes, 1964: 261).

12. In view of the above considerations (p.37) on red *li* and of the composition of northern Indian alloys, I suggest that Padma-dkar-po is here equating white *li* with brass.

13. *Cf.* Tucci (1959: 187). Dagyab (1977, I: 55) suggests that such statues were probably used in the public 'ceremonial' acts of worship (*sku-rim*) offered by the Yung-lo emperor (1403-1424). *Cf.* also Karmay (1975: 95-6).

14. Padma-dkar-po (1973, I: 295, 1.2) explains that "those images which are made with white *li* for the body and red *li* for the garment are called *zangs-thang-ma*" see also Tucci (1959: 181, n. 6) and Dagyab) 1977, I: 52 and 57).

15. It is possible that during the early monarchic period Tibet imported brass from Iran. Close connections between Tibet and Iran at that time are confirmed by a number of historical sources.

16. See also Dagyab (1977, I: 56-7). Gilded brass images are increasingly encountered in Sino-Tibetan statuary from the 15th century onwards (see above, p.35).

17. This kind of Sa-skya-pa portraiture may have reached its climax before the rise of the dGe-lugs-pa power in Tibet, at a time when the Sa-skya-pa enjoyed the patronage of the Mongols, and continued during the reign of the Yung-lo emperor, only to diminish from the triumph of the Yellow Hats in the 17th century. Describing the "new Chinese" statues, Padma-dkar-po specifies that "the two corollas (Tib.: *kha-sbyar*) of the lotus divide one above the other and adhere at the front and back" of the base (1973, I: 304, 1.4). Karmay (1975: 95) notices that "in many

respects, Padma-dkar-po's account, although describing Ming bronzes in general, concords with "her description of the Yung-lo bronzes in particular.

18. "Upper" and "lower", as used by Tibetans in a geographical context, mean respectively "upstream" and "downstream" and here, as is often the case, they stand for "West" and "East" of the gTsang-po river, namely Western Asia and China respectively. Although no one would question the presence of important tin deposits in China, the picture is quite different for India, a country which has traditionally imported tin ores, at least since the 3rd-2nd centuries B.C.: "The oxide of tin cassiterite, has been found at a number of places in the Hazaribagh, Ranchi and Gaya districts of Bihar, but none of the occurrences appear to possess economic importance, though as long ago as 1849 tin ore was being smelted in village iron furnaces at Purgo, in the Palganj estate near Parasnath" (Brown and Dey, 1955: 167). "Outside Bihar, cassiterite has been found, but again only in insignificant amounts (...) There are no recorded instances of the occurrence of tin ore in Pakistan" (Brown and Dey, 1955: 168). Discussing the use of metals at Taxila, Marshall (1951, II: 563) acknowledges that "even if these deposits were worked in ancient days (which is uncertain), they would not have been adequate to meet the needs of the country.". Marshall infers that tin was then imported from the West, to which may be added Finch's observation (1599), as reported by Brown and Dey (1955: 168), that Burmese tin served all India. A detailed study of the history of Indian statuary metals is outside the scope of the present paper and I am satisfied with bringing circumstantial evidence to my suggestion that bronze was not the obvious alloy to use for statuary purposes in India, owing to its lack of tin ores. Significantly, Marshall (1951, II: 566) states that the Sanskrit *kastīra* derives from the Greek word for tin, *kassíteros*, and "not vice versa". Indeed, we understand from Pliny that the coastal districts of western and southern India "possessed neither bronze (*aes*) nor lead, but exchanged precious stones and pearls for them." (Marshall, 1951, II: 564-566). Ray (1956: 57) confirms that, "silver, tin and mercury ores (...) are till now not known to occur in India". The "upper Indian" tin mentioned by 'Jam-dpal-rdo-rje may have been Western or Burmese. As I cannot find any trace of Burma being regarded as a separate geographical entity in Tibetan literature, I assume that Tibetans may have assimilated Burma to India. Since in the 19th century the British felt justified in regarding Burma as a province of the Indian Empire, it is difficult to expect that Tibetans would have been more sensitive to the subtleties of geographical distinctions in the Indian subcontinent. Similarly, Arab writers did not regard Lower Burma as a separate geographical entity from Bengal (Gopal, 1965: 51-2). The suggestion that Burmese or western tin was exported to Tibet via north-western India and western Tibet may answer 'Jam-dpal-rdo-rje's apparent contradiction of "upper, Indian" tin.

19. It has been suggested that white *li* is "an alloy of silver and bronze" (*cf.* Neven, 1975: 35, no. 67), although such a statement has not been supported by metallurgical evidence and is challenged by its accurate definition as given here by 'Jam-dpal-rdo-rje. Padma-dkar-po's recurrent use of the term for various periods and schools of statuary and the rarity of images cast in any kind of "white" metal point to the suggestion that white *li* must have been some other kind of alloy. On the evidence provided by the results of the analyses discussed above, Craddock suggests that white *li* is a high zinc brass (above, p.24), although the zinc percentage could not be higher than 30 in Padma-dkar-po's day. However, 'Jam-dpal-rdo-rje's definition, coupled with Klong-

rdol's statement that both red and white *li* as well as yellow *li*, iridescent *li*, and dark reddish-brown *li* are used to make musical instruments suggests that in this particular instance those names of alloys actually indicate bronze (see the analyses of nos. 47 and 80 and Craddock above p.24). On iridescent *li*, see above, p.43. Neither the yellow nor the reddish-brown varieties of *li* are mentioned by Klong-rdol in connection with statuary purposes (Chandra, 1973: 1462, ll. 2-3).

20. See note above. Cymbals "and other musical instruments" were also exported to Tibet from China (Turner, 1800: 381). Hor was the best source of bronze products and in Amdo Tibetans would receive bronze items from Peking and Dolonor (Ronge, 1978: 146-7). On the metal workshops of Peking see Montell (1954); on those in Dolonor see Huc (1924, I: 80) and also Rockhill (1891: 131).

21. Tib.: "Li-yul". This name is sometimes also used to designate Nepal. The Tibetan *yul* means "country".

22. It may be mentioned here that in upper Hor (East Turkestan) a mixture of white and red (*li*?) was used to manufacture "dark *khro-li*" (Padma-dkar-po, 1973, I: 302, ll. 1-2), a term not to be found in 'Jam-dpal-rdo-rje's *Materia Medica*, but for which the word "bronze" might be suggested if only the bronze objects from that area analysed by Werner did not belong mainly to one bracket of three centuries (7th-9th centuries) and come mostly from one site (*cf*. Werner, 1972: 190-2). On *khro* see below. On *khro-li* see Dagyab, 1977, I: 52, no. 7.

23. A brass Green Tārā studied by me at Messrs. Spink of London in 1979 and a brass White Tārā studied by me at Sotheby's in 1980 bear identical inscriptions. Karmay (1975: 30) mentions a standing Vajrasattva bearing the same inscription in a private collection in London. I have never come across the description of a "*de-mo*" type of *li-ma* in any of the Tibetan texts dealing with the subject and I am rather inclined to follow the suggestion that the inscription was the owner's mark. From Ferrari, we know that *De-mo* (Qutuqtu) was the name of three important regents of Tibet: "the first incarnate, an important figure in the history of Tibet, was regent for the VIIth Dalai-lama from 1757 to 1777; the second was regent for the IXth and Xth Dalai-Lama from 1810 to 1819; and the third was regent for the XIIIth Dalai-lama from 1886 till he was in 1895 deposed and thrown into prison by the young Dalai-Lama, who took the government in his own hands.". Their residence was bsTan-rgyas-gling, the most important monastery in Lhasa, in the northern part of the city. In 1912 the monastery was destroyed by the Tibetan government because it had taken sides with the Chinese. Afterwards, the Post Office of Lhasa was installed on its premises. We know that at the time of H. Richardson's mandate in Tibet the *De-mo* lived in the gZhi-sde College in Lhasa. bsTan-rgyas-gling was apparently built by the regent of Tibet, which means later than 1642 (Ferrari, 1958: 93). It is possible that due to the vicissitudes of the *De-mo* and their seat, their collection of metal images started being scattered even before the Chinese occupation of Tibet in 1959.

24. In this connection it may be interesting to note that according to dPa'-bo gTsug-lag-phreng-ba, who completed his *History* in A.D. 1565, all statues in the temple of 'U-shang-rdo, erected by Ral-pa-can south of Lhasa, "were modelled on the gods of Magadha in India, cast in white and red *li* and gilt with gold from the river Dzam-pu" (Karmay, 1975: 5 and 7). Direct connections between Tibet and Bengal started at the latest in the mid-8th century, when the Pāla kings had to pay tributes

to king Khri-srong-lde-brtsan in A.D. 755-6 (see Stein, 1962: 39 and 43).

25. For a different type of *zangs-thang-ma*, see above, n. 14.

26. It may be suggested, as Béguin does, that these images are replicas of more ancient Pāla and Sena statues. A few of these statues, however, may have been made by Indian artists working in Tibet (see p.34). Others were produced by Newar and Tibetan artists working from Indian models. Indian statuary styles were in fashion in Tibet for centuries as illustrated by the fact that the Tibetan scholar Tāranātha (b. A.D. 1575) commissioned Newar sculptors to make a statue of Jambhala "in the Indian style" (Tucci, 1949, I: 278). Tibetan images in Indian style are difficult to date because they were produced at various times. The ability of Newar sculptors to imitate alien schools is witnessed by the occasional appearance of 20th century artifically aged copper and brass statues on the international antiques market. What appears to me to be a copy of no. 119 on p.109, for example, was sold as an "antique" in London eight years ago.

27. Elsewhere, Neven (1975: 12) describes *li-dkar* as "a rarely encountered alloy, characterised by a whitish tinge (*dkar*), differing from silver in its lack of oxidation". The term is of very frequent occurrence in Tibetan literature describing Tibetan and Indian statuary alloys which, however, are seldom made of silver or bronze. See also note 19.

28. These items are described and illustrated by Dagyab (1977, I: 34 and II: 17, Fig. 19).

29. *Cf.* Das (1976 repr.: 175): "The kind of bronze called *khro-nag* or dark bronze is also called *lcags khro* on account of the predominance of iron in the compound." The analyses reported above (pp.26-31) exclude the likelihood of such an alloy being used for statuary purposes. Das never mentions tin but rather speaks of zinc - to justify his translation of *mkhar-ba* as "bronze". In fact, Klong-rdol seems to take great care to exclude *khro* from the various types of *mkhar-ba* (bronze) he mentions. If we had to follow Das's own explanations, we should suggest translating the term as "brass" rather than any kind of bronze, at least as far as *khro-dkar* is concerned (*cf.* Dagyab, 1977, I: 50). 'Jam-dpal-rdo-rje (Chandra, 1973: 44) qualifies *khro-nag* as "iron" and mentions that the Chinese one is used to make ploughshares and roasting pans (those used for parching barley), thus confirming that we are in the presence of an iron compound, not quite of "bronze". Farming tools are specifically said by Klong-rdol (Chandra, 1973: 1461-2) to be made of iron from Khams and Kong-po. It is likely that, as in the case of *zi-khyim*, which is absent from 'Jam-dpal-rdo-rje's compilation - and probably of non-Tibetan origin too - Tibetans imported *khro-nag* and did not know its constituents, or that its manufacture was limited to eastern Tibet (Dagyab, 1977, I: 50). Even Das (1976 repr.: 175) acknowledges that the alloy "is largely manufactured in China". Dagyab's definition of *khro-nag* as "an alloy of iron and '*khar-ba*" (1977, I: 50) does not cast much light on the issue, for he fails to define '*khar-ba* with any certainty and, generally, to provide any kind of metallurgical evidence in his study of Tibetan statuary metals.

30. On the white tin alloy used by sDe-dge metalworkers, see above, p.49.

31. It is possible that this eastern "Tibetan" tin came from ores near the

border with Burma. A region with the name of 'Dzud is placed precisely in proximity of the Tibeto-Burmese border in Wylie's map of Tibet according to the *'Dzam-gling-rgyas-bshad* (Wylie, 1962: opp. p.286). However, it is more likely that this eastern Tibetan tin was in fact imported from China and Burmese (see above, n. 18).

32. My informant, Jagat Man Sakya, uses an English word either found in dictionaries or heard from foreigners. His proportions should be taken very cautiously until they are substantiated by metallographic analyses of actual samples of the objects he mentions.

33. *Cf.* Klong-rdol's text on "the manner to recognize precious substances": "there appear various counterfeit types of *li* in Nepal, Khams and Tibet, soundless and of a black colour." (Chandra, 1973: 1462, 1.3).

34. The "pottery drinking vessel, said to have been used by *Srong-brtsan-sgam-po* and now enclosed in silver" as mentioned by Snellgrove and Richardson (1968: 50-1), appears to correspond to Srong-btrsan-sgam-po's bowl described by Tucci (1952: 77) as being encased in a silver vessel on which he could read a date corresponding to A.D. 1946. However, Richardson (1977: 181) maintains that the "round-bellied silver jar with a long neck surmounted by a horse's head" bears a date corresponding to 1946, "a new covering in exact replica having been put over the original jar for its protection" and mentions Srong-brtsan-sgam-po's "earthenware beaker, now protected by a silver case", without giving a date for the latter.
A silver portrait of Khri-srong-lde-brtsan is mentioned by dPa'-bo gTsug-lag-phreng-ba (Karmay, 1975: 4 and 31, n. 28). From Chinese sources we also know that in A.D. 824 Tibet presented China with a yak, sheep and a deer "all cast in silver" (Demiéville, 1952: 203, footnote): "Gold and silver objects are often mentioned among the presents offered by Tibet to the Chinese court.".

35. Klong-rdol (Chandra, 1973: 1461, 1.3) seems to have a high opinion of Chinese silver, but not to extend it to Indian silver: "the 'Indian yellow' one is the faulty one from India and Nepal". It is true that Newars sometimes use a poor type of silver, with a yellow tinge, to cast jewellery items. As a rule, however, Newars use almost pure silver for their jewellery.

36. In the shrine of Mr. Ravi Raj Karnikar, the keeper of the main teashop in the Darbar Square of Pātan, there are two splendid cast silver images of a six-armed Bhairava and of an eight-armed Mahālakṣmī standing on two lions. Unfortunately they are displayed for public veneration only once a year, on Yunyapuni. As I missed the opportunity of studying them on September 16, 1978, because of the compact crowd of visitors, I could not examine their inscriptions and can only provisionally assign them to the early 20th century. They both measure 22 cm x 15 cm.

37. Nain Singh gives the location of a few goldfields between N. lat. 31° and 33° and E. long. 84° and 88° and describes their organization and methods of extraction (Trotter, 1877: 102-5 and map). These fields were not as rich as the western Tibetan ones and their exploitation was not very lucrative.

CASTING OF DEVOTIONAL IMAGES IN THE HIMĀLAYAS: HISTORY, TRADITION AND MODERN TECHNIQUES

E Lo Bue

Both solid- and hollow-casting by the lost wax process have a long history in Northern India. According to Reeves (1962:29), the earliest literary evidence for the process is the description contained in the *Madhūcchiṣṭavidhāna*, as recorded in chapter 68 of the *Mānasāra*, which is believed to have been compiled in the Gupta period (Shukla, 1958, II:108). Unfortunately, surviving cast metal statuary from this period is rare, and Bhattacharya (1979:62) suggests that the extensive use of metal for sculpture in northern India may not be earlier than the late Gupta period. From the early medieval period (7th to 12th century AD), more texts are found containing references to metal casting techniques. Of particular importance is the *Viṣṇudharmottarapurāṇa* (III:43-4), which mentions both hollow- and solid-casting by the *cire-perdue* method (Reeves 1962:32). This text is well-known in Nepal (Pal, 1970:13; Lévi, 1905, III:133). However, the best medieval description which gives detailed instructions is contained in the *Abhilāṣitārtha-cintāmaṇi* (a text also known as *Mānasollāsa* or *Mānasollāsa-śāstra*) which was written in c. AD 1131 by king Someśvara Bhūlokamalla of the late Cālukya dynasty of the Deccan (Saraswati, 1936:139; Reeves, 1962:32; Ruelius, 1974:2.1.2). The verses on the lost-wax process, as translated by Saraswati (1936:143), also specify that the ratio of brass and copper to wax should be 10:1 (or, according to a variant reading, 8:1). By this time, hollow-casting had reached a degree of perfection which enabled sculptors to attempt very large images, for which the repoussé technique is otherwise generally preferred. The 2.225 m. high Sultanganj copper Buddha (in Birmingham City Museum) was cast in more than one piece by the hollow-casting method and it is very likely that the 1.86 m. high Devsar brass backplate (in Srinagar Museum, Kashmir) was cast by the same method.

The History of Buddhism in India, written in AD 1608 by the Tibetan scholar Tāranātha (b.1575) states that during Devapāla's rule (c. AD 821-861) the work of two outstanding Bengali painters and sculptors, father and son named Dhīmān and Bitpalo respectively, gave rise to new schools of painting and metal statuary (Chattopadhyaya, 1970:348). Reeves (1962:23) suggests that the resultant "widespread use of the *cire-perdue* process was to influence the manufacture of copper icons in Nepal and Tibet at the turn of the 10th century AD, particularly with respect to copper gilt images which are still produced there today". As in the past (Khandalavala, 1950:22), both solid and hollow lost-wax casting methods are still used by Newar sculptors, the former for medium size (15 cm to 45 cm) to large (from 45 cm) images, the latter for small (15 cm or below) and sometimes medium size images. The use of the two methods overlaps for medium size images ranging from 30 to 45 cm. There is no evidence to support Dagyab's claim that in Tibet permanent moulds for solid-casting were more widely used than the method of lost-wax casting (Dagyab, 1977, I:50). Ronge (1980:269) also appears to overlook the use of the lost-wax process in Tibetan statuary: "in Tibet bells as well as statues were made by the sand-casting method which requires the mould to be destroyed after casting". However, Pal (1969:29) accepts that the "bronzes in Tibet were usually cast by the *cire-perdue* method". A careful visual examination by Craddock (personal communication) of the 121 objects whose analyses are presented above (pp.26-31)failed to show any evidence of flash lines, especially on the underside of the bases. It seems probable that both techniques of casting were used in Tibet. The earliest evidence for the introduction of the lost-wax process into Tibet is probably provided by a western Tibetan Vajrapāṇi at the Musée Guimet in Paris (MA.3546). This statue was hollow cast in brass (11.7% zinc and 1% lead) by the lost-wax process, as is shown by radiography which revealed the presence of a core held together by a metal armature (Hours, 1980:95-98). This image, attributed by Pal (1969:22, Figure 6) to the 11th-12th century and regarded by Béguin (1977:89) as a copy of an 11th century Kashmiri "original", appears to provide the earliest evidence for the introduction of the lost-wax process into western Tibet.

The continuous presence of Newar sculptors in Tibet is attested in Tibetan and Western sources from the 7th (Norbu and Turnbull, 1972:143; Dagyab, 1977, I:36) to the 20th century (Huc, 1924, II:244; Bista, 1978:196 and 202-3). The career of Aniko, a Newar artist who was sent to Tibet at the head of a team of eighty artists in AD 1260 (Lévi, 1905, III:187; Petech, 1958:59; but see Tucci and others who give the figure twenty-four, probably mistranslating Lévi's French "quatre-vingts") is only one example. Aniko was subsequently invited to the Mongol court in China, where he was put in charge of the imperial metal-works, and received posthumous honours. Beeswax and copper are listed by the *Yuandai huasu ji* (see below, p.82) amongst the materials used by Aniko (Karmay, 1975:23). For every subsequent century, the presence of Newar sculptors is documented in various parts of Tibet. Newar communities existed at Lhasa, Shigatse, Gyantse, Sa-skya and Tsetang. Although the figure of 20,000 Nepalese residents in Tibet (Nepali, 1965:25) is certainly exaggerated, what matters rather than their numbers are their social and anthropological features. They all belonged to the three Newar castes among which metal sculptors are still to be found: Vajrācārya, Śākya and Uda. During the early 17th century in particular, their activities extended from Guge (Pereira, 1926:96-7; see Lévi, 1905, I:79-80) to Bhutan (Ardussi, 1977:245-6), which is still supplied by the Newar metal sculptors of Pātan. The number of Nepalese metal images in Tibetan temples was legion and Newar sculptors have also been active producing statues in Tibetan style (Lo Bue, 1978 and 1981). There is, however, no historical evidence that Tibetan metal sculptors ever worked in Nepal. Furthermore, the current absence of local lost-wax statuary manufacture from Bhutan, Ladakh, and the Tibetan areas of Nepal, including the Tibetan refugee settlements where there are quite a few outstanding painters, suggests that Tibetan lost-wax metal statuary depended heavily upon Newar sculptors well into the 20th century (Lo Bue, 1978 and 1981). For these reasons, and in the absence of living Tibetan lost-wax metal sculptors to act as informants, I have thought it acceptable to base the following sections on fieldwork which I carried out in 1977 and 1978 among Newar sculptors working for Tibetans in Nepal.

A pioneering study by M-L de Labriffe (Mrs Anthony Aris) on lost-wax metal casting in the workshop of Jagat Man Sakya in Oku Bahal, Pātan, was published in *Kailash* in 1973. Another study by Alsop and Charlton was published in *Contributions to Nepalese Studies* later the same year. The following sections are intended to sum up the knowledge of the contemporary technique of Newar lost-wax casting and aim chiefly at supplementing these earlier studies with more detailed information, especially with regard to the timing of investing and casting.

Wax model

The composition of the wax used in modelling varies according to season in the Nepal Valley. The light "summer" wax is made with a mixture of 50% beeswax, bought from Tamangs living in the hills surrounding the Nepal Valley, and 50% *sila*, a tree resin imported from India. Reeves (1962:30) restating, perhaps with the aid of a Tamil translation, the defective (Saraswati, 1936: 140; Krishnan, 1976:7-8) Sanskrit text of the 68th chapter of the *Mānasāra*, defines the dammar used to manufacture statuary wax as the resinous sap of the *sāl* tree. Now the *sāl*, or *Shorea robusta*, abounds in the sub-Himalayan regions, including the Nepalese Terai. The dark "winter" wax is made with a mixture of one *dhārnī* (= 216 *tolās*. One *tolā* = 11.663 gm. Regmi, 1961:21) of

Plate 1

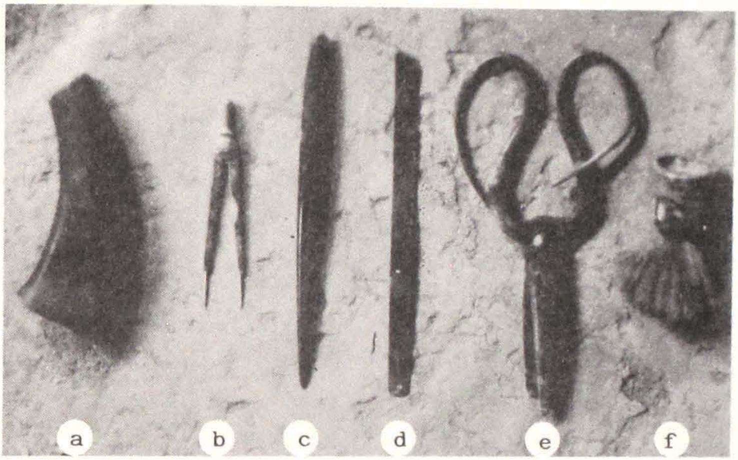

Plate 2

Plate 3

beeswax, 1.5 to 2 *pāos* (27 to 36 *tōlās*) of *sila* and about 0.5 *pāo* (9 *tōlās*) of vegetable ghee extracted from the seeds of the tree *Madhuca butyracea* (Roxb.) Macbride (*sive Bassia butyracea* Roxb.; Nep. *cyurī*), a Sapotacea attaining 21 m. in height which is distributed in the sub-Himalayan tract from 300 to 1500 m. altitude and grows also in the Kathmandu district (Suwal, 1970: 52). We thus have the proportion 24:3 (or 4):1 for beeswax:resin:vegetable oil. Krishnan (1976:30) mentions mustard seed oil instead of vegetable ghee and gives the following proportions: sixteen parts of beeswax, eight parts of resin and one part of oil. To manufacture the modelling wax, small pieces of beeswax are first melted in a brass or aluminium pan over a low flame on a charcoal brazier and then the powdered resin is added and stirred well. Finally, the vegetable fat is added and stirred vigorously.

The round wax sheets (Plate 1) used by sculptors for modelling their images are prepared by beating a cake of wax with a mallet and by spreading it uniformly on a stone slab with a roller. The thickness of the wax used varies according to the size of the statue to be cast and the type of metal to be used. Hollow copper images require a thicker wax model than brass ones. The chief tool used in wax-modelling is the *silatu*, a buffalo-horn spatula rounded at both ends, one end being wider than the other, and with one side slightly rounded and the other almost flat, so that its edges are not sharp (Plate 2c). Labriffe gives the spelling *silāyakū*. The outline of this spatula is reminiscent of the shape of a fountain pen. *Silatus* vary slightly in size, but they usually measure between 14 cm and 18 cm in length and are about 5 mm thick. A larger type of *silatu*, keeping the shape of the horn from which it is made, but cut at both ends (Plate 2a), is used to roll wax rods, which are employed to make attributes, necklaces, etc. The importance of the smaller *silatu* in modelling the wax is such that Kalu Kuma, one of the leading sculptors in Pātan who specialises in the manufacture of tantric deities in Tibetan style, regards it as a sixth "finger". Other tools, such as the scissors (Plate 2e) used to cut wax, are made of metal or wood.

The sculptor models the parts of his image, whether hollow or solid, without a core, by skilful manipulation of portions of wax sheet and use of the *silatu* (which is frequently moistened with saliva to avoid sticking) near a portable charcoal stove (Plate 1), (*ou cha*; Labriffe, 1973: caption opp. p. 187 has *milācā*) made of clay called *ghoti cha* (Labriffe, 1973:189, n.13c has *gathi*), and provided with a door to admit the draught in the lower section and a perforated fuel receptacle in the upper. The stove used by Kalu Kuma measures 18 cm in height and has an external diameter of 28 cm. The various sections of a wax figure or of its component parts are joined by evening out and heating their edges before attaching them (Plate 3). Once the wax model is completed, the artist wets the surface with water and presses on pieces of slightly heated thicker wax in order to obtain the *thāsā* ("key") (Plate 4) or "female" sections of a mould which will allow him to duplicate the same image, or parts of it, in future. The *thāsā* also ensures that in case of mis-casting the time employed to remodel the image will be reduced. In order to model from a *thāsā* the sculptor or his apprentices wet the insides of the sections and press the slightly heated thinner sheets of modelling wax against them. The various sections obtained from the *thāsā* are then jointed together following the original model to form a complete figure or parts of it. The method of casting images in several parts with separate attributes which are subsequently joined together is a traditional feature of Tibetan and Himālayan sculpture (see below, p.78, and Khandalavala, 1950:22).

Although apprentices may be involved in all modelling operations connected with the *thāsā*, the modelling of the prototype is carried out by the sculptor alone. Finally, ornaments, jewellery and attributes to be cast with the figure are modelled and fitted to the assembled wax figure. Kalu Kuma makes use of a black stone obtained from Tibet, carved in low relief with the "female" moulds of a number of religious attributes and ornaments which

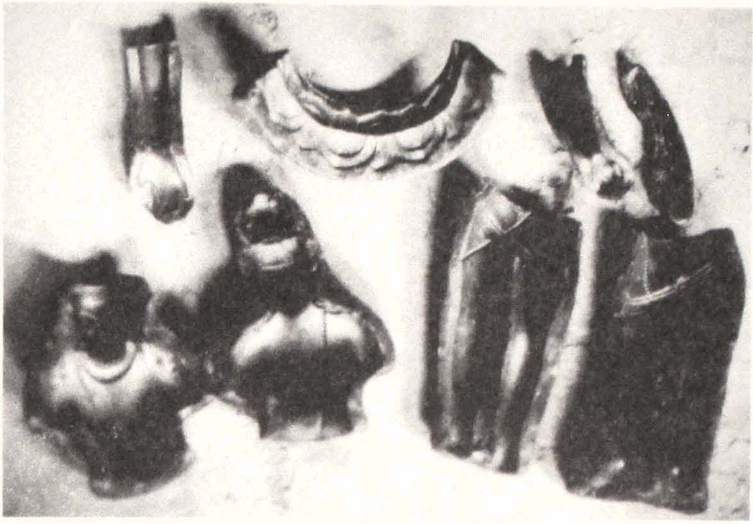

Plate 4

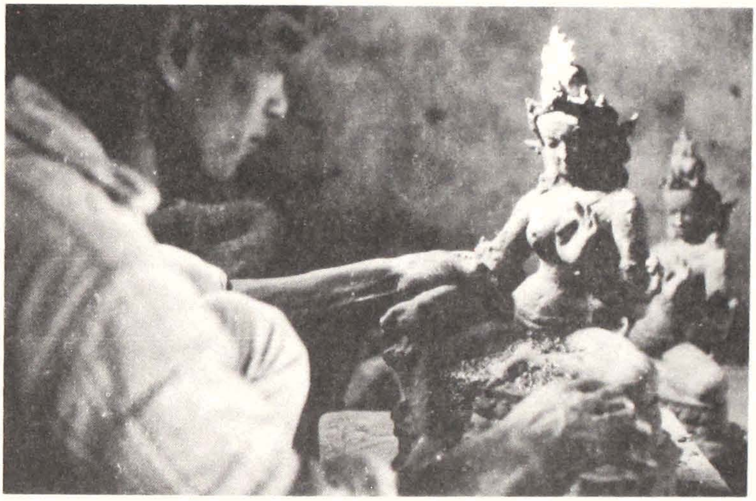

Plate 5

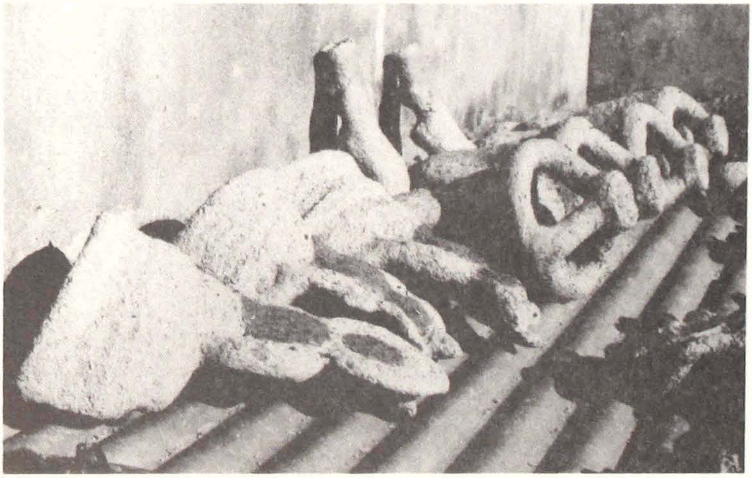

Plate 6

are part of the accoutrements of his tantric deities. Once a wax model or its parts are complete, a wax tripod is fitted to their bottom edge; its rods will become sprues when the wax is melted away.

During the whole process, the artist makes use of a basin filled with water to cool and harden the wax as necessary, and of a small pot filled with molten wax for retouching and joining. It should be noted that he does not use cores at any stage of the modelling, although a core is automatically formed when investing the wax of hollow models.

Investing the wax

The investment of the wax is carried out by the sculptor or an apprentice, or by a specially hired clay worker, as was the case with the investing of a number of small and medium size wax images which I observed in one of Kalu Kuma's workshops in the summer of 1978. The investment of Kalu Kuma's models by this artisan was carried out during four days of sunshine. This account follows a chronological sequence to give an idea of the time involved in the various operations.

5 September 1978

A paste made of fine clay (Nep. *mashinō mātō*; New. *mashin cha*), water and cow dung in equal proportions is applied to all the less accessible parts of the model. Immediately afterwards, a more liquid, creamy solution of the same composition is splashed and poured over and, where appropriate, inside the wax model or its parts (Plate 5). To improve access to the interior of a hollow model a small window may be cut in the wax and the paste pushed through to form a core. The window may be replaced before smearing the outer surface with subsequent layers, or may be filled with clay and only closed with a piece of copper sheet after casting is complete. The excess creamy solution is then shaken off and the clay left to dry in the workshop for about twenty-four hours.

6 September 1978

A thick paste made of yellow clay (Nep. *pahenlō mātō*; New. *masu cha*), water and rice husks is applied on top of the first layer. The resulting moulds are then put on a roof terrace to dry in the sun for a couple of days. Clay and rice husks are kept separately and mixed with water in a large clay pot as required.

8 September 1978

One or more iron nails are driven through the outer layers into the wax and the inner layers of clay to act as chaplets, so that during the melting of the wax the core of hollow models will not be displaced and thus hinder the molten metal from reaching all parts of the mould. A thicker layer of thick clay paste is subsequently patted onto the moulds, which are finally left to dry completely (Plate 6).

Removing the Wax

Dewaxing and the subsequent operations will be described here in a time-sequence referring to the casting in copper of the images whose investment has been described above. They took place in the small courtyard (320 cm x 210 cm) and porch of Kalu Kuma's old house, on the evening of 13 September, 1978. The evening was chosen because casting is obviously more bearable in cooler conditions. Kalu's son, Rajesh, directed the operations, which involved four other workers, including his own brother-in-law, two other assistants

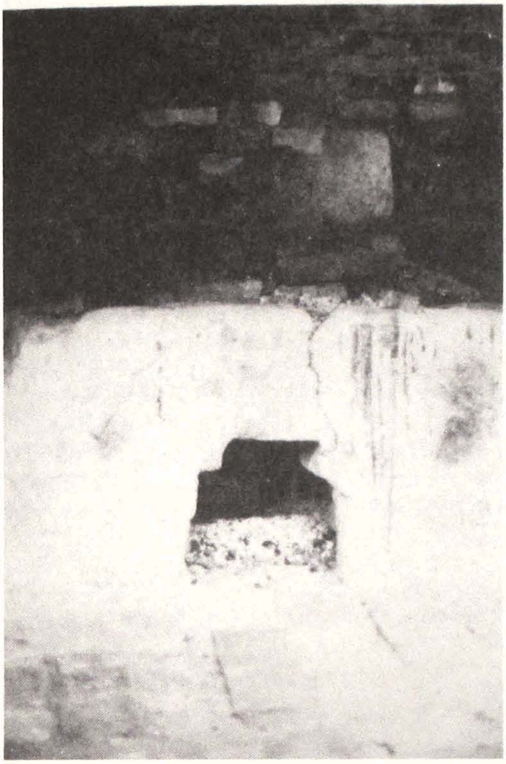

Plate 7

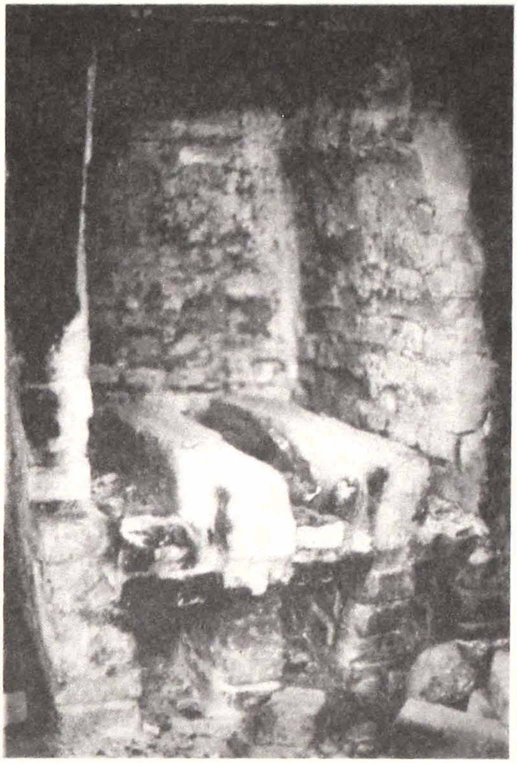

Plate 8

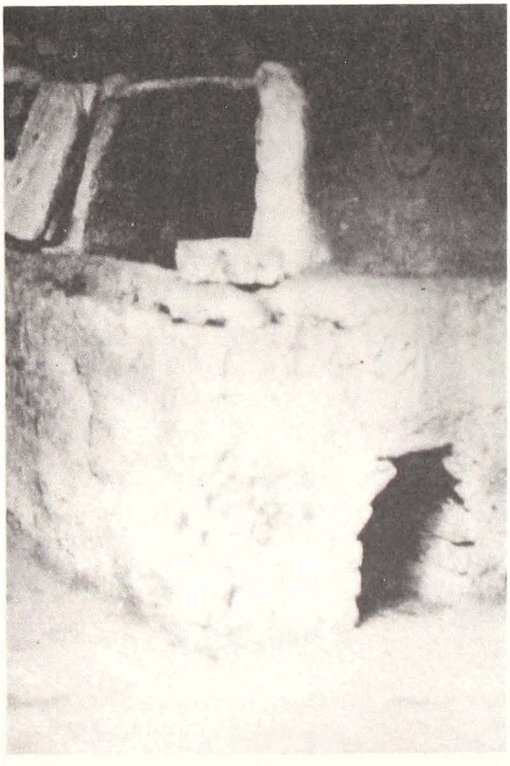

Plate 9

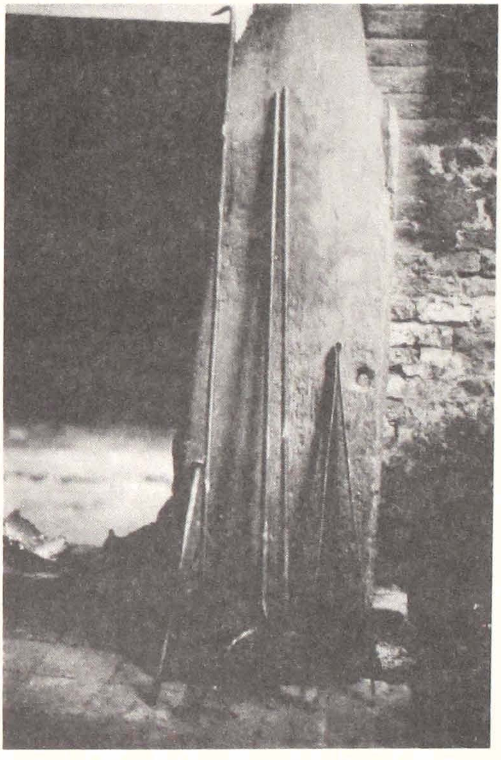

Plate 10

of Kalu, and one of another sculptor's apprentices.

Although some workshops are provided with a dewaxing stove (Plate 7) and firing kiln (Plate 8) besides the furnace for melting the metal (Plate 9), the Kumas use a dual-purpose yellow clay kiln measuring 68 cm x 48 cm x 56 cm and built on a similar principle to the stove described above (p.72). Here, however, the lower compartment has a larger door for admitting the draught, and the top compartment is a chamber built with a temporary front wall of loose bricks. The kiln is not moveable, being built against one of the walls of the courtyard.

5.00 p.m. The moulds are placed on a charcoal fire resting on the receptacle separating the lower from the upper compartment of the kiln. They are turned with tongs until thoroughly heated, but not baked, for a period varying from 2 to 5 minutes according to the size of the mould. They are then removed, the head of the tripod is pierced and the wax flows out through the sprues into an earthenware bowl. It takes a few minutes for all the wax to escape, and eventually the sprues are cleared with metal tools in order to ensure a passage for the molten metal to be poured in later. The wax will be re-used for modelling, after replacement of its vegetable ghee.

5.15 p.m. Copper sheets and scraps (including wire and a variety of bits and pieces) are hammered to the smallest possible size and jammed into an open glazed ceramic crucible 20 cm high and 16 cm in external diameter. These crucibles are imported from India and are used especially for casting copper.

Firing the mould and melting the copper

5.40 p.m. The fire in the kiln is reactivated with paper, dry corn-cobs and small bits of wood,and then the draught from an electric fan is directed into the door. Charcoal is added and once it is burning well the fan is switched off.

5.45 p.m. Coal is placed in the hearth of a furnace built like the stove and the kiln from bricks and yellow clay, and located in the corner opposite the kiln. Its measurements are 79 cm x 79 cm x 66 cm. Coal is not found in Nepal (Imperial Gazetteer of India, 1908:119) and is now imported from India, but it does not appear to have been imported in the past. As a fuel it has probably replaced charcoal for casting, whereas wood is still used for firing moulds (Alsop and Charlton, 1973:38). In Tibet, coal was available in the eastern part of the country (Cooper, 1871:463; Saunders, in Turner, 1800:406; Duncan, 1964:19). Combustion is aided by directing an electric blower into a pipe protruding 15 cm from an opening in the lower compartment of the furnace. The blower is luted to the pipe with clay.

5.50 p.m. Cross-armed crucible tongs are brought into the courtyard (Plate 10). Their length varies from 117 cm to 142 cm and their fulcrum is located so as to allow maximum grip when holding the crucible. Their ends are semi-circular so as to fit almost all the way round the crucible. Glowing coal is transferred from the furnace to the kiln in order to reach a higher firing temperature.

5.55 p.m. The coal in the furnace is burning with a flame 60 cm high, undoubtedly because of the draught from the electric blower.

6.00 p.m. The crucible containing the metal is placed directly on the coal in the furnace and a brick chamber is built around it. The chamber is one brick thick and leaves the upper portion of the crucible visible. Pieces of copper stick out of the crucible to a length of 15 cm. The crucible is not fixed in position, but rests on the coals which are continually topped up.

6.10 p.m. A convex iron lid is placed over the furnace chamber. Charcoal is added to the receptacle of the kiln and moulds are placed on it for firing. They will have to be brought to a temperature close enough to the melting point of copper (1083°C) to prevent the metal from starting to solidify before the mould is completely filled, and the mould itself from cracking

during pouring. No thermometer or other form of temperature control or measurement is used by Newar sculptors even today.
6.12 p.m. Blue flames 15 cm long spit horizontally from beneath the furnace lid.
6.17 p.m. The lid is red hot and four sheets of scrap copper hammered to equal size are put around it, leaning partly on the temporary brickwork of the chamber. More copper scraps, mostly sprues recovered from previous castings, are beaten, and coal is hammered into fragments.
6.20 p.m. The kiln receptacle is filled with coal and a slate is put as a roof over its three walls, while a temporary wall of bricks and clay is raised in front of it to seal off the moulds in a chamber. The scrap copper sheets which were being heated on the top of the furnace are hammered while hot to a size to fit the crucible.
6.28 p.m. The furnace lid is so red as to appear almost transparent. A large ceramic bowl, measuring 18 cm in height and 51 cm in diameter, is filled with water in preparation for cooling the moulds after casting.
6.35 p.m. The position of the crucible is adjusted with a long iron bar through an opening in the temporary chamber wall, and the lid lifted. The copper in the bottom of the crucible must have started melting because the level of the red hot copper scraps visible above the rim has dropped. They are further pressed down with an iron bar. Small copper scraps are poured into the crucible from a ladle, 9 cm in diameter and 27 cm long, provided with a wooden handle.
6.37 p.m. The crucible is red hot and more coal is added to the chamber by hand. Both coal and scrap copper are carried in metal buckets.
6.45 p.m. The furnace lid is lifted to add more scrap copper to the crucible. After removing part of the temporary front wall, Rajesh puts five more moulds into the kiln chamber and adds charcoal.
6.50 p.m. The bricks are put back and the flames in the kiln chamber are fanned with a piece of straw matting.
7.10 p.m. The furnace lid is lifted again to add more bits of scrap copper.
7.20 p.m. More charcoal is added to the kiln chamber.
7.35 p.m. The coal level in the furnace chamber is topped up. The kiln is fanned again.
7.40 p.m. A wall two bricks high is built on the ground in the porch to support the fired moulds during casting.
7.45 p.m. The temporary front brick wall of the kiln chamber is dismantled and the fired clay moulds are placed on the ground, leaning against the two-layer brick wall. They are red hot and stand upside down with the opening (i.e. the head of the tripod) pointing upwards, ready to receive the molten metal.
7.50 p.m. The copper is molten and casting begins. Rajesh stirs the molten copper with an iron bar to check that melting is complete before pouring it into the opening of the mould. A certain amount of spilling occurs, probably because the open glazed crucibles are difficult to handle. No precaution is taken to ensure that the air escapes from the moulds. Consequently mis-castings are not rare, as I saw the following day, when the tripod-shaped sprues were sawn off the bottom of the copper statues and parts of statues.

The above time-table shows that it took one hour and fifty minutes for the copper in the crucible to melt and one hour and thirty-five minutes for the clay moulds to be fired. The copper castings are allowed "to cool and harden for about fifteen to thirty minutes. The cooling is speeded by pouring cold water over the mould, which emits huge amounts of steam. Finally the entire mould is placed in a large jug of water to complete the cooling process" (Alsop and Charlton, 1973:39).

The casting operations for copper were not very different from those for casting brass, as I had observed them in the house of the sculptor Sanu Kaji Sakya on 12 September, 1978. Preparations started there at 4 p.m. Both his kiln (71 cm x 71 cm x 120 cm) and his furnace (94 cm x 91 cm x 132 cm) are located in the porch adjacent to the courtyard. Sanu Kaji's furnace is larger than Kalu Kuma's and has a 14 cm x 14 cm window to admit the draught located 25 cm from the floor. The sculptor and his assistants were casting medium size images of Vajrapāṇi, Amitāyus and a Burmese style Śākyamuni. Lotus bases, bodies and head-dresses were cast separately. The crucibles were oval and 24 cm high with a short spout near the bottom. They were completely sealed to prevent loss of zinc from the alloy. These crucibles are made by the artists themselves and, according to Krishnan (1976:31), withstand only one melting operation. After the crucibles had been sufficiently heated for the brass to melt, they were removed from the furnace and their spouts perforated with an iron rod. Brass melts at a lower temperature than copper and appears more fluid and easier to cast; the molten alloy was poured into the moulds without the spilling noticed in Rajesh's workshop.

After casting, Sanu Kaji dropped each hot clay mould into a brass basin full of water, with considerable steaming and bubbling. The moulds remained in the water for a few minutes and were then taken out to be broken with an iron bar (Plate 11). The fired clay came off the metal statues easily and, as is to be expected with brass, Sanu Kaji's casting had a higher rate of success than Rajesh's in copper.

Cleaning up and assembling the cast

After removing the clay from the casts, the sprues are sawn off and the statues are then cleaned and polished for hours with the help of files (Plate 12), sandpaper and rags. None of the operations described above has to be performed by the artist, although most sculptors do their own casting.

Finally the statues are assembled, mostly by means of crimping and riveting although in the past split pins were also occasionally used. The backs of the neck, shoulders and wing attachments of Kalu Kuma's 44 cm high copper Garuḍa, made in c. 1971, provide a good example of crimping combined with riveting and dovetailing; the head is held in place by fitting it between the shoulders and driving a rivet between the shoulder-blades into the neck. The neck ornaments conceal the junction and the continuation of the neck into the shoulders so that the rivet is hardly noticeable. A crack in the dovetail joining the right wing and shoulder-blade of the Aniko Collection Garuḍa (Inv. no. 119; on loan to the Victoria and Albert Museum) reveals that the wing is also provided with a tenon inserted into a corresponding hole in the shoulder-blade (Plate 13). The latter type of fitting is always used to join medium or large size figures to their base or vehicle. The bottom of the figures and their backplates are provided with tenons which fit into corresponding sockets in the base or vehicle (Plate 14 a-c).

The casting of an image in several parts has the advantage of reducing to a minimum wastage due to mis-casting, besides allowing the sculptor to model wax surfaces which, being smaller, are relatively easy to handle. Newar and Tibetan sculptors adopted this technique from an early date, as may be seen from a c. 13th century gilded copper image of Maitreya, cast in four pieces by the lost-wax process and regarded by von Schroeder as an example of the Sino-Newar school of Aniko (Uhlig, 1979:168-9, no.95). Separate casting is favoured for both medium size and large images, but is also frequently used to cast components such as the base, backplate and attributes of smaller statues, sometimes in different alloys or metals, according to circumstances and taste. Although specialists in Tibetan and Himalayan art tend to be suspicious of figures where analysis has revealed a different composition from that of the base, backplate or halo, it should be noted that such differences are not necessarily evidence of forgery or restoration work. Bases and backplates may be cast, or even hammered, several weeks after the figure to which they belong, for a number of reasons, such as division of labour, availability of metal, delays due to weather conditions, time of year (Newar metalworkers are extremely reluctant

Plate 11

Plate 12

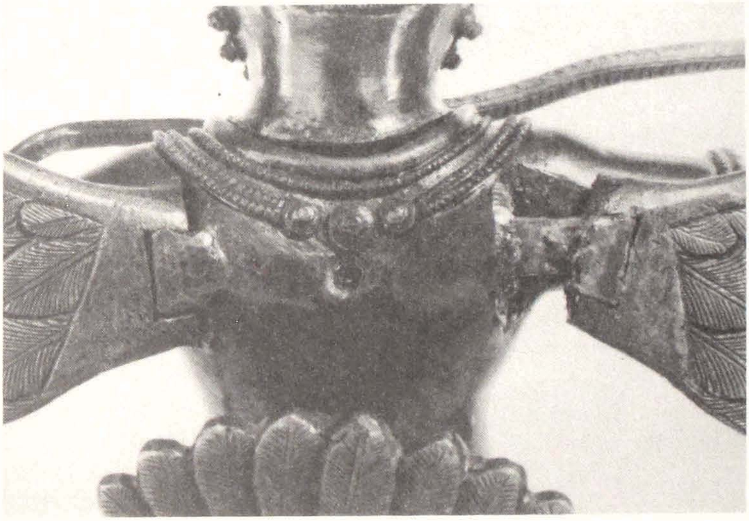

Plate 13

to work during the numerous festivals of the Newar calendar), and mis-casting. Because of the use of scrap in the alloy, it is not surprising that brass castings of different parts of an image made only a few days apart in the same workshop may give significantly different results in the composition of the alloy. Furthermore, availability of metal and taste may also account for the use of different alloys for different parts of the same image, as is the case for a c. 17th century Tibetan copper image of Na-ro-mkha'-spyod -ma dancing on a brass base (British Museum: 1905.5-19.11; p.105, no.38) and for an 18th-19th century Ṣaḍakṣarī (Werner, 1972: Figure 31). The same applies to other pieces, like a Tibetan copper statue of Sitatārā sitting on a brass base (British Museum: 1880:126; p.103, no. 4), the 15th century 25 cm high Tibetan statue of Padmasambhava illustrated in Christie's catalogue of their sale on 19 February, 1980 (p. 19, no. 79), and various other pieces. Although the possibility of later restoration work cannot be excluded as an explanation of the use of different metals in the same image, it is important to stress the role played by chance and taste in composite metal statuary from Tibet and the Himālayas. The same observations apply to original restoration work, where different metallurgical data from the same statue only prove that time has elapsed between the first and second casting, but cannot quantify it, whether in terms of days or centuries, unless other evidence is available.

With the polishing of the casting, the task of the sculptor is completed; for chasing, engraving and inlaying are carried out by the chaser, who also seals the underside of the statue with a sheet of hammered copper after the consecration of the image,and may inlay semi-precious stones where necessary. Although the first two operations are decisive for the final appearance of a metal image, the techniques and tools of the chaser (Dagyab, 1977, II:51-2, pls. 67-69 and 71) are rather different from those of the sculptor, and chasing, engraving and inlaying, as well as statuary embossing, deserve separate treatment. Suffice it to say that the chaser gently beats the surface of the casting with the aid of a little hammer and punch,before engraving it with a hammer and chisel. Copper is soft and relatively easy to chase and engrave, whereas brass is hard and brittle and few chasers challenge that medium with more than an average performance, though such was the case for a brass Tārā (Victoria and Albert Museum, I.S.21-1980; no. 121 on p.109 below). Copper is also more suitable for mercury-gilding than brass, particularly the leaded brass commonly used by Newar metalworkers (see p. 59). The materials used for inlay work in copper are usually silver and gold, but copper is used for inlaying brass. Gilding is seldom associated with inlay work, although I have seen one example of gold and silver inlay in a partially gilded copper statue of Dīpaṅkara. This combination of techniques finds an antecedent in at least one example of a post-Gupta gilded metal image, whose eyes are inlaid with silver (Majumdar, 1926:425). According to Khandalavala (1950: 24-25) "the practice in Nepal of setting ornaments and crowns of images with semi-precious stones was .... derived from late Pala art .... . The practice of gilding Nepalese copper images is also borrowed from Pala metal sculpture where gilded images are frequently met with". Even earlier, however, "stones and pearls" are reported to have decorated statues in the four pavilions of a building in the ancient capital of the Nepal Valley at the time of the missions of Wang Hiuen-ts'e in AD 647/8 and 657 (Lévi, 1905, I:157 and 159 and II:164-5). Tibetans traditionally prefer turquoise and coral for inlaying their metal images.

Gilding

Fire-gilding or mercury-gilding, that is gilding by means of a mixture of mercury and gold, is mentioned by Padma-dkar-po as being used in Tibet from the 7th century (see p.58). However, textual references are scanty and the technique is not described in detail by any of the Tibetan sources used for this introductory study. Ray (1956:115) refers to a text of the *Kubjikā Tantra*

Plate 14a

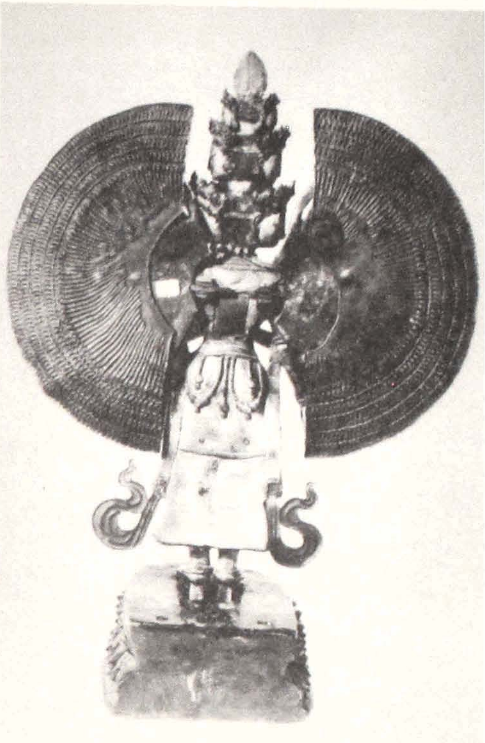

Plate 14b

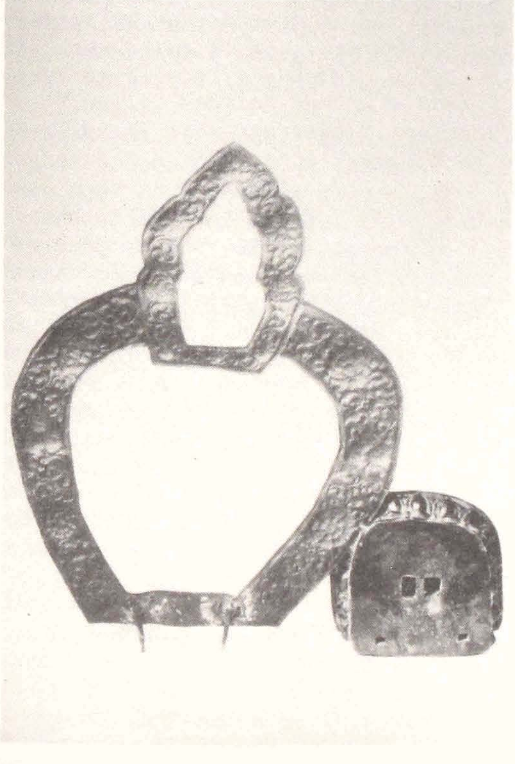

Plate 14c

Plate 15

"in the valuable manuscript collections of the Maharaja of Nepal. This was written in Gupta character and copied about the 6th century AD. In this Tantra we find allusions to the transmutation of copper into gold with the aid of mercury". It is possible that mention of such a transmutation in Indian and Tibetan alchemical literature is merely descriptive of fire-gilding. Mercury is referred to in connection with copper in the *Rasāyanaśāstroddhṛti*, a text which was translated and included in the Tenjur, and is therefore earlier than AD 1335. The translation by Suniti Kumar Pathak (Ray, 1956: 469) of the Tibetan version of verses 17 and 18 concerning copper and mercury interprets it as hinting at fire-gilding on copper, but is, to say the least, excessively free. The word for "gold" does not appear once in the corresponding Tibetan verses. On p. 30 of the *Yuandai huasu ji*, a record of the materials used by artists of the Mongol court between AD 1295 and 1330 at a time when Aniko was active there, mention is made of an image being "adorned with Tibetan liquid gilding" (Karmay, 1975:23), which is perhaps a reference to mercury-gilding. In the Nepal Valley, mercury-gilding has been used from the 10th century (see p.88) and Newar artists have always preferred this gilding technique on metal statuary almost to the exclusion of any other, even after 1979 when electro-plating was first introduced. The Newars probably derived that gilding technique from India, although few examples of gilded northern Indian statuary have survived. Majumdar (1926:427) assumes that the 84 cm tall standing Mañjuśrī from the ancient city at Mahasthan (Bogra District, Bangladesh) was mercury-gilded. However, he contradicts himself in regarding the image first as "not earlier than the Pala period" (Majumdar, 1926:425), then ascribing it to the Gupta period (ibid.:426-7). S K Saraswati, who knew the piece well, calls it "of definitely Gupta workmanship" and "gold-plated" (Saraswati, 1962:26), by which he seems to have understood fire-gilding. He describes its "fine plating, thinner even than an egg shell" and, in explanation, briefly quotes an account of contemporary Newar fire-gilding (Saraswati, 1962:30). Antiquities found at Mahasthan indicate that the city continued to flourish after the Gupta period and, since very few surviving metal images can be unquestionably given a Gupta date, it may be safer to assign the statue to the post-Gupta period. This view finds support in Dani (1959) and Asher (1980:94).

Although the method of fire-gilding became very popular in the Nepal Valley for the gilding of cast or repoussé Buddhist and Hindu copper images (Pal, 1974:33), there is no evidence that all copper statues from Nepal were gilded or were meant to be gilded. Parcel-gilding appears in Newar statuary from at least the 17th century, perhaps less for aesthetic reasons than as an economy measure, as the back of the image often remained ungilded (Khandalavala, 1950:22) and was painted red. This kind of parcel-gilding became very common in Nepal in subsequent centuries. The front of the statues, with the exception of the hair, was always entirely gilded and polished. Sometimes the main figure was gilded and its accessories left ungilded. Waldschmidt (1969: no. 39) and Werner (1972:211, Figure 31) illustrate an 18th-19th century Newar gilded image of Ṣaḍakṣarī seated on an ungilded throne with an ungilded ornamental back and canopy. This statue and all its parts were cast in brass (Werner, 1972:184-5, no. 173 a-c). Examples of mercury-gilded brass from an early period are less common, but brass was being used in Newar statuary from the 10th-11th century (see table on p.88). Since 1959, parcel-gilding for aesthetic purposes has occasionally been carried out on copper statues meant for the Western and Tibetan markets. This was also a common feature in eastern Tibetan and Sino-Tibetan brass statuary from at least the 18th century onwards. Usually the jewellery and naked parts of a figure, with the exception of the hair, were gilded, and the garments, or parts of them, were left ungilded, or vice versa. This applied to both the front and back of the statue. Parcel-gilding has also been used on repoussé metal work from at least the 18th century and is still very common, particularly on domestic and ritual objects meant for Tibetan customers.

Newar artists are aware nowadays of the difficulty of fire-gilding brass and of the impossibility of fire-gilding leaded brass (pp.92-4), but it is uncertain how far they were acquainted with the problem from an early period. Tibetans probably learnt from them, as is suggested by a fire-gilded brass Śākyamuni dated to c. 1500 (Uhlig, 1979:180 and 183, no. 107). The alloy of that image contains only 0.16% lead and 8.40% zinc, the percentage of these two elements probably having been kept low in order to avoid any adverse behaviour of the alloy when exposed to heat during the fire-gilding process (see pp. 92-4).

Cold gilding is mentioned by Padma-dkar-po as being used to gild the statues of Tibetan kings during a period corresponding to the 8th century (Padma-dkar-po, 1973, I:301,1.3). Cold gilding may be done by the application of gold leaf to the surface of the statue, either by burnishing it on, or by using an adhesive. It seems, however, that the most common technique for cold gilding statues is painting. Traditionally, gold paint is prepared by binding ready-made lentil-shaped drops of gold dust with glue. The exact method of preparation of these drops is still a secret known only to the Newars, and in Tibet only a few Newar goldsmiths residing in Lhasa possessed the technique, the names of their establishments being "well known to the painters of Central Tibet" (Jackson, 1976:232). However, one way of making finely powdered gold is by cutting sheets of gold leaf into small ribbon-like strips, mixing them with powdered stone and glass and grinding them with a little water (Dagyab, 1977,I:45).

Cold gilding is particularly suitable for statues made of materials other than metal, and the 14th century clay groups of Srong-brtsan-sgam-po and his two wives preserved in the Potala (Snellgrove and Richardson, 1968: 154; Stein, 1962:247 and pl. opp. p. 246) and the Jo-khang (Sís and Vaniš: [1957] 133 and 147-9 are certainly gilded by that technique. Gold paint is still used by Tibetan and Newar artists to give the faces and necks of Tibetan images their characteristically matt golden colour. This practice is very common in Tibetan metal statuary, whether fire-gilded or not, and in the former case the gold paint is applied over the mercury-gilded surface of the face.

Finally, mention should be made of the use of gold as an offering in the alloy of statuary metals, as is revealed by Himalayan copper and brass images with a gold percentage higher than about 0.01%, although Werner suggests a lower limit of 0.05% (Werner, 1972:146-7, table 9.6, nos. 167, 173 and 208). The 25 cm high brass statuette of Ṣaḍakṣarī (Werner, 1972:184-5 no. 173 a-c; see above p. 82) has a gold content of 0.13%, although it is not clear whether the result of the analysis may have been biased by the fact that the main image is actually gilt, because its backplate and base have only 0.012% and 0.008% of gold in the alloy. However, the detection of pieces of gold leaf beneath the surface of a few *thang-kas* (Bruce-Gardner, 1975) by means of an infra-red viewer, suggests that gold may have been similarly added to statuary metals for purely religious reasons. It is possible that this circumstance contributed to the creation of the myth of the "octo-alloy" (see above, p. 33).

The surfaces of ungilded copper images made nowadays by Newar sculptors are often finished by smearing them with mustard seed oil or even shoe polish in order to give them a patina. The aim of this is not necessarily to make them look antique. The tradition of waxing metal images is very ancient in Tibet and may be due to aesthetic reasons or to the realization that it was a good method of preventing oxidation. The fire-gilded images made at the time of king Srong-brtsan-sgam-po were smeared with *byo rtsī* (for "*byo rtse*") (Padma-dkar-po, 1973, I:300, 1.6) a term translated by Tucci (1959:185) as "resin or greasy material". Similarly, the statues made during the reign of Khri-srong-lde-brtsan "were smeared with *byo rtsi*" (Padma-dkar-po, 1973, I: 301,1.2)and Chinese statues made during the Ming dynasty "were actually smeared with *zho rtsi*" (Padma-dkar-po, 1973, I:304,1.5). This literally means "curds varnish", although Tucci (1959:186-7) translates the corresponding expression from his anonymous manuscript as "red".

Antiquing

The antiquing of images in the Nepal Valley started in the nineteen-sixties as a result of the growing demand for Tibetan and Himalayan antiques in the Western art market, and it is now carried out by a few specialists in Pātan and Kathmandu. The artificial ageing of works of art is forbidden in Nepal and this makes it very difficult for the researcher to get in touch with professional forgers who, in any case, are not ready to disclose their trade secrets. Some artists, like Kalu Kuma, mark their images in order to avoid trouble with the Department of Archaeology of Nepal, which issues the permits and seals necessary for the legal export of all works of art, the export of items over one hundred years old being now forbidden. However, that does not prevent some Newar and Western dealers from having artificially aged a large number of the statues bought from modern artists. Various methods of antiquing have evolved during the last two decades. In the nineteen-sixties, dealers were generally happy with darkening brass images by heating them at a high temperature, thus obtaining a black patina on the metal surface. Labriffe (1973:192) mentions heating over oil lamps, but it is doubtful whether such a method was ever popular, for the soot would come off the metal surface easily and stain the hands of any potential customer, thus defeating its purpose. I understand, however, that a similar method was used to age paintings. Occasionally oxidation is induced by smearing the statue with acids and Labriffe (1973:192) says that some statues were smeared with a mixture of lemon and salt and kept in a damp place surrounded by cloth for a period varying from six to twelve months. She also mentions another method, consisting of smearing the statue with liquid manure, ashes, salt and cow-dung and burying it in the ground for a year, in order to obtain a corroded surface. However, such relatively primitive methods of oxidation are now seldom used, perhaps because collectors have realized that ancient Newar and Tibetan metal images are never excavated from archaeological sites, but come from temples and shrines where they are reasonably well protected and corrosion is minimal. A green patina on any Himalayan statue is almost certainly the result of forgery (Pal, 1974:32-33).

During my visits to the Nepal Valley in the nineteen-seventies, I made several cautious attempts to get in touch with professional forgers, but only managed to create suspicion and fear amongst my informants. Although antiquing methods vary, they can be reduced to two basic techniques: rubbing and heating with a chemical agent. Rubbing is carried out for many days with cloth which may be imbued with any kind of greasy material, including milk, and incense. The heating of mercury-gilded images smeared with sal-ammoniac (ammonium chloride, which was, according to Buchanan Hamilton (1819:212) an item imported from China to Nepal in the 18th century) partially destroys the gilding, but gives the effect of mild corrosion which successfully dupes many buyers of Tibetan and Himalayan antiques. Finally vermilion and other ritual substances may be smeared on the forehead or other sacred parts of the statue to add the final touch of "authenticity" to the image, as if it had just been snatched from the altar. In some cases forgeries are left incomplete to simulate loss due to age. The most sophisticated methods of antiquing are used for statues which are especially commissioned from sculptors by Western dealers, on the understanding that no other images will be produced from the same *thāsā*. A model produced in only one or two copies is obviously more expensive and I understand that the professional artificial ageing of a statue may cost up to 100 U.S. dollars, but the investment must be worthwhile for some dealers are ready to pay.

Western collectors should be particularly supicious of black or green corroded "Tibetan" metal images, for anyone who is familiar with the way they are kept ought to be aware of the generally good state of preservation of their surface. Tibetans have a less physical contact with their images than Newars and seem to regard the direct application of offerings to their surface as not far short of sacrilege. A good example of the contrasting Tibetan and Newar attitudes towards Buddhist images kept in Tibetan monasteries of the Nepal Valley is provided by Kuber Singh Sakya's 360 cm high fire-gilded copper repoussé Sha-kya-thub-pa (plate 15) which in about 1975 had to be protected by glass panels from the offerings thrown at it by Newar devotees. Drier climatic conditions in Tibet, where precipitation is generally less than 25 cm per year, also contribute to the better preservation of metal images there than is the case in the Nepal Valley, where they are exposed to the intense dampness of the monsoon; from July to September the Valley receives most of the annual rainfall of 127 cm to 140 cm. Thus, as a rule, Tibetan antiques are in a better state of preservation than forgers would have us believe.

The problem of establishing whether Newar metal images are ancient or modern is sometimes difficult. Newar statues are quickly worn by worshipping and the organic ritual substances deposited on them do not provide a clue to dating by chemical or carbon-14 analysis because their application is perfectly compatible with contemporary worship. Furthermore, it is doubtful whether antiqued gilded images will retain sufficient traces of ammonium chloride on their surface to be detected by chemical analysis. It is likely that the considerable demand for Himalayan antiques will lead to the perfecting of artificial ageing methods, particularly as far as Newar statuary is concerned, and especially where those methods are encouraged and supervised, if not actually practised, by Western dealers.

Conclusions

Apart from the methods of forgery, it appears that very few technological innovations have occurred in the statuary techniques used by Tibetan and Himalayan sculptors to this day. They still manufacture their own modelling tools and they model clay and wax in a traditional manner. Their investment techniques find a parallel in the use of different grades of clay as described in various Indian texts (Reeves, 1962:31), including the *Mānasollāsa*. Apart from the use of coal, the only improvement made in firing the mould and melting the metal is the modern use of electric fans and blowers by some sculptors, instead of hand-operated bellows. No innovation has been applied to the seemingly difficult problem of measuring the temperature of the clay mould before pouring the molten metal into it. Artists obviously feel confident enough to rely exclusively on their own experience.

Casting of separate parts of the same statue is not a novelty, as is shown by the instance of the Sultanganj Buddha (see above, p.69). Occasionally medium size statues, whether hollow or solid, may still be cast in one piece (Alsop and Charlton, 1973:38). A few minor changes have occurred in the fitting techniques; tenons tend to be bigger than in the past and can no longer be bent, and split-pins are no longer used. However, examples of unsecured base in ancient statuettes are not rare. Brazing and silver-soldering are nowadays used to repair minor mis-castings and both techniques appear to have been introduced in Newar statuary after 1975. However, chasing, engraving, inlaying and gilding are still carried out with the traditional techniques, and it may thus be concluded that Himalayan metal statuary has undergone few technical changes since it was introduced into Tibet from India and Nepal and that it is still practised by ancient methods by Newar sculptors in Pātan.

Acknowledgements

I should like to acknowledge a grant from the Central Research Fund of the University of London towards my second season of fieldwork in Nepal (in 1978) which allowed me to record the casting operations published here. I should also like to express my gratitude to Mrs Anthony Aris who has generously provided illustrations for this section.

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GILDING HIMALAYAN IMAGES: HISTORY, TRADITION AND MODERN TECHNIQUES

W A Oddy, Mavis Bimson and Susan La Niece

Scientific examination shows that two very different methods of gilding were used to decorate the surfaces of Himalayan religious images : fire-gilding and cold-gilding. The experimental evidence (reported on pp.103-109,and 88 for objects in the British Museum) shows that fire-gilding was in use at least from the 9th-10th century in Nepal, but not in Tibet before the 14th century (p.105, no. 44). (It should be said, however, that the chronology of Tibetan art is uncertain and this latter date should be treated with caution.) In view of the earlier date for fire-gilding in Nepal, there seems no reason to rule out its occurrence in Tibet before the 14th century; however no apparently earlier gilded pieces were available for analysis. The dating of cold-gilding is more uncertain because it is always possible that the gold paint is not original and has been applied more recently as an act of devotion. Cold-gilding has been detected on Tibetan images of at least the 15th century (pp.104-108, nos. 35, 83, 104 and 109) and later, but not on any undoubted Nepalese figures (but see p. 107, no.77). This is not surprising as the Newars much prefer the use of fire-gilding and do not use cold-gilding techniques unless the figure is destined for the Tibetan market (personal communication from E. Lo Bue).

Fire- or mercury-gilding (or less commonly wash- or amalgam-gilding) is a method of gilding silver and copper alloys which was in use in the western world from at least the 3rd century AD until relatively modern times, and it can be carried out by two different procedures. In one of these, gold is dissolved in mercury to form an amalgam (i.e. a solution of gold in mercury) which is spread over the surface of the baser metal. The object is then heated and the mercury is lost by evaporation, leaving behind a firmly bonded layer of gold. In the second technique, the surface of the object is amalgamated with a layer of mercury and then pieces of gold leaf are laid on. They at once dissolve in the amalgamated surface, and the mercury is again lost when the object is subsequently heated.

Cold-gilding generally means the application of gold as a paint. This is made from powdered gold mixed with a suitable binder, and is most commonly observed on the face and neck of the images, and very occasionally on hands, feet or other parts of exposed 'flesh'.

The Characterisation of Fire-Gilding

Of the 121 copper-alloy (and one silver) images for which analyses are presented in this volume (pp.26-31), 45 have part or all of their surfaces covered with a layer of gold applied by the fire-gilding technique. The criterion for the recognition of a fire-gilt surface was the detection of a small amount of residual mercury in the gold layer. In most cases this mercury was detected by the non-destructive technique of X-ray fluorescence spectroscopy, indicating a concentration at the surface of the gold greater than about 0.2-0.5%, but when this method failed to indicate the presence of any mercury, a minute sample of the gilding was analysed by the much more sensitive method of emission spectrography.

Although the majority of these Tibetan and Nepalese fire-gilded images, or their component parts (e.g. separately cast bases, backplates, etc.), are attributed to the 17th, 18th and 19th centuries, a few are somewhat earlier. (For details of the results on particular pieces see the catalogue descriptions on pp.103-109 below.)

Apart from the above results, no other scientific examinations of the gilding on images from the Indian sub-continent, including Nepal and Tibet, are known to have been published, although von Schroeder (1981) includes analyses of two Pala period (c. AD 750-1150) figures and Uhlig (1980) a number of Himalayan ones which are all said to be fire-gilt. However, a number of Nepalese figures in the British Museum, analysed by T G Padley in 1976 (using X-ray fluorescence spectrometry), were shown to contain mercury in the gilding:

Analyses of Nepalese Images			
Type of Figure	British Museum Registration No.	Date	Type of Alloy
Maitreya	1967.7-13.1	c. 9th-10th century	Copper alloy, not analysed
Avalokitesvara	1965.6-14.1	c.10th-11th century	Brass
Vasudhara	1971.9-25.1	c.12th century	Copper
Kuvera	1959.7-20.1	Dated equivalent to 1659 AD	Brass
Amitabha Buddha	1928.5-15.1	Dated equivalent to 1740 AD	Copper alloy, not analysed
Manjusri	1952.11-21.1	Dated equivalent to 1819 AD	Brass

The classification of the alloy type in this table is only provisional, being the result of a rapid qualitative X-ray fluorescence analysis of the base metal. Padley also found two Ceylonese figures to be fire-gilt, using emission spectrography in the case of the famous 12th century AD Tara.

Analyses of Ceylonese Images			
Type of Figure	British Museum Registration No.	Probable Date	Type of Alloy
Buddha	1898.7-2.29	9th century	Bronze
Tara	1830.6-12.4	12th century	Copper alloy, not analysed

Although the analytical techniques used to detect the mercury are only qualitative, it is clear that the amount of mercury remaining in the layers of gilding varies. This, however, only indicates how prolonged the final heating may have been and gives no indication of whether the gold was applied to the surface as an amalgam, or as gold leaf onto an already amalgamated surface. So far as is known, the two techniques of applying fire-gilding are indistinguishable scientifically once the heating has been carried out to evaporate the mercury. However, one factor common to all fire-gilding is an analytically detectable amount of mercury, and prolonged heating will, in fact, destroy the gilding by causing the gold to be absorbed into the base metal substrate before it eliminates all traces of the mercury from the gold. Lins and Oddy (1975:370) heated for 24 hours a piece of recently fire-gilded copper at 500°C, which is considerably above the 357°C boiling point of mercury, and found that the mercury was readily detectable by emission spectrography at the end of the experiment.

If the presence of mercury is to be used as the sole criterion for the characterisation of fire-gilding, it is pertinent to ask whether mercury can be present in gold for any other reason. It is true that minute traces of mercury are sometimes detected in unrefined natural gold (Jones and Fleischer, 1969:13), but the reported levels are well below those found in practice on fire-gilded objects. More serious is the possible use of mercury in the purification of mined gold. Amalgamation as used for this purpose in the Roman world is described by Pliny in the 1st century AD (Forbes, 1971:178; Healy, 1978:157) and, more significantly in the context of this paper, the process is perhaps also described in the *Arthaśāstra* (Allchin, 1962:205), a Sanskrit text believed to contain material from c. 300 BC. (Kangle, 1965:59-117, argues for an early date but denies the reference to mercury. *Contra* Shamasastry, 1967:91.) Amalgamation was also used for the recovery of waste gold, and Pliny records the burning of worn out gold-embroidered clothes and the recovery of the gold from the ashes with mercury (Forbes, 1971:178-9), while Biringuccio, in the *Pirotechnia*, first published in 1540 but reflecting many aspects of metallurgical practice which were obviously of considerable antiquity, describes the separation of gilding from damaged silver and copper articles by putting them in a large crucible of boiling mercury (Biringuccio, 1966:383).

Whenever mercury was so used to purify gold, the latter was recovered by first pressing the mixture through a fine textile or a piece of chamois leather. Free mercury passes through, leaving a more concentrated gold amalgam behind. Heating the latter releases the gold by evaporating the mercury. However, unlike the case of a fire-gilded object, this gold/mercury amalgam can be very strongly heated with the express purpose of removing as much as possible of the mercury. Hence gold which has been refined in this way would be expected to contain only a trace of mercury, an amount which is most unlikely to be mistaken for the residue from fire-gilding on a gilt object.

The Origins of Fire-Gilding in India

The experimental evidence from the examination of the British Museum collections implies that fire-gilding was known in Ceylon and Nepal by the 9th-10th century, but not in Tibet until about the 14th century. However, documentary evidence may indicate a much earlier date for this method of gilding.

India has an alchemical tradition which can be detected as far back as the Vedic period (Ray, 1956:38). Indian alchemy is thought by Ray (1956:114 and 127) to have developed quite independently of Greek and Arabic alchemy, but it obviously owes much to interchange with China (Subbarayappa, 1971: 316-8). The beliefs of Indian alchemy include the search for prolongation of life, which was connected with the possession of gold (Ray, 1956:37-8; Subbarayappa, 1971:309 ff), and these ideas are already apparent in the *Atharvaveda* , composed around the beginning of the first millennium BC (Ray, 1956:36). Alchemy seems to have flourished in India particularly in the second half of the first millennium AD, to which time the belief in the possible transmutation of base metal into gold can first be traced (Subbarayappa, 1971:313), and it is significant that, in a manuscript supposedly of the 6th century AD, the agent of this transmutation is mercury (Ray, 1956:115). The belief in the power of mercury is an idea common to both Chinese (Needham, 1974, 1976 and 1980) and Indian alchemy (Subbarayappa, 1971:318-322, 335), and to the 12th century AD is attributed the text known as the *Rasarnava* ("sea of mercury") which describes the use of this metal for prolonging life and for converting base metals into gold (Ray, 1956:118-9).

That alchemists in India used gold amalgams to convey a golden appearance to base metal, there seems little doubt, but how far these ideas can be connected with the metallurgical practice of gilding images, which flourished at the same time as the development of alchemy, must remain an open question. In medieval Europe, the alchemists functioned quite separately from the smiths who made and gilded copper alloy and silver objects for secular and religious use. Both used the same technique of gilding but, while the alchemists used it fraudulently to support their belief in the possibility of the transmutation of base metals into gold, to the smiths it was only a method of decoration for baser metals, along with enamelling and the inlaying of precious stones. This is not to say that no medieval smith ever tried to sell a gilded article as solid gold, but this is deception of a different order from that of the alchemists who claimed to have converted base metal into gold (Read, 1939:22; Holmyard, 1957:125ff; *contra* Needham 1974:15–21 who accuses the smiths of carrying "on their operations with intent to deceive" while regarding the alchemists as having "adequate philosophical and mystical justification for calling any gold-like substance that they made 'a gold', as good indeed as natural gold if not better because made by art ...").

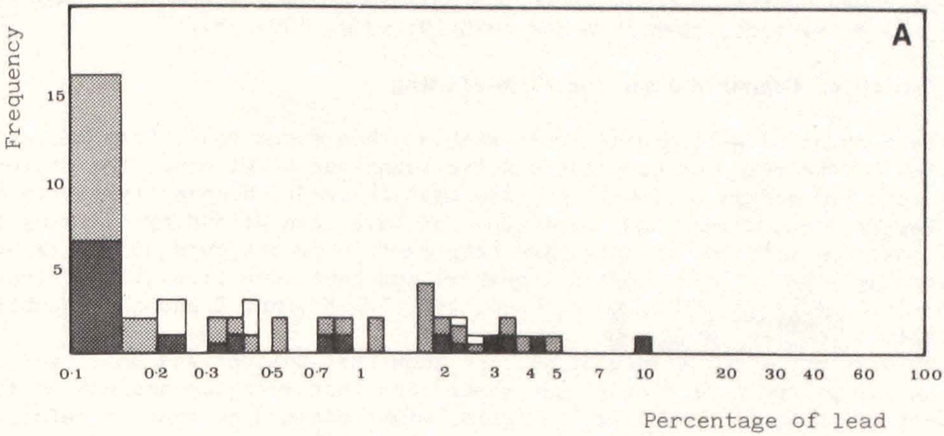
The oldest reference in Indian literature which may reasonably be interpreted as indicating a knowledge of fire-gilding is in the *Arthaśāstra* (2.13.44), attributed to Kauṭilya, minister of the first Mauryan Emperor (c. 300 BC) to which period the text has been assigned (Kangle, 1965: 59-115). Although Kangle, in his commentary on this text (1965:71-2), is very doubtful about the meaning where mercury and amalgamation may be mentioned, it is not unreasonable to assume that "he should gild (the silver article) with one fourth part gold by means of the liquid or powder of sand-vermilion" (Kangle, 1963:130) is an allusion to fire-gilding and that "the liquid...of sand-vermilion" is, in reality, mercury (which can be obtained from vermilion, a sulphide of mercury, by the application of heat).

Although the documentary sources possibly take the history of fire-gilding in India back to about 300 BC, this knowledge may not have entered Tibet until after the introduction of Buddhism in the 7th century AD (see also Lo Bue, above p.80). Indian literature was gradually introduced into Tibet from this time (Ray, 1956:123) and later Tibetan literature preserves accounts of medicine, science and alchemy which may have originated in the 7th century and before. Indeed, Ray includes a translation of a Tibetan manuscript known as the *Dhatuvada* which, he believes, probably derives from a Sanskrit original of the 8th-9th century (Ray, 1956:125 and 144-6). The *Dhatuvada* includes verses apparently on the transmutation of base metal into gold with the aid of mercury.

The evidence of the literature leaves little doubt that fire-gilding might be expected on works of art of the Gupta period and earlier, although, since the survival of metal statuary from this time is rare, it has not been possible to confirm this hypothesis. However, assuming that a knowledge of fire-gilding in India can be postulated by about 300 BC, the question arises of how the technique reached India.

Fire-gilding has been identified by chemical analysis on Chinese belt-hooks of the late Warring States period of the Eastern Zhou Dynasty (3rd century BC), on ornamental bronzes of the Han Dynasty (206 BC - AD 220) (Chase, 1973:82; Lins and Oddy, 1975:369), and on a number of Chinese Buddhist images ranging in date from the 5th to the 18th centuries AD (T G Padley, unpublished analyses). The earliest of these occurrences of fire-gilding corresponds more or less with the period (in the 4th century BC) when the properties of mercury were first being explored in China (Needham, 1974:248). In Japan, references to the use of gilding with the aid of mercury go back at least to 713 AD (Moran, 1969:56 footnote 6), and Moran has no doubt that the Japanese learnt the technique from China. However, recent X-ray fluorescence analyses of the surfaces of two excavated gilt-bronze sword pommels of the 6th-7th centuries AD, now in the British Museum (OA. 1249 and 1936. 4-16.1) have shown that both were fire-gilt, indicating an even earlier introduction of the technique into Japan.

Further to the west, fire-gilding was known to the Sasanians (3rd century AD), but apparently not to the Parthians (Lins and Oddy, 1974:366; Oddy and Meeks, 1978:5-6) while in the Mediterranean area it became common only from the 3rd century AD (Lins and Oddy, 1974). Whether true fire-gilding was known in Hellenistic times, as suggested by Craddock (1977:109; but see



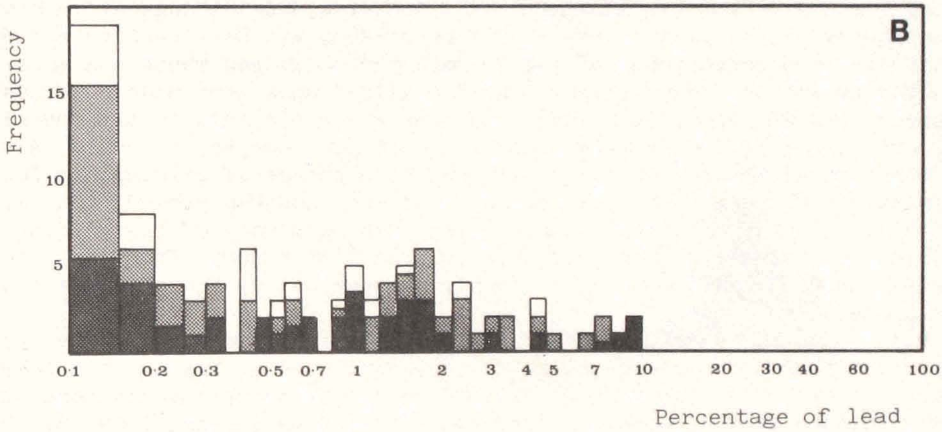


Figure 1 : Histograms of lead content of Tibetan and Himalayan metalwork for A, fire-gilded objects, and B, ungilded or cold-gilded pieces.

(Note: the percentage of lead has been plotted on a logarithmic scale in order to allow more differentiation of results below 10%)

Key: 20th century
18th-19th centuries
11th-16th centuries

Oddy, 1981: 78) and, in particular, to the Roman authors Vitruvius, in the 1st century BC, and Pliny, in the 1st century AD, is still a debatable question, but modern opinion is tending towards the belief that true fire-gilding became known to the Romans only in the 2nd-3rd century AD (Moran, 1969:55 footnote 5; Vittori, 1979:35-6 and 1978:73; Oddy, 1981:78).

The Choice of Copper Alloys for Fire-Gilding

A recent study of gilt-bronze Roman statuary has shown that, from the point of view of the alloy composition and the technique of gilding, the statues fall into two groups : either they are cast in leaded bronze (typically 65-80% copper, 15-30% lead and 5-10% tin) and have been gilded by sticking gold leaf onto the surface, or they have been cast in almost pure copper (> 95% containing < 5% of lead and tin together) and have been fire-gilded (Craddock, 1978:13; Oddy et al. 1979:182-7; Oddy, 1981:77; Oddy and Craddock: unpublished analyses).

This is explained by Theophilus, who knew that "silver and unalloyed copper can be gilded more easily than brass" and that when the amalgam on the surface of brass is heated "white spots [might appear] so that it refuses to dry evenly; this is the fault of the calamine [i.e. zinc content].... or of the lead" (Hawthorne and Smith, 1979:145-6). According to Theophilus, the problem of gilding brass could be overcome by heating the object to red heat and then wire-brushing the surface before amalgamating it.

It is obviously pertinent to enquire whether the importance of alloy composition in this context was known in India. The sources used by Ray (1956) for his *History of Chemistry in.....India* did not suggest to him that, in antiquity, the artisans knew that fire-gilding was best carried out on relatively pure copper, but of the 10 Pala period images whose analyses are reported by von Schroeder (1981), the 8 ungilded ones were made of brass, bronze or leaded copper (together with many trace elements in all cases) while the two gilded ones were cast of almost pure copper (c. 99%). A similar correlation between lead-content and the presence of gilding was found by Chase for Chinese belt-hooks of the late Zhou and Han periods (Chase, 1973:82). Although, in this case, no analyses were made of the gilding to confirm the presence of mercury, there can be little doubt from the results of Lins and Oddy (1975:369) that the pieces examined by Chase were actually fire-gilded.

With regard to Japan, Moran has also commented on the preference for high copper castings when fire-gilding is to be carried out, but it is not very clear whether he is reporting traditional practice or basing his comments on a knowledge of the composition of ancient statues (Moran, 1969:58). However, analyses have shown that one of the 6th-7th century Japanese sword pommels mentioned above (British Museum: OA 1249) contains 93% copper and 5% tin and that two 8th-10th centuries gilt bronze images of the Buddha from Korea (British Museum: 1957.7-18.1 and 1959.4-16.1) contain 95% copper/4% tin and 98% copper respectively (P T Craddock, unpublished analyses). Unfortunately, no extensive series of analyses of related ungilded objects is available for comparison with these results and so it is impossible to say with certainty that the high level of copper is correlated with the use of fire-gilding.

As far as the Tibetan and Nepalese metalwork is concerned, correlation of the analyses reported in this volume (pp.26-31) with the presence or absence of mercury in the gilding (see catalogue on pp.103-109) shows that there is a tendency for the fire-gilded pieces to contain less lead and zinc than the ungilded ones.

Figures 1a and b show that only three fire-gilded objects contain more than 4% lead, compared with 10 ungilded ones, and that the distribution of lead-contents remains much the same from the 12th century to the present.

As far as zinc-contents are concerned, figures 2a and b show a significant

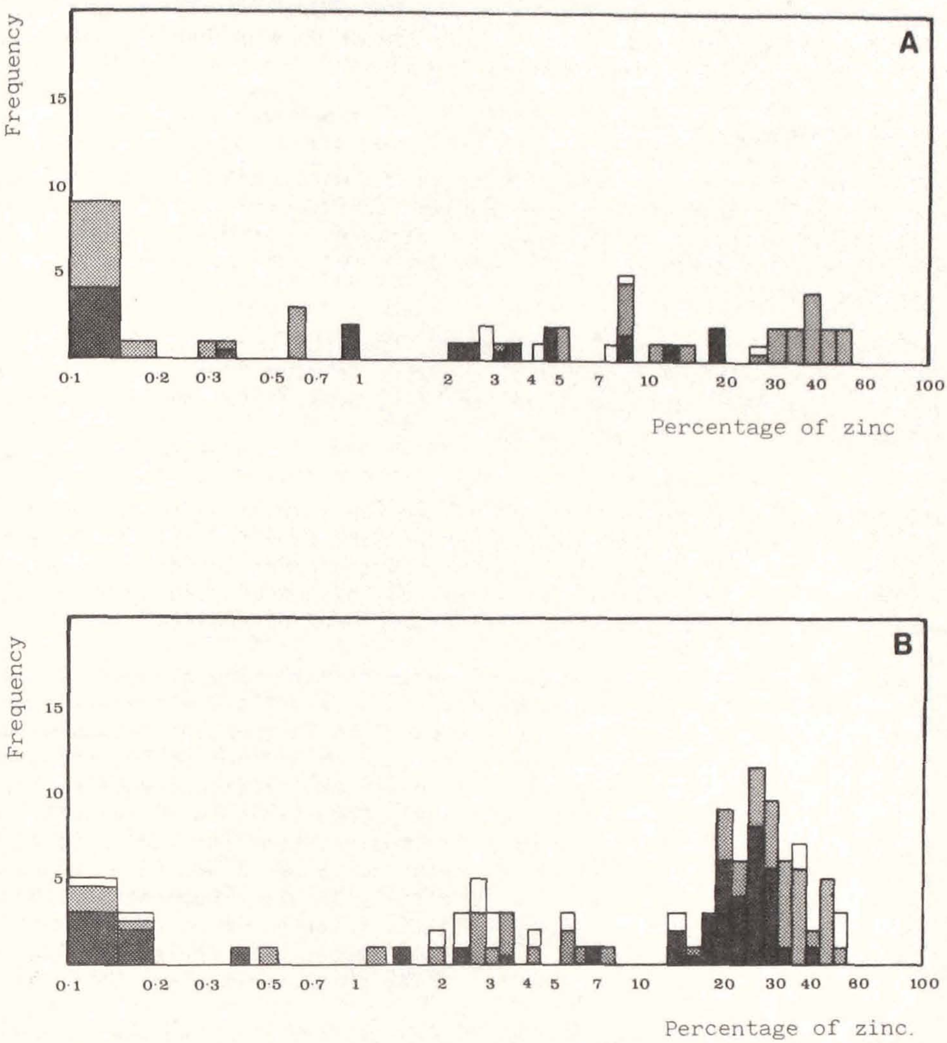


Figure 2 : Histograms of zinc contents of Tibetan and Himalayan metalwork for A, fire-gilded objects, and B, ungilded or cold gilded pieces.

(Note: the percentage of zinc has been plotted on a logarithmic scale in order to allow more differentiation of results below 10%)

Key: 20th century
18th-19th centuries
11th-16th centuries

difference in the 17th century and earlier, when the fire-gilded metalwork mostly contains less than 5% zinc, while there is a large group of ungilded objects with from 12% to 32% of zinc. This is not so noticeable in the 18th and 19th centuries, or in the 20th, although the modern tradition in Patan is that figures for gilding should be cast in almost pure copper (Lo Bue, above: pp.39&82; Alsop and Charlton, 1973:36, 40 and 43).

Historical Descriptions of Fire-Gilding

Among all the references to fire-gilding in the ancient Indian literature, not one of those so far available in English translation preserves a detailed practical description of the method. The earliest detailed description from a western source is given in the 8th century book of recipes known as the *Compositiones Variae:*

> You beat out gold and make thin leaves, then put in quicksilver (i.e. mercury) and melt the leaves till the gold is dissolved .... Then you will rub down what you intend to gild, besmear it somewhat [with the amalgam and] ... put it on the fire.
>
> (Burnam, 1920:127-8)

The text is rather garbled as it follows the intruction to "besmear" the article to be gilded with directions to "warm it and strain it in a clean linen cloth", but this is obviously part of the preparation of the amalgam, as is clear from the more detailed description of the procedure in the *Mappae Clavicula*, which is also an 8th century book of recipes.

> Take an extremely thin gold sheet, shear it into tiny pieces and put it in a mortar. Add a little quicksilver and leave it for a short time. Afterwards, add some natron and vinegar; rub it thoroughly with a pumice stone until it has the consistency of glue on account of the abundance of quicksilver. And now you put it in a clean cloth and squeeze it, so that most of the quicksilver comes out. Then you take the vessel [that is to be gilded], polish it with fine pumice, heat it, and while it cools coat it with the amalgam, and you heat the vessel a second time and again coat it and put it on the fire. And the gold alone becomes enriched. ... But if you were gilding a copper vessel, after you have polished it, coat it with liquid alum, for it will [then] receive the amalgam.
>
> (Smith and Hawthorne, 1974:36)

However, by far the best description of gilding from medieval Europe is to be found in a treatise by Theophilus on workshop practice which was written in the early 12th century.

> Put eight pennyweight of it [i.e. gold] into a dish and weigh out eight times as much mercury. Immediately add the gold to this and rub it until it becomes white; then break it up into little pieces. Also take one of the small crucibles in which gold or silver is melted, but which for this work ought to be thicker than those, and put it into the fire until it becomes red-hot, hold the crucible with tongs over a dry wide platter and pour the mercury with the gold into it. Quickly rub it and muddle it with the red-hot bent tool until you feel nothing but liquid in the crucible and at once pour it into water. Now, when the water has been removed, put the gold into your left hand and wash it carefully, testing with your finger to see if it is well milled, and if it is, put it upon a clean linen cloth and toss it to and fro until the water is dried off.
>
> After this weigh the gilding material in a balance and divide it in two, again divide each half in two [and keep on so dividing] until you reach single pennyweights [denarii]; put these individually into goose

quills in order that you may know how much you are to put on each place that is to be gilt. Then hammer a piece of red copper into a shape like an engraving tool and fit it into a handle; file and scrape its end until it is rounded and quite thin. Rub the end with mercury until it becomes white and then you can gild with it. After this, make a composition for amalgamating and gilding the work in this way.

Take some argol [i.e. potassium bitartrate].... and grind it carefully on a dry stone and add to it a third part of salt and put it in a large earthenware dish; pour over it that water into which you put the newly milled gold and add a little mercury. Put it on the coals until it becomes hot and stir it with a stick. You should also have [brushes of] hog-bristles, three or four fingers thick, bound in the middle with iron: two clean ones with which to wash the gold and silver, and two for gilding, one dry and the other wet. When all this has been prepared in this way, take the silver handles in your hands and dip a small, folded linen cloth into the hot composition and with it rub all the places on the handles that you want to gild. When they begin to amalgamate, heat them over the coals and rub them vigorously with a brush that has been wet in the same mixture. Continue, now heating and now rubbing, until all the engravings become white from the mercury. In those places that you cannot reach with the bristles, rub with the copper gilding tool and a thin stick. Do this over a wooden gilding platter, which for small work should be turned on a lathe and capacious, while for large work it should be square, hollow, and smooth.

Then with a small knife cut the gilding material [i.e. the amalgam] into tiny pieces over this platter and lay it carefully on every place with the copper gilding tool, and spread it evenly with the wet bristles. Pick up [the handle] with long thin tongs, the jaws of which are wrapped in two small pieces of cloth, and put it on the coals until it is hot, and again spread [the material] with the bristles and keep on doing so until the gold adheres all over. Cut up gold a second time and lay it on with the copper tool and so as before with fire and bristles. Do the same again a third time. When, on the third round, the gold begins to dry, rub it carefully all over with the dry bristles and heat it again and rub it again until it begins to turn pale. If it happens through carelessness that a blemish appears on the silver where the gold is thin and unevenly applied, lay on [mcre amalgam] with the copper tool and spread it evenly with the dry bristles until it is even all over. When you see this, put it into water and wash it with the clean bristles. Put it on the coals again and heat it until it becomes completely yellow.

Take thin brass wires and bend them over so that the distance between the bends is the length of your little finger. When they are quadruple tie them together with a linen thread so that they are like a bundle. Make four, five or six of these bundles in such a way that one has three bends, another four, a third five, and so on up to eight. When all these have been tied individually, make a small hollow in a piece of wood and put one of these parcels in it and pour in lead, so that when it is cold and you take it out, the bends are stuck together, fixed in a sort of knob of lead. In this way make separate lead knobs on each bundle. Then cut all the bends at the other end and file and scrape the tips so that they become round and smooth. Polish the gilded handles by, so to speak, scratching with these in fresh water in a clean pot. When you have polished them by scratch-brushing with the end of the bundle put them on coals until they are hot and turn a reddish-yellow color and lose the brightness they had acquired by polishing. Then quench them in water and polish them again by scratch-brushing carefully, until they take on a most brilliant lustre. Then color them with the following composition.

Take green vitriol [i.e. iron sulphate] and put it in a clean fire-

> tested earthenware dish and set it on the coals until it completely liquefies and begins to turn hard. Then take it out of the dish and put it beneath the coals and cover it carefully and blow with the bellows until it is burnt and turns a reddish color. Remove it from the fire at once and when it is cold grind it on a flat wooden platter with an iron hammer, adding to it a third part of salt. Then temper it with wine or urine and grind it vigorously again until it is a thick as lees. Cover the gilding with this composition with a feather so that no gold remains visible and put it on the coals until it is dried out and a little smoke comes from every part of it. Immediately remove it from the fire, put it in water and wash it carefully with clean hog-bristles. Dry it on the coals again and wrap it in a clean cloth until it is cold.
> (Hawthorne and Smith, 1979:110-115)

This description has been quoted in full because of its importance for comparisons with the technique of fire-gilding as it is still practised in Nepal (see below pp.97-100).

The next important description of fire-gilding is by Cellini, first published in 1568, but this adds almost nothing to the above, except to suggest the scratch-brushing of the copper or silver surface before applying the amalgam. Cellini, however, does not recommend rubbing mercury onto the baser metal before applying the amalgam (Ashbee, 1967:96-7).

Based on references from the Nara and subsequent periods in Japan, Moran has described step by step the two variations of the fire-gilding process as he believes they were carried out from at least the early 8th century, which is the date of the earliest records used by him. These descriptions are worth repeating as they must reflect traditional Chinese practice and, perhaps, that followed in the Indian subcontinent.

> The gold to be used was beaten thin, to about the thickness of ordinary paper; that is, not as thin as what is known technically as gold leaf.
>
> The gold was then cut up into small pieces with scissors.
>
> These pieces were now taken up by pincers made of bamboo wood and placed in a crucible (*rutsubo*) containing mercury.
>
> Over the top of this crucible was stretched a thick Japanese paper (*washi*), affixed with paste.
>
> After these preparations, the crucible was heated. The reason for the use of paper was to prevent the mercury from evaporating. Steam or vapor could come out through the type of paper used but not mercury. The crucible was heated until the paper became a light brown.
>
> The resulting liquid was poured out into a piece of paper, the same kind as had been placed over the top of the vessel. This paper was then twisted and a certain amount of the mercury was squeezed through the paper.
>
> Manwhile the surface of the statue to be gilded had to be prepared. This took arduous labor, for the raw surface after casting would be very rough and most unsuitable for receiving the gilding. There would be seams from the joining of the moulds, various surface irregularities, and imperfections in the casting. Filing, smoothing down with a whetstone (*toishi*), and also polishing with charcoal or some such material, were all necessary. In addition, the surface had to be thoroughly cleansed to rid it of oily substances. For this some kind of acid was used such as that from pickled plums (*ume-boshi*).
>
> The amalgam of gold and mercury was now applied to the surface of the statue. The surface was then rubbed down (presumably with cloth) to do away with excess amalgam and to make the surfacing even and uniform, so far as possible. It should be added, however, that a completely uniform thickness was not to be expected by this hand method, nor, in turn, a uniform thickness of the resulting gilding. The amalgam was not gold

in color but a silver-white with a slightly yellowish tinge, and of a butter-like consistency.

The entire statue was then heated and the mercury evaporated. This was done either by burning charcoal (*sumi*) inside the statue or in containers around it. A high temperature was not necessary; just enough to evaporate the mercury was all that was required. In fact, if the temperature were allowed to go higher the gold would permeate the metal and the surface would become spotted.

This process of applying gold amalgam to the statue, and then heating the statue, was repeated a number of times, even as many as five or six.

The final step was to polish the metal. This was done with a metal spatula-like tool (*migaki-hera* or *migaki-bo*). A mask was worn over the nose and mouth by those performing this step in the process as the fumes of any mercury that might be left were poisonous.

It should be pointed out that the amount of time and labor involved simply in the process of gilding, over and above the casting of the metal statue itself, was extraordinary. According to ancient records the gilding of the Daibutsu of Nara, took a little over five years (i.e. from March 752 to April 757).

The second technique involves the application of gold leaf to an already amalgamated surface.

The statue to be gilded was first smoothed, polished, and cleaned thoroughly with acid, as explained (above).

The statue was then painted with mercury that had been mixed with some material such as polishing powder (*tonoko*) in order to ensure greater control of the medium. Some of the mercury formed an amalgam with the copper of the surface of the statue.

To this prepared surface was applied thick gold leaf, which immediately formed an amalgam with the mercury.

The figure was next heated in order to evaporate the mercury.

These last three steps were repeated a number of times, even as many as five or six.

Finally, the gold surface was polished.

(Moran, 1969:56-9)

In the Nara period (645-794 AD) the proportion of mercury to gold for making the amalgam was 5:1 (Moran, 1969:56 footnote 8). In the West the 12th century manuscript of Eraclius gives 7:1 (Merrifield, 1849:220) and Theophilus gives 8:1 (see above).

The Fire-Gilding Process as Used in Patan Today

Nepal, and possibly Tibet, is one of the few places where fire-gilding is still carried out by traditional techniques which are largely unaffected by the modern world. Krishnan has stated that images are gilded in Patan by sticking gold leaf onto the surface with an adhesive lacquer (1976:32), but this is not in accordance with observations made on site by Lo Bue (above pp.39&82) and Bimson (below pp.98-100). Neither is it in accordance with the results of the scientific examinations made on the objects catalogued on pp. 103-109. Only one of these images, a Tibetan Amitayus, perhaps of 18th century date (p.108, no. 101), showed evidence for the use of lacquer and gold leaf, but this had been subsequently covered with a layer of paint. A flake from the surface was examined microscopically in cross-section and this revealed that next to the metal is a layer of some organic material (? lacquer) on top of which is a layer of gold leaf. On top of this is another organic layer, which may have been transparent and intended to protect the very thin layer of gold. Subsequently the figurine has been painted over with cinnabar, perhaps in an organic (? lacquer) binder.

Dagyab has described the fire-gilding process as it was carried out in Tibet until at least 1959, and his description correlates remarkably with that of Theophilus, which was quoted above.

> The gold used for gilding (*tsha-gser*), meaning literally 'hot gold') is prepared in a similar manner to the 'cold gold' used in painting. The gold is first smelted and pounded into paper-thin sheets. These thin sheets are cut up into small ribbon-like strips and mixed with mercury. The amount of mercury added is four times the amount of gold. Small bits of broken glass are also added. With the addition of some water the ingredients are thoroughly stirred in a mortar till the mixture acquires a liquid, white consistency like moist clay.
>
> Before gilding can start the surface to be gilded must be thoroughly cleaned. Large statues and sections of roof tops to be gilded are rubbed down with moistened re-ba (coarse yak's hair) and powdered bits of stone or sand. For smaller statues and articles a brass brush is used to clean them down. Next a layer of mercury is applied. This is done by carefully pouring on small quantities of mercury with brass spoons - known as *gser-thur* - of many sizes. The area to be gilded must be entirely covered. When the mercury has dried the surface is rubbed down with pigs' bristle. If the mercury does not touch the entire surface gilding is not possible for the hot liquid gold will not stick. The liquid gold is then applied evenly and the gilded objects are dried over a medium-heat fire. During the drying process the statue is turned over carefully and the gold is evenly distributed with the help of pieces of cotton wool and by brushing the surface with a wire brush until the colour turns a golden yellow.
>
> After the gilding process is over the newly gilded surface is polished by gently rubbing with a piece of metal such as a long metal needle, similar to a knitting needle.
>
> If only engraved parts and edges of articles are to be gilded, that is to say only certain parts of an object are to be gilded, then the areas which are not to be gilded are covered with a strong yellow paint (*ṅaṅ-pa gser-gdan*) which prevents the mercury from affecting the metal surface. If this paint is not applied in sufficient quantity the mercury may seep through and the gilding will turn out to be patchy.
>
> In addition to gilding there is another process by which gilded objects are further treated to enhance the golden colour and give the surface a warm reddish glow (*gser-mdaṅs*) much prized by Tibetans.
>
> With gilded objects this is done by reheating the articles and then soaking them in a solution made from the bark of a tree. The best results of all are obtained by dipping the gilded objects in *glog-chu*.
>
> (Dagyab, 1977,I:48-9)

In November 1979 a fire-gilding operation was observed in Patan (by M B) on a copy of Jagat Man Sakya's copper Dipankara. The gilding was carried out in the workshop belonging to Puspa Raj Sakya in a room at the top of the house. The windows were all open to allow maximum ventilation, which is very important because of the poisonous effect of the mercury vapour emitted during the process. In order to mitigate this effect the gilder had taken some alcoholic refreshment before starting his work, a precaution which he repeated a number of times during the gilding operation. (Dagyab confirms (1977, I:49) that the artisan should have drunk a quantity of alcohol before starting the gilding and then work with his nose and mouth covered (with a cloth). Theophilus, writing in the 12th century, says that gilding should not be carried out when the operator is hungry, because of increased danger of damage to health, and among various possible antidotes he lists garlic and wine (Hawthorne and Smith, 1979:112).

The statuette had been completely "finished" by the chaser before being submitted for gilding and the first operation was to immerse it briefly in a very dilute solution of nitric acid in order to remove all traces of dirt or oxide which would prevent the mercury from amalgamating with the metal surface. (Jackson (1976:284) states that the traditional way of cleaning the surface was with ashes, but that this has been replaced with a chemical solvent, i.e. the nitric acid.) The statuette was then washed with water.

Meanwhile a mixture of mercury and charcoal had been ground together in an oval stone mortar. This mixture was then rubbed onto the cleaned copper surface with the assistance of a small piece of rag held in the fingers and by using a slender metal rod with which to reach the more inaccessible parts. Altogether it took about half an hour to rub the mercury onto the surface where it amalgamated with the copper. Throughout this stage of the process the statuette was repeatedly rinsed in a bowl of water in order to wash away the charcoal and reveal any areas where amalgamation had not taken place. These were rubbed with a rag dipped in a brown liquid, said to be soya sauce, before reapplying the mixture of mercury and charcoal. When the surface was completely amalgamated it had a bright silvery appearance.

An amalgam of mercury and gold had been prepared by grinding together 22.5 *tolas* of mercury with 5 *tolas* of small pieces of gold foil in a mortar until all the gold had dissolved. This gives a ratio of mercury to gold of 4.5:1, similar to that of 4:1 given by Dagyab (1977,I:48). When the amalgam was ready for use it was stored under water in a small porcelain bowl.

The gold amalgam was applied in a similar manner to the mercury/charcoal mixture, and spread over the surface with a hog's-hair brush. The application of the amalgam dulled the bright surface appearance of the statuette, which was then allowed to stand for about ten minutes. If a green tinge appeared anywhere on the surface it was an indication that amalgamation was incomplete at this place, and the brown liquid (? soya sauce) was rubbed on, followed by a second application of amalgam.

When the gilder was satisfied with the appearance of the surface, the statuette was placed on a brick on the earth floor near to a wall and it was gently heated using a blow-lamp to evaporate the mercury from the surface. The use of a blow-lamp is a relatively recent innovation, and the traditional source of heat would have been the embers from a small fire (Dagyab, 1977, I:49; Jackson, 1976:284).

After being heated for a few minutes, the statuette was taken up and rubbed with cotton wool in order to improve the final appearance of the gilding. Heating then continued until the mercury appeared to have been completely driven off, and the gilding assumed a dull mustard-yellow colour. This matt surface was next burnished with an agate in order to produce a brightly polished gold appearance. The face of the statuette, however, was not burnished, but left with its matt colour. According to Jackson (1976:284) another burnishing tool, like a smooth steel rod, may be used to polish the surface. The process of burnishing left striations on the surface and these were removed by immersing the figure in water and brushing it with a soft brass polishing brush, using a soap-nut (identified by the Jodrell Laboratory, Royal Botanic Gardens, as the fruit of *Sapindus* sp., and said to be well-known as a soap substitute for washing clothes and bathing) to create a mild foam. The same procedure is used in the final polishing of cast (but not gilt) images by the *sthapati* craftsmen of Swamimalai (Krishnan, 1976:19).

Finally the gilder took two handfulls of twigs obtained from a tree which he referred to as 'munu' and poured boiling water over them in a large shallow brass bowl. (One of these twigs was identified as *Rubia* sp. by the Jodrell Laboratory, Royal Botanic Gardens. In reporting this identification, D F Cutler added that "woody material (usually the roots) of species of this genus is a source of the red dye alizarin. *Rubia tinctorium* (common madder) is a commercial source of the dye.) The liquid quickly assumed a red colour and the statuette was immersed in it and swirled around for about a minute. Dagyab must be alluding to the same process (1977, I:49) when he says that "there is another process by which gilded ... objects are further treated to enhance the golden colour and give the surface a warm reddish glow much prized by Tibetans. ... This is done by reheating the articles and then soaking them in a solution made from the bark of a tree".

The whole gilding operation from start to finish lasted about three hours.

Cold Gilding and the Application of Pigments

Among the 121 pieces of Tibetan and Himalayan metalwork which have been analysed, 32 have been painted with a gold paint on the faces and, in three instances, on other parts of the exposed flesh. In seven cases the figures are also fire-gilded and, in some of these at least, the gold paint has been applied over the fire-gilding on the face. (For details of the analyses see the catalogue descriptions of pp.103-109 below.)

Analysis has shown that the gold paint really does consist of powdered gold (rather than of an appropriately coloured copper alloy), but no investigations have been made of the binding medium. The preparation of gold paint is said to be a closely guarded secret (Lo Bue, above p.83) but the medieval western technical treatises are full of recipes for making inks containing powdered gold (e.g. Smith and Hawthorne, 1974; Levey, 1962).

Apart from fire-gilding and cold-gilding with gold paint, one other technique of gilding has been carried out on two or three of the pieces. Images of a Kālacakra, a Yama and a Lama (pp.103&105, nos.11, 16 and 49) have smooth burnished gilded surfaces which do not contain any mercury, but are too shiny to be the result of painting on the gold. It seems most probable that they have been gilded by laying gold leaf on the surface and burnishing it, with an occasional brief spell of annealing to prevent the gold becoming brittle (Oddy et al. in press).

Many of the images were painted, particularly on the back of the headdress with red pigment and on the hair with blue pigment. A selection of these pigments was analysed by X-ray diffraction, but there is no certainty that they are contemporary with the date of manufacture of the statuettes.

X-RAY DIFFRACTION ANALYSES OF PIGMENTS

Catalogue No. (on pp.103-109)	Registration No.	Probable date of image	Identification of pigment
RED PIGMENTS			
82	1952.11-1.1	14th century	red lead
109	1979.5-14.1	15th-16th century	red lead
59	1921.2-19.1	16th century	cinnabar
58	1910.11-18.1	16th-17th century	cinnabar
100	1961.2-17.2	17th century	cinnabar and red lead
76	1946.12-17.3	17th-18th century	cinnabar
81	1951.7-18.1	17th-18th century	red lead and cinnabar
52	1907.5-27.6	18th century	red lead
7	1880-157	18th century	red lead on hair, cinnabar on lips
112	W.413	18th century	red lead and calcite

6	1880-152	18th century	red lead
120		20th century	red lead
118		20th century	red lead

BLUE PIGMENTS

63	1922.12-15.2	12th century	azurite
105	1969.11-4.1	12th century	azurite
104	1968.12-16.1	14th century	azurite (mixed with amorphous black component)
109	1979.5-14.1	15th-16th century	azurite
59	1921.2-19.1	16th century	azurite
32	1905.5-19.4	16th-17th century	azurite
37	1905.5-19.10	16th-17th century	azurite
26	1893.3-20.140	17th-18th century	azurite
76	1946.12-17.3	17th-18th century	azurite
48	1906.12-26.41	18th century	azurite
7	1880-157	18th century	azurite
6	1880-152	18th century	gypsum and hauy-nite
41	1905.5-19.14	18th century	gypsum and hauy-nite

PINK (acutally a layer of pale grey on top of red)

3	1880-125	15th century or later	red lead

PINK PIGMENTS

120		20th century	zincite and un-identified com-ponent
118		20th century	zincite and un-identified com-ponent

WHITE PIGMENTS

120		20th century	zincite

BLACK AND BROWN PIGMENTS

120		20th century	zincite and un-identified com-ponent
118		20th century	zincite and un-identified com-ponent

Illustrated inventory of pieces analysed

The following inventory gives the serial number of the text references and the sequence of illustrations, the name of deity or object, provenance or attribution, date, technical description, donor, bibliography and museum accession number where applicable. Objects are deemed Tibetan unless stated otherwise. Technical descriptions are based on laboratory examinations only in respect of metal composition (but not inlays), gilding and the analysis of pigments. Otherwise they depend on visual observation. The use of the word stones may include glass. All dates (except of 91, 111, 115, 118, 120 and 121) are approximate.

1. Vajrasattva. 18th century A.D. Brass with gold paint on face. Ht. 11.8 cm. Given by Maj.-Gen. A.Meyrick. O.A. 1878.11-1.352.

2. Mahākāla. 18th century A.D. Brass fire gilt. Ht. 21 cm. O.A. 1880-124.

3. Yamāri and female partner. 15th century A.D. Copper base (no more sampled) fire gilt; black and pink (red lead) pigments on hair; some red paint elsewhere. Set with green and red stones. Made in several parts. Ht. 21.5 cm. O.A. 1880-125.

4. Tārā. 18th century A.D. Figure copper; base and surround brass. Made in several parts. Ht. 28.6 cm. O.A. 1880-126.

5. Lama. 18th-19th century A.D. Brass with red paint on back of base. Ht. 17.3 cm: O.A. 1880-142.

6. Vajradhara and female partner. 18th century A.D. Copper (detected by XRF) fire gilt; blue pigment (mixture of gypsum and hauynite) on hair; red pigment (red lead) behind crowns and draperies. Set with red and green stones; made in several parts. Ht. 14 cm. OA. 1880-152.

7. Yamāntaka and female partner. China (?). 18th century A.D. Brass with gold paint on face; red pigment (cinnabar) on lips; red pigment (red lead) on head; blue pigment (azurite) on head. Made in several parts. Ht. 16.5 cm. O.A. 1880-157.

8. Avalokiteśvara. 18th-19th century A.D. Copper. Made in several parts; flanking figures missing. Ht. 17.2 cm. O.A. 1880-158.

9. Buddha. 17th century A.D. Gun metal fire gilt with gold paint over gilding on face; blue pigment on hair. Probably single casting with added base-plate. Ht. 12.1 cm. O.A. 1880-159.

10. Amitāyus. 18th century A.D. Copper with gold paint on face; blue pigment on hair; red pigment on headdress. Traces of core material visible. Ht. 16.2 cm. O.A. 1880-160.

11. Kālacakra and female partner. 18th-19th century A.D. Brass probably gilt with heated and burnished gold leaf. Set with green and red stones; made in several parts. Ht. 18.4 cm. O.A. 1880-165.

12. Buddha. 18th-19th century A.D. Brass. Made in separate parts with figure and base perhaps not intended for each other. Ht. 15.2 cm. O.A. 1880-166.

13. Amitāyus. 17th-18th century A.D. Copper fire gilt. Cast in one piece and riveted to lost base. Ht. 14.7 cm. O.A. 1880-375.

14. Buddha ("Amitāyus"). Burma (Arakan). 17th century A.D. (?). Leaded bronze. Ht. 24.8 cm. From the collection of Hugh Nevill. O.A. 1880-4070.

15. Mañjuśrī. 18th century A.D. Brass fire gilt. Ht. 12 in. O.A. 1880-4071.

16. Yama and female partner. 18th-19th century A.D. Copper probably gilt with heated and burnished gold leaf. Red and green paint present. Made in several parts. Ht. 42 cm. O.A. 1880-4072.

17. Avalokiteśvara. 17th-18th century A.D. Brass. Made in at least three parts. Ht. 12.3 cm. O.A. 1885.12-27.19.

18. Buddha. 18th century A.D. Brass with gold paint on exposed 'flesh' and uṣṇīṣa; blue pigment on hair; red pigment on lips. Figure and base made separately, Ht. 16.5 cm. Given by Sir Alexander Cunningham. O.A. 1887.7-17.164.

19. Lama. 17th-18th century A.D. Copper fire gilt. Single casting. Ht. 9.5 cm. Given by Sir Alexander Cunningham. O.A. 1887.7-17.165.

20. Amitāyus (vase missing). 19th century A.D. Copper fire gilt with gold paint on face; blue pigment on hair; red pigment (red lead) on back of crown; red paint behind drapery. Ht. 18.4 cm. O.A. 1893.2-5.116.

21. Citipati. Collected in North China. 18th-19th century A.D. Brass silvered (no mercury detected); red pigment containing mercury (probably cinnabar) on base. Ht. with standard (khaṭvāṅga) 61.6 cm. O.A. 1893.3-20.5.

22. Karttrikā (ritual chopper), Collected in North China. 19th century A.D. Brass fire gilt. Ht. 17.5 cm. O.A. 1893.3-20. 110.

23. Amitāyus. Collected in North China. 17th century A.D. Copper fire gilt with gold paint over gilding on face; blue pigment on hair; red pigment on lips; white, red and black pigment on eyes. Vase of life set with blue stones. Ht. 18 cm. O.A. 1893.3-20.133.

24. Avalokiteśvara. Collected in North China. Late (18th century A.D. ?) imitation of Pāla type. Brass with silver inlay in lower garment. Ht. 16.5 cm. O.A. 1893.3-20.134.

25. Maitreya. Collected in North China. 18th century A.D. Copper fire gilt with traces of red pigment on back of base. Single casting; set with green and blue stones. Ht. 18.4 cm. O.A. 1893. 3-20.139.

26. Buddha. Collected in North China. 17th-18th century A.D. Brass fire gilt; blue pigment (azurite) on hair; red pigment on lips. Ht. 15.9 cm. O.A. 1893. 3-20.140.

27. Lama. Collected in North China. 19th century A.D. Brass fire gilt; blue pigment on hair; red pigment on lips. Single casting with separate base-plate. Ht. 14.3 cm. O.A. 1893.3-20.143.

28. Garuḍa (?). Collected in North China. 19th century A.D. Brass fire gilt. Figure, base and wings (?) made separately. Ht. 8.9 cm. O.A. 1893.3-20. 145.

29. Stupa (bKa'-gdams-pa type). Collected in North China. 12th century A.D. or later. Brass. Ht. 21 cm. O.A. 1893.3-20.149.

30. Guhyasamāja and female partner. Obtained in North China. 18th century A.D. Silver with fire gilt attributes (cast separately), crown and other ornaments. Ht. 15.2 cm. Given by W.M. Laffan. O.A. 1893.4-10.1.

31. Tārā. 18th century A.D. Brass with gold paint on face. Ht. 8.6 cm. Given by Sir A.W. Franks. O.A. 1894.7-27.45.

32. Padmapāṇi. 16th-17th century A.D. Brass with blue pigment (azurite) on hair; copper inlay. Ht. 38.3 cm. O.A. 1905.5-19.4.

33. Samantabhadra Bodhisattva (?). 18th-19th century A.D. Brass fire gilt with gold paint over gilding on face; blue pigment on hair. Made in several parts; set with green stones. Ht. 20.3 cm. O.A. 1905.5-19.5.

34. Ratnasambhava. 16th century A.D. Brass with black paint on hair; set with green stones. Ht. 22.8 cm. O.A 1905.5-19.6.

35. Avalokiteśvara. From Lhasa. 16th century A.D. Brass with gold paint on face and blue pigment on hair; copper and silver inlays; set with red and blue stones. Probably single casting with separate base-plate. Ht. 14.3 cm. O.A. 1905.5-19.7.

36. Tārā. 17th century A.D. Brass with remains of blue pigment on hair. Ht. 13 cm. O.A. 1905.5-19.8.

37. Buddha. 16th-17th century A.D. Copper with gold paint on face; blue pigment (mainly azurite) on hair. Probably single casting; set with green and red stones. Ht. 17.8 cm. O.A. 1905.5-19.10.

38. Ḍākinī. 17th century A.D. Copper figure and brass base. Inlaid with silver and set with green stone and bone (?) in earrings. Ht. 16.5 cm. O.A. 1905.5-19.11.

39. Buddha. From Lhasa. 17th century A.D. Brass with dark pigment on hair. Ht. 12.7 cm. O.A. 1905.5-19.12.

40. Maitreya. From Lhasa. 18th-19th century A.D. Gun metal with blue pigment on hair. Ht. 9.5 cm. O.A. 1905.5-19.13.

41. Buddha. From Lhasa. 18th century A.D. Brass with traces of gold paint on face; blue pigment (gypsum and hauynite) on hair; red pigment on lips; white and red pigment on eyes. Ht. 8.9 cm. O.A. 1905.5-19.14.

42. Mañjuśrī. Western Tibet. 11th-12th century A.D. Brass image and arsenical copper base. Ht. 12.5 cm. Pub.: von Schroeder, 1981. O.A. 1905.5-19.15.

43 Tārā. Perhaps from Lhasa. 18-19th century A.D. Brass with gold paint on face; red pigment on lips; white, red and black pigment on eyes. Ht. 10.8 cm. O.A. 1905.5-19.16.

44. Figure holding ghantā (bell). 14th century A.D. Copper fire gilt. Ht. 10.2 cm. 1905.5-19.18.

45. Stūpa (bKa'-gdams-pa type). 12th century A.D. or later. Brass. Ht. 55.8 cm. O.A. 1905.5-19.20.

46. Stūpa. 17th century A.D. Copper fire gilt; set with green stones. Ht. 16.2 cm. 1905.5-19.21.

47. Pair of cymbals. From dPal-'khor-chos-sde monastery, Gyantse. 19th century A.D. Bell metal; joined by leather cord and metal chain. Diameter 6.8 cm. O.A. 1905.5-19.133.

48. Vajrasattva. 18th century A.D. Brass with gold paint on face; blue pigment (azurite) and sandy yellow pigment on hair. Set with red and blue stones and mother of pearl (?). Figure and base made separately. Ht. 44.5 cm. O.A. 1906.12-26.41.

49. Lama. From Peking. 18-19th century A.D. Brass with cold gilding on face (no mercury detected). Ht. 17.3 cm. O.A. 1907.5-27.1

50. Tārā. From Peking. 18th-19th century A.D. Brass fire gilt and with traces of red pigment behind crown. Ht. 17.2 cm. O.A. 1907.5-27.2.

51. Tārā. From Peking. 18th century A.D. Brass fire gilt and with traces of red pigment behind crown. Ht. 16.9 cm. O.A. 1907.5-27.3.

52. Dhvajāgrakeyūra. From Peking. 18th century A.D. Brass with gold paint on face and hands; red pigment (mixture with red lead) on headdress. Ht. 8.9 cm. O.A. 1907.5-27.6

53. Dhṛtarāṣṭra. From Lhasa. 18th century A.D. Copper fire gilt. Base and figure made separately. Ht. 20 cm. O.A. 1908.4-21.2

54. Vajrapāṇi. From Lhasa. 17th century A.D. Copper with gold paint on face; blue pigment on hair; red pigment on hair and face. Ht. 22.6 cm. O.A. 1908.4-21.3

55. Mahācakra Vajrapāṇi (?) with upper part of female partner missing. Collected in China. 18th century A.D. Brass; made in several parts. Ht. 16.5 cm. Given by Mrs Brooke. O.A. 1909.8-2.4.

56. Amoghasiddhi. Collected in China. 16th-17th century A.D. Brass with black paint on headdress and set with one green stone. Ht. 16.2 cm. Given by Mrs Brooke. O.A. 1909.8-2.5.

57. Buddha. Collected in China. 16th-17th century A.D. Brass. Ht. 13 cm. Given by Mrs Brooke. O.A. 1909.8-2.6.

58. Vajrapāṇi. 16th-17th century A.D. Brass with gold paint on face; red pigment on hair is probably cinnabar (contains mercury). Ht. 12.4 cm. O.A. 1910.11-18.1.

59. Samvara and female partner. Nepal (?). 16th century A.D. Copper fire gilt with red pigment (cinnabar) on base; blue pigment (azurite) on hair. Made in at least two parts; set with green and blue stones. Ht. 26.7 cm. Given by Louis King. Pub.: Pal, 1974: 157-8; pl. 281. O.A. 1921.2-19.1.

60. Sarvabuddha Ḍākinī. 18th-19th century A.D. Copper figure and brass base with gold paint on face; red pigment on hair; white, red and black pigment on eyes. Apron, necklaces, etc. of detachable silver wire set with green stones. Figure and base made separately, Ht. 21.6 cm. Given by Louis King. O.A. 1921.2-19.3.

61. Buddha (Bhaiṣajyaguru). 18th century A.D. Brass fire gilt on robes and base; blue pigment on hair. Single casting with separate base-plate. Ht. 16.9 cm. Given by Louis King. O.A. 1921. 2-19.5.

62. Hevajra and female partner. From Tatsienlu. 17th century A.D. Brass fire gilt with traces of red pigment on hair. Ht. 15.2 cm. O.A. 1921.2-19.6.

63. Buddha and Bodhisattvas. Western Tibet. 12th century A.D. Brass with blue pigment (azurite) on hair. Ht. 10.5 cm. Pub.: von Schroeder, 1981. O.A. 1922. 12-15.2.

64. Vajrasattva. Western Tibet. 12th-15th century A.D. Brass. Ht. 19 cm. Pub.: Béguin, 1977: no. 42. O.A. 1922.12-15. ·3.

65. Uṣṇīṣavijaya. 18th-19th century A.D. Copper fire gilt with gold paint over gilding on face; blue pigment on hair; red pigment on lips; red, white and black pigment on eyes; red paint behind drapery. Set with green stones. Ht. 15.9 cm. O.A. 1922.12-15.5.

66. Maitreya (?). 18th-19th century A.D. Brass with red pigment on lips; imitation gold paint on front of figure. Ht. 8.6 cm. O.A. 1924.6-20.10.

67. Padmasambhava. Nepal (?). 19th century A.D.Brass. Ht. 10.5 cm. Given by Mrs A.E. Pool. O.A. 1929.4-10.2.

68. Tārā. Nepal (?). Collected in "Little Tibet". 18th-19th century A.D. Brass fire gilt with red paint on back of figure; set with green stones. Figure and base made separately. Ht. 16.5 cm. GIven by Miss E.F. Paske and Major E.L. Paske. O.A. 1931.6-9.14.

69. Holy water vessel (?). 19th-20th century A.D. Brass. Length 15.2 cm. Given by Sir Charles Bell. O.A. 1933.5-8.1.

70. Phur-bu (ritual dagger). 19th-20th century A.D. Brass handle and iron blade. Length 20.3 cm. Given by Sir Charles Bell. O.A. 1933.5-8.2.

71. Rāhula. 18th century A.D. Copper fire gilt. Base and figure made separately and riveted together. Ht. 17.2 cm. Bequeathed by Col. H. Wood. O.A. 1940. 4-15.1.

72. Padmasambhava. 18th century A.D. Copper figure and brass base fire gilt at the front only; made in several parts, many riveted together. Ht. 38.1 cm. Given by C.A.W. Oldham from the estate of Lady Holmwood. O.A. 1942.4-16.1.

73. Avalokiteśvara. 17th century A.D. Brass fire gilt with blue pigment on hair; set with red, blue and green stones. Single casting. Ht. 20.6 cm. Given by C.A.W. Oldham from the estate of Lady Holmwood. O.A. 1942.4-16.2.

74. Altar lion (?). From Lhasa. 19th-20th century A.D. Ht. 20.3 cm. Given by Miss M.L. Hall. O.A. 1942.11-14.4.

75. Lama. 17th-18th century A.D. Brass with remains of fire gilding. Figure and base cast separately. Ht. 14.6 cm. Bequeathed by Sir Charles Bell. O.A. 1946.12-17.1.

76. Tārā. 17th-18th century A.D. Brass with gold paint on face; blue pigment (azurite mixture) on hair; red pigment (cinnabar) on headdress. Probably single casting. Ht. 14.9 cm. Bequeathed by Sir Charles Bell. O.A. 1946.12-17.3.

77. Vajrasattva. Nepal (?). 17th-18th century A.D Brass with gold paint on face, hands and feet; blue pigment on hair. Made in several parts. Ht. 28 cm. O.A. 1947.7-15.1.

78. Phur-bu (ritual dagger). 18th century A.D. Copper handle with silver inlay and iron blade. Length 38.4 cm. Given by H.G. Beasley. O.A. 1948.7-16.2.

79. Vajra (thunderbolt symbol). 19th-20th century A.D. Brass fire gilt. Length 17.8 cm. Given by H.G. Beasley, O.A. 1948.7-16.11a.

80. Ghaṇṭā (bell). 19th-20th century A.D. Handle: brass fire gilt; bell: bell metal. Ht. 22.6 cm. Given by H.G. Beasley. O.A. 1948.7-16.11b.

81. Maitreya. 17th-18th century A.D. Copper fire gilt with blue pigment on hair; red pigment (cinnabar and red lead) on back of headdress. Single casting. Ht. 18.1 cm. O.A. 1951.7-18.1.

82. Jambhala. 14th century A.D. Brass with red pigment (red lead) on hair. Ht. 16.2 cm. Given by Mrs H.G. Beasley. Pub.: Pal, 1974: 157; pl. 280. O.A. 1952.11-1. 1.

83. Vajrasattva. 16th century A.D. Brass with gold paint on face; blue pigment on hair. Ht. 17.8 cm. Given by Mrs H.G. Beasley. O.A. 1952.11-1.3.

84. Vajrapāṇi. 16th-17th century A.D. Brass. Ht. 20 cm. Given by Mrs H.G. Beasley. O.A. 1952.11-1.4.

85. Padmasambhava. Nepal (?). 19th century A.D. Brass. Ht. 24.2 cm. Given by Mrs H.G. Beasley. O.A. 1952.11-1.5.

86. Yama. 19th century A.D. Brass fire gilt; red pigment in hair. Cast in at least three parts. Ht. 25 cm. Given by Mrs H.G. Beasley. O.A. 1952.11-1.6.

87. Monk. 18th century A.D. Brass fire gilt with red paint on lips and bowl; black paint on hair. Figure, base and probably bowl separately cast. Ht. 14.3 cm. Given by Mrs H.G. Beasley. O.A. 1952.11-1.7.

88. Aṅgaja. 18th century A.D. Brass with remains of fire gilding. Single casting. Ht. 13.7 cm. Given by Mrs H.G. Beasley. O.A. 1952.11-1.8.

89. Vajradhara. 18th century A.D. Brass with gold paint on body; blue pigment on hair. Ht. 11.5 cm. Given by Dr W.L. Hildburgh. O.A. 1953.7-13.2.

90. Vajrasattva. 18th century A.D. Brass. Ht. 11.7 cm. Given by Dr W.L. Hildburgh. O.A. 1953.7-13.3.

91. Mañjuśrī. China. Mark and period of Yongle (A.D. 1403-24). Brass fire gilt with gold paint on a prepared surface at the back of the crown. Ht. 19 cm. Given by Dr W.L. Hildburgh. Pub.: Béguin, 1977: no. 64. O.A. 1953.7-13.4.

92. Maitreya. 17th century A.D. Bronze with gold paint on face; blue pigment on hair. Probably single casting. Ht. 10.8 cm. Given by Dr W.L. Hildburgh. O.A. 1953.7-13.6.

93. Abheda. 18th century A.D. Gun metal. Ht. 15.9 cm. Given by Mrs H.G. Beasley. O.A. 1954.2-22.2.

94. Gopaka. 18th century A.D. Brass. Ht. 15.5 cm. Given by Mrs H.G. Beasley. O.A. 1954.2-22.3.

95. Avalokiteśvara. 12th century A.D. Copper with traces of gold (no mercury detected) on face. Ht. 11.5 cm. O.A. 1954.7-14.1.

96. Tārā. Nepal. 17th century A.D. Brass fire gilt and set with green stone. Ht. 11.5 cm. Given by P.T. Brooke Sewell. O.A. 1956.7-21.1.

97. Maitreya (?). 17th century A.D. Brass with gold paint on face and blue (?) pigment on hair. Set with red and green stones; inlaid with copper. Chaplets and core material visible inside. Ht. 35 cm. Given by Dr Lydeard Wilson. O.A. 1957.2-13.1.

98. Maitreya. 16th century A.D. Brass with silver and copper inlays. Ht. 19 cm. Bought from the Brooke Sewell Fund. Pub.: Béguin, 1977: no. 153. O.A. 1959.10-16.2.

99. Buddha. 17th century A.D. Gun metal fire gilt. Ht. 7.6 cm. Given by Mrs E.M. Cox. O.A. 1959.11-18.2.

100. Tārā. Nepal. 17th century A.D. Brass with traces of fire gilding; traces of red pigment (cinnabar with red lead added later) on base and behind headdress; blue pigment on hair. Inlaid with copper and set with green stones. Ht. 12.5 cm. O.A. 1961.2-17.2.

101. Amitāyus. 18th century A.D. Brass with pseudo-gilding (a golden pigment) above gold leaf over mercuric sulphide (SEM file 256); blue pigment on hair. Figure and base made separately. Ht. 14.5 cm. Given by the Church Missionary Society, London. O.A. 1963. 11-11.3.

102. Avalokiteśvara. Eastern India. 12th century A.D. (or Tibetan copy?). Brass. Set with green stones. Ht. 26.2 cm. Bought from the Brooke Sewell Fund. O.A. 1965.2-25.2.

103. Amitāyus. 16th-17th century A.D. Brass fire gilt with gold paint over gilding on face; blue pigment on hair. Set with blue and green stones. Figure, base and vase perhaps made separately. Ht. 23.5 cm. Given by Dr E.G. Miller. O.A. 1966.10-15.1.

104. Mañjuśrī. 14th century A.D. or later. Copper figure and brass base; gold paint on face; blue pigment (azurite mixed with amorphous black component) on hair. Gold inlays. Figure riveted to base. Ht. 14.2 cm. Bought from the Brooke Sewell Fund. Pub.: Béguin, 1977: no. 219. O.A. 1968.12-16.1.

105. Śiva and Pārvatī. Eastern India. 12th century A.D. (or Tibetan copy? Inscribed De-mo li-ma). Brass with gold paint on face; blue pigment (azurite) on hair. Cast in at least two parts. Ht. 20.3 cm. Bought from the Brooke Sewell Fund. Béguin, 1977: no. 11. O.A. 1969.11-4.1.

106. Avalokiteśvara. Eastern India or South Tibet (?). 12th century A.D. Brass inlaid with silver and copper. Ht. 10.2 cm. Pub.: Béguin, 1977: no. 8 O.A. 1971.5-17.2.

107. Mañjuśrī. Eastern India or South Tibet (?). 12th century A.D. Brass inlaid with silver and copper; set with green stones. Ht. 11.5 cm. Bought from the Brooke Sewell Fund. Pub.: Beguin, 1977: no. 12. O.A. 1973.5-14.2.

108. Samvara. Eastern India or South Tibet (?). 12th century A.D. Brass inlaid with silver and copper. Ht. 14.6 cm. Bought in part from the Brooke Sewell Fund. O.A. 1976.9-27.1.

109. Vajradhara. 15th-16th century A.D. Brass with gold paint on face; blue pigment (azurite) on hair; red pigment (red lead) on headdress. Inlaid with silver and copper. Probably single casting. Ht. 24.2 cm. Bought from the Brooke Sewell Bequest. O.A. 1979.5-14.1.

110. Lama, perhaps Phyogs-las rnam-rgyal of Bo-dong (A.D. 1306-1386?). 15th century A.D. Brass inlaid with silver and copper. Cast in three parts, not necessarily at the same time. Ht. 35.5 cm. Bought from the Brooke-Sewell Fund. O.A. 1979.7-26.1.

111. Yāmantaka and female partner. Said to be from a temple in Peking; inscribed in Chinese and dated to A.D. 1811. Brass (analysed by XRF) fire gilt with red and blue pigments on headdress. Made in many parts, some cast but mainly in hammered sheet metal. Ht. 49 cm. Given by George Witt (1865). O.A. W.412.

112. Kṛṣṇāri Vajrabhairava. China (?). 18th century A.D. Brass with gold paint on faces; traces of pink pigment (mixture of red lead and calcite) on headdress. Single casting. Ht. 15.5 cm. Given by George Witt (1865). O.A. W.413.

113. Simhavaktrā. 18th century A.D. Brass. Ht. 13 cm. Given by George Witt (1865). O.A. W.415.

114. Klong-chen (fl. 14th century A.D). Nepal. c. A.D. 1958. Brass. Ht. 11 cm. Private collection (now deposited at the Victoria and Albert Museum, London).

115. Tārā. Nepal. A.D. 1973. Leaded gun metal. Ht. 7.5 cm. Private collection (now deposited at the Victoria and Albert Museum, London).

116. Dīpamkara. Nepal. c. A.D. 1970. Copper figure inlaid with silver; brass base. Figure modelled by Jagat Man Sakya, chased and inlaid by Siddhi Raj Sakya; base by Rajesh Kumar. Ht. 26 cm. Aniko Collection (now deposited at the Victoria and Albert Museum, London).

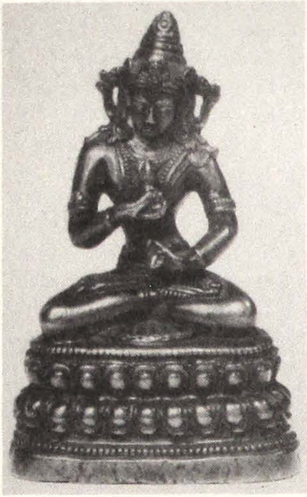
117. Vajradhara. Nepal. c. A.D. 1968. Copper. Modelled by Babu Kaji Vajracarya; engraved by Rudra Bahadur Sakya. Ht. 18.5 cm. Aniko collection (now deposited at the Victoria and Albert Museum, London).

118. Yamāntaka. Nepal. A.D. 1974. Copper fire gilt; with red (red lead), pink (zincite and unidentified component) and black and brown (zincite and unidentified component) pigments. Modelled by Dambar Sakya and chased by Kem Raj Sakya. Ht. 23 cm. Private collection (now deposited at the Victoria and Albert Museum, London).

119. Viṣṇu Vaikuṇṭha. Nepal. c. A.D. 1971. Copper inlaid with silver, Modelled by Nhuche Raj Sakya with Earth Goddess added in 1978 by Rajesh Kuma. Ht. 55 cm. Aniko Collection (now deposited at the Victoria and Albert Museum, London).

120. Varāha. Nepal. A.D. 1974. Brass fire gilt; with red (red lead), pink (zincite and unidentified component) and black and brown (zincite and unidentified component) pigments; set with stones. Modelled by Santa Kumar Sakya. Ht. 28 cm. Private collection (now deposited at the Victoria and Albert Museum, London).

121. Tārā. Nepal. A.D. 1975. Brass. Modelled by Babu Kaji Vajracarya; engraved by Rudra Bahadur Sakya. Ht. 16.5 cm. Victoria and Albert Museum. I.S. 21-1980.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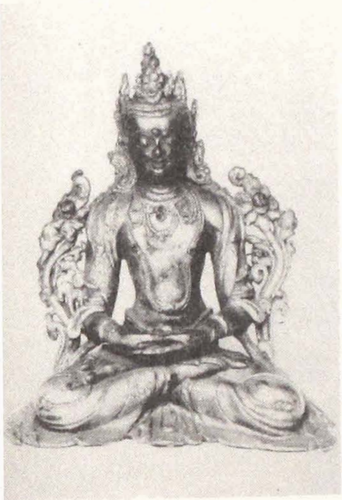
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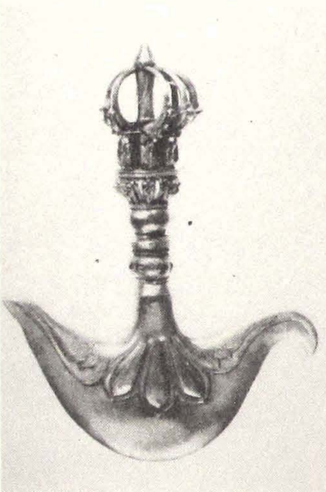

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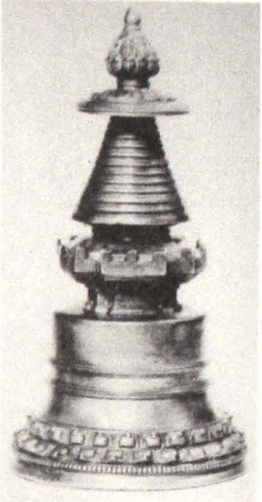

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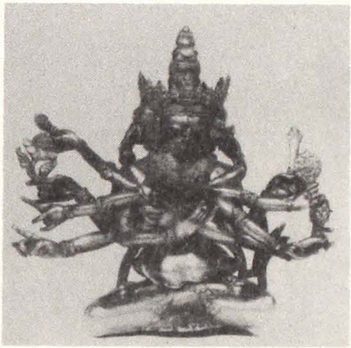

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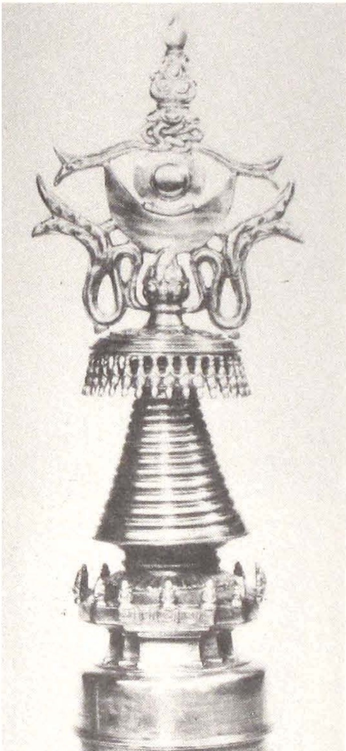

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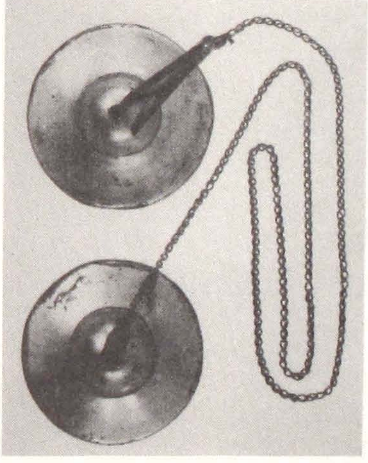

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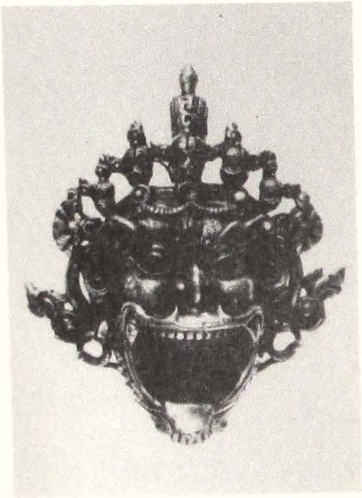
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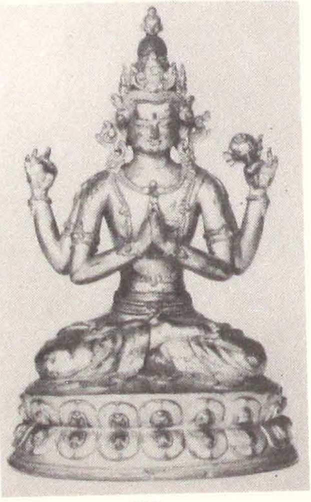
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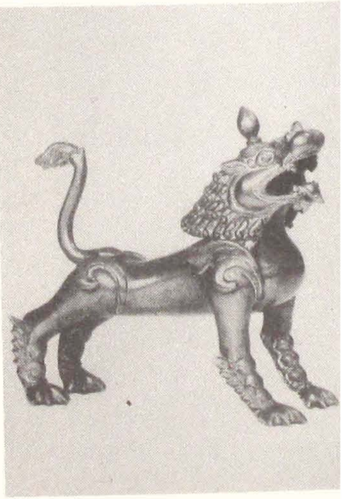
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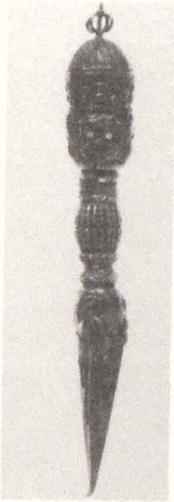
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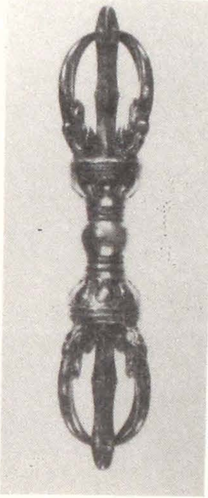
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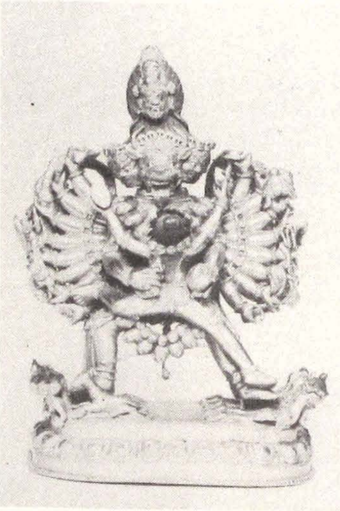

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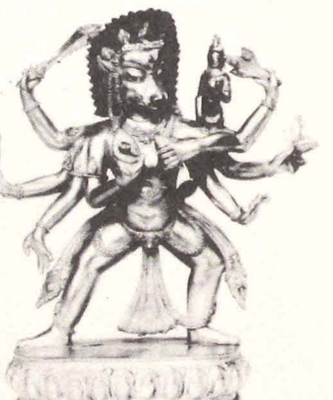

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