A RECONSIDERATION OF THE IBERIAN BACKGROUND TO BEAKER METALLURGY

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INTRODUCTION

Copper and gold metallurgy has been recognized as a feature of Iberian Beaker groups since Carthailac first published some of the Portuguese Beakers from Palmela in 1886. Shortly afterwards the construction of a road at Ciempozuelos, just south of Madrid, revealed and destroyed several rock-cut tombs and their now eponymous Beakers (Riaño *et. al.* 1894). In both instances, well preserved copper tools and weapons were associated with the pottery, and since then there has not been serious doubt that Beakers and copper metallurgy were intimately connected. Consideration of the relationship has normally been confined to broad statements deriving Beaker metallurgy from the older traditions in the south and west of the peninsula, becoming a tenet in the classic works of Bosch Gimpera (1915; 1926; 1940), and allowing Castillo (1947: 709) to say that "metal and Bell Beakers are two elements of the same phenomenon.". The argument ran that Beaker pottery was a lineal descendent from the EN – MN pottery found in various Andalucian caves, and that subsequent expansion by the pastoralist Beaker groups brought them into contact with the Almerían and Millaran cultures, from whom they acquired their metallurgical skills (op. cit.; Muñoz 1970).

The idea has become widely accepted since first being made over fifty years ago, and it seems an appropriate moment on the eightieth anniversary of the discovery of the first Bell Beakers in Spain, to reconsider some aspects of Beaker metallurgy.

The problem is whether there is any discernable technological distinction between pre-Beaker and Beaker metallurgical industries particularly around the Tagus estuary in Portugal. The raw data are the trace element analyses taken from the monumental volumes of Junghans, Schröder and Sangmeister (1960; 1968; afterwards abbreviated to SAM 1, 2) who continue the traditions of chemical investigation pioneered by Siret (1913). The conclusions of this paper are at variance with those proposed by the authors of SAM, but it is entirely due to their tireless publication of such a mass of material that we can approach the problem at all. It is not intended to discuss many points relating to typology, nor to provide a catalogue of Beaker metalwork in the peninsula: these are to be discussed more fully in a forthcoming work on the entire Iberian Beaker problem. More interesting is to see the degree to which observed variations can be accounted for by reference to specific regions, sites, phases (or cultures), and metal types.

NATURE OF THE DATA

The SAM analyses

The elegant commentary and critique by Waterbolk and Butler (1965) clearly isolated the main areas of disagreement; the metallurgical questions concerning the adequacy and reliability of the analyses, and their clustering and interpretation.

The SAM programmes were initially designed to determine the provenance of eneolithic and EBA metals whose composition was less likely to have been affected by alloying re-smelting of scrap or addition of new ore, than the later MBA and LBA metals. But questions of provenance are not the only ones that can be phrased, as McKerrell and Tylecote (1972) showed by demonstrating how intentional control of the arsenic content can account for consistent variations between North British halberd blades and their rivets.

Another SAM assumption was the presumed lack of scrap metal in the eneolithic and EBA. This is belied in Portugal where large amounts of scrap copper and broken fragments of axes, saws and casting droplets are a consistent feature of Vila Nova de São Pedro (VNSP) metallurgy, occurring in large quantities at Vila Nova, Zambujal, Penha Verde, Castro da Ota and Rotura. At least half of the VNSP analyses are from scrap or waste pieces, and there is no indication that these were simply thrown aside and not reused. After all, with the complete range of tools, weapons, crucibles, slags, 13½ kgs. of limonite ore and a stone mould all from Vila Nova itself (Jalhay and do Paço, 1945), it would be very odd if old metal and casting waste were not valued and husbanded for reuse.

The main metallurgical questions centre on the degree to which a single SAM analysis accurately represents the composition of the whole object, and whether the recorded trace elements are evenly distributed so as to determine provenance or group allocation. The papers by Slater and Charles (1970; 1973), McKerrell and Tylecote (1972) and Charles (1973) all concluded that the uneven distribution of trace elements caused by segregation during cooling of the hot metal and the differential oxidation of certain other trace elements during roasting and smelting, made the refined parameters of SAM groups impractical. Unless multiple samples were taken from each object, neither the structure nor the composition could be determined to the degree of precision required to support the SAM clusterings. In discussing the question of heterogeneity in metals, Charles concluded (1973; 114):

"...in normal casting there is the liklihood, almost the certainity, of a substantial variation in chemical composition from point to point on a scale which is going to influence samples for chemical analysis. ... For most elements this variation will remain in the metal, even if it is subsequently worked to a different shape ... Where high levels of accuracy are required in analyses, multi-position sampling is an essential feature for metal objects. Where this is not possible, as applies to most archaeological contexts, then the existance of variance must be assumed, particularly where the elements concerned give phase relationships with large temperature ranges for freezing. In this case we can only use a single sample as an indication of the level of major alloying elements, and the presence of specific impurities. There is, however, great danger in trying to type materials in terms of small differences in impurity contents without multiple sampling."

But making allowances for all these factors and error sources, the great number of analyses invite further study. The logarithmic graphs of Waterbolk and Butler (1965) were claimed to have an 80% chance of accurately reflecting groupings within the data provided that at least 20 analyses were in each graph. Presumably the more analyses are included, the higher the degree of reliability.

All the analyses were originally grouped by a statistical procedure designed by Klein (1953), but the logarithmic charts cluster data far more reliably since specific archaeological questions can be asked and answered. In any case, the charts make all the data visible in such a way that skewed or normal distributions are quickly appreciated, and aberrant analyses (perhaps caused by some of the factors mentioned above) usually fall within the limits of the normal distribution without seriously distorting the cluster. In a system of analyses with so many sources of potential error, allowance must be made for the extreme variants, otherwise there is an endless proliferation of tiny metal groups, almost certainly without much reality.

Both Case (1966) and Coles (1969) recognised that the "very low" bracket for analyses (0.001%) fell outside the accurate range of trace element detection, and accordingly omited it. Similarly modified logarithmic charts are used here to regroup the SAM analyses.

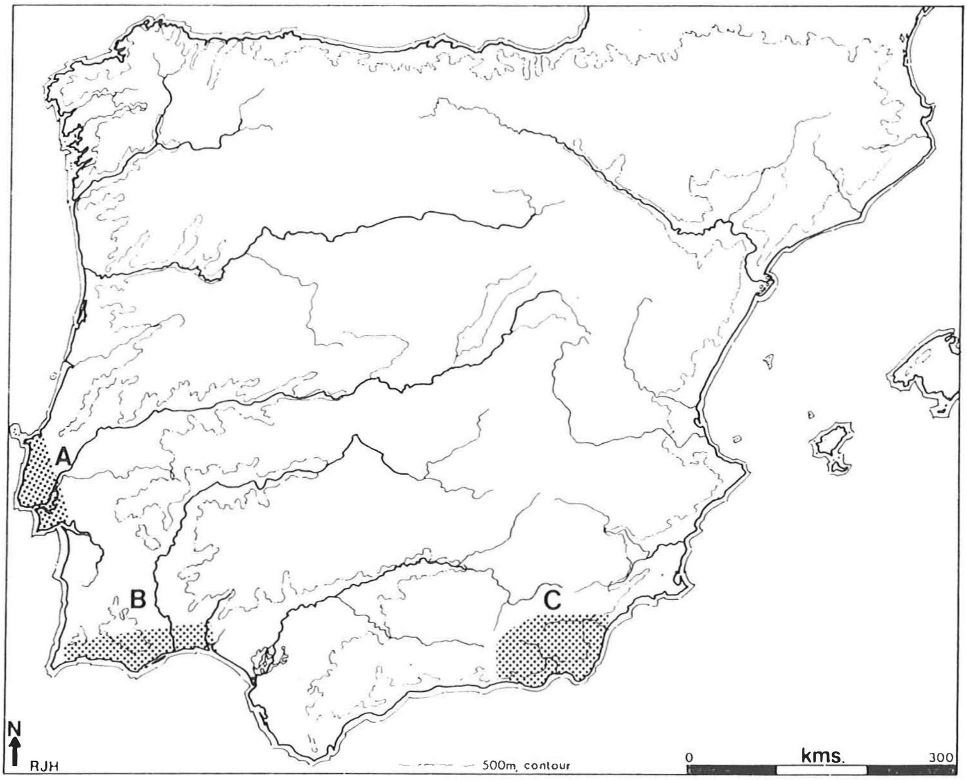
Multivariate analysis

The attractive multivariate analysis programmes used by Hodson (1969; 1970) distinguished between widely separated metal groups in Iberia, the Balkans, Southern Germany, etc. which are clearly dissimilar, but they were less successful when applied to a sample of 95 SAM 1 analyses from the eneolithic – EBA of Portugal.

Average Link Cluster Analysis programmes work from a correlation coefficient matrix where all the variety within each analysis is individually expressed as a single number, usually on a scale from 0-200. (Robinson, 1951; Sokal and Sneath, 1963) The main problem was the pronounced skewing of the coefficients by the preponderance of zero percentages of trace elements, which bulked all the coefficients within a bracket of 165-200 on a 200 point scale; ie. indicating that all the analyses had a great deal in common with each other, since each analysis had at least half of its trace elements represented by zero. There was more similarity then difference observed because the programme gave the same value to the absence of a trace element as to its presence. Even after the elimination of the zero percentages, there was still very little differentiation among the coefficients (138-200). The only way to achieve a sufficiently wide range of coefficient values was to weigth the value of the trace elements; ie. make tin twice as important for determing groups as iron. This is a slippery procedure because it is impossible to justify the various weightings sufficiently closely, which would result in manipulation of the analyses to conform to the desired – or expected – groupings. For instance, unless we can state exactly why tin should be twice valuable for determing cluster parameters than iron, why should tin not be weighted 1.7 or 2.3 or even 10 times more (or less) critically? The result is circularity of argument. Since interesting variations can be identified by the simpler logarithmic groups, they have been retained rather than making an attempt to regroup the material by cluster analysis techniques.

ARCHAEOLOGICAL SETTING

It is widely recognised that over much of Europe the appearance of Beaker pottery coincides with the introduction of a true complex of metallurgical skills, and not merely the occasional import of copper objects. Case (1966) suggested that the "impact phase" responsible for so many of the flat copper axes in Ireland was of Beaker inspiration, and the series of cushion stones associated with the Veluwe Beakers in the Netherlands show copper was worked there (Butler and van der Waals, 1966). Now it is obvious that the tradition is an acquired one since Beakers and large scale copper working arrived simultaneously in both areas where they were previously unknown. There are only two areas where such a metallurgical complex could reasonably have been derived; Central Europe, and southern Iberia. In each region comparable pre-Beaker metallurgical industries had long flourished, and both areas have dense Beaker concentrations. Detailed arguments have been made only for the Central European end of the question, where Hájek (1966) indicated how Beaker tanged daggers in Czechoslovakia could be traced back to older Baden models. The general picture has not been altered by the recent recognition of pre-Beaker metal in S. W. France, since the amount of metal is infinitesimal, and can hardly be compared to the other two zones (Constantini 1970). The latest count by Constantini lists 10 small objects. Nor are there any reliable signs that metallurgy



Map 1.
Pre-Beaker Metal Industries in Iberia.
A. Tagus Estuary
B. Algarve – Huelva
C. Almería

was understood or practised in Cataluña before the appearance of the Bell Beakers. Therefore, to appreciate the development of Iberian Beaker metallurgy we must briefly look at the preceding traditions in the same area.

Iberia: pre-Beaker metallurgy

Pre-Beaker metallurgy flourished in the Algarve-Huelva region, South East Spain, and the Tagus estuary (Blance, 1971) (Map 1). The Algarve-Huelva group with the famous ribbed daggers from the Alcalá tombs is the smallest, but since Beakers are conspicuously absent from almost the whole region, it is of interest to us only for comparative purposes. But for S.E. Spain and especially around the lower Tagus, the industries have a richer and more varied aspect, producing awls, fish-hooks, flat axes of various sizes, saws, straight and curved

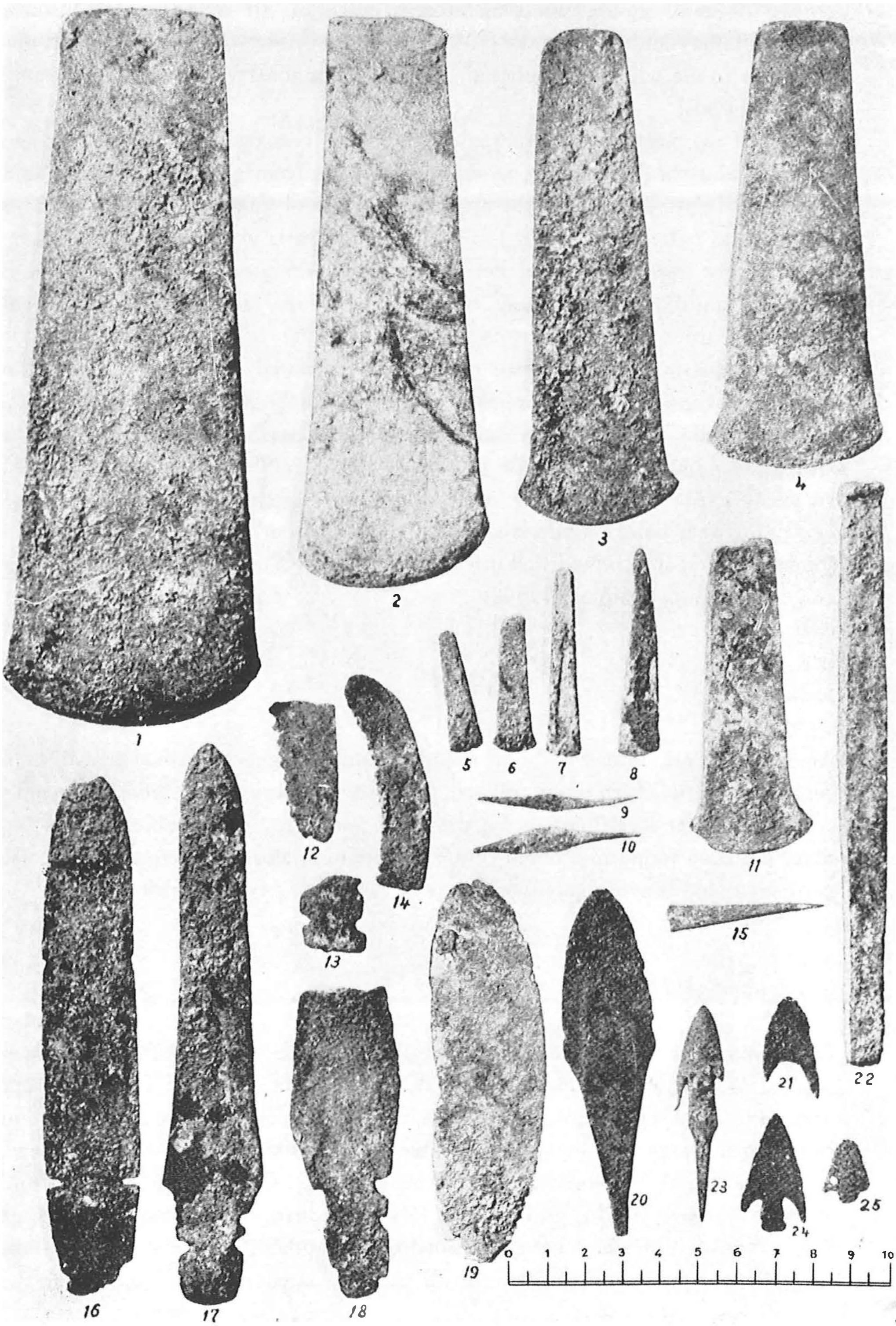


Fig. 1. Copper tools and weapons from Vila Nova de São Pedro, Portugal (After Jalhay and do Paço, 1945: Lam. XVII)

knives, daggers, chisels, scrap metal and crucibles, all found where Beakers abound (Jalhay and do Paço, 1945. Lám. XVII; our Fig. 1). There is a good opportunity to see whether functional, spatial or temporal variation exists among these materials.

Most of the metal from S. E. Spain comes from cemeteries excavated long ago by Siret, and we do not have as many specimens from any one site as around the lower Tagus. As a result the available number of analysed copper objects is smaller, less balanced between funerary and domestic assemblages, and is correspondingly less informative. For instance, no Almerían or Millaran site has produced anything approaching the number of analysed copper items from VNSP or Fórnea/Penedo. Some copper awls from the rock-cut tomb of Loma de los Peregrinos in Murcia (Nieto, 1959) were associated with "early" Almerían pottery which suggests that copper working was known in the S.E. from the 4th. Millennium B.C., substantially before the Los Millares and VNSP floruit. The much larger question of the rise of Millaran (and VNSP) metallurgy has been variously explained as due to local innovation (Bosch Gimpera, 1915; Veiga Ferreira, 1970; Schuchhardt, 1921), to colonists from the East Mediterranean (Blance, 1971), and to modified diffusion from the Near East in general (Leisner and Leisner, 1943; Savory, 1968).

Silver

At Almizaraque, Almería, Siret found abundant signs of Almerían-Millaran copper working, with slags, ingots, crucibles and ores, but Bosch-Gimpera's claims for silver metallurgy being practiced are highly improbable, (1935). No silver has been found in a dated context in Spain or Portugal before the Argaric period, nor has it been unequivocally associated with any Bell Beaker.

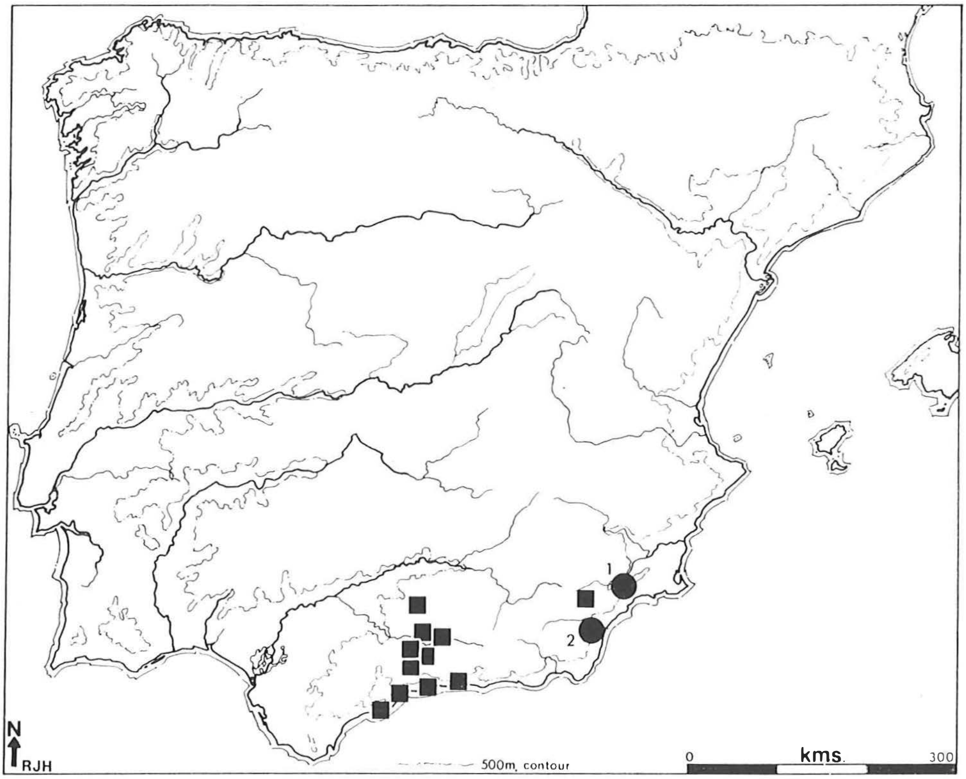
Copper and gold

Our perspective of the pre-Beaker metallurgy in the Tagus estuary is broader because we fortunately have several hundred pieces of metal from funerary sites, caves, and settlements. In addition, the military architecture and proficient copper metallurgy can be seen associated at such sites as Vila Nova (Savory, 1970), Zambujal (Sangmeister and Schubart, 1965), Olelas (Cunha Serrão and Prescott Vicente, 1958), and Rotura (Veiga Ferreira and Carlos Tavares da Silva, 1970), all of which have published stratigraphies. Copper appears to have been the only metal worked, since all the associated finds of gold occur for the first time with Beakers, with a few possible exceptions. A nail-headed gold pin was recovered from a mixed VNSP-Beaker deposit at Penha Verde (Zbyszewski and Veiga Ferreira, 1958). Now pins of this sort are presumed to have been used as dress fastenings, and they have a long ancestry in the Tagus region. Professor Sangmeister observed (1966) that such pins were characteristic only in pre-Beaker times, and that with the appearance of Beaker pottery the preferred dress fastenings became buttons and toggles rather than pins. In this instance, it may well be that the Penha Verde pin represents an instance of VNSP gold working. The other two finds are more doubtful, being a piece of gold foil from Tomb 4 at Alcalá (Leisner and Leisner, 1943; Taf. 80 fig. 23), and from Matarubilla, near Seville, there are numerous tiny shreds of gold foil. (Collantes de Terán, 1969)

Alluvial gold is known to occur in the Guadiana river gravels, but whether or not these uncertainly associated gold pieces are of pre-Beaker date is questionable. In any case, the point of immediate concern is that accomplished copper metallurgy was practised in S.E. Spain and around the Tagus estuary in the 3rd. Millennium B.C. and that it is definitely much older than the Beaker materials found there.

Relationship of Beaker metallurgy to Millaran and VNSP industries

In spite of the well-known links between the Millaran and VNSP complexes (Blance, 1971), the relationship of the Bell Beaker pottery – and therefore of Beaker metallurgy – to each of them is not the same. On the Millaran settlements and in the collective tombs, there is no particularly close relationship visible with Beaker pottery, despite the hundreds of excavated tombs so comprehensively published by the Leisners, and the later excavations at Los Millares (Almagro and Arribas, 1963) and Orce in Granada (Schüle, *et. al.* 1966). At Los Millares, only about 10 of the more than 80 known tombs had any Beakers at all, and then often a single sherd or sherds from the same vessel. Beakers are very rare at Almizaraque too, where there are scarcely a dozen sherds among the thousands of others recovered. Nor is there any preponderance of Beakers in the caves of the S.E., as Map 2 indicates. In fact, the only caves to produce unequivocal Beakers in the whole of S.E. Spain are the Cueva de la Hacha, Almería, and the Cuevas de los Blanquizares de Lebor, Murcia. All the other cases cited (eg. in Savory, 1968; 171ff) are either without Beakers at all, or possess only one doubtful sherd abstracted from many others. (ie; Cueva Ambrosio, Almería; Carigüela de Pinar, Granada.) The actual quantity of Beaker pottery in relation to the vast Almerían-Millaran-Argaric collections is



Map 2. (Modified after Savory, 1968; Fig. 18)
Southern Spanish Caves with Impressed or Incised Neolithic Pottery, and Beaker Cave Sites.
squares: Caves with Impressed or Incised Wares
circles: Beaker Cave sites;
1; Cuevas de los Blanquizares de Lebor, Totana, Murcia.
2; Cueva de la Hacha, Vera, Almería.

astonishingly meagre considering all the attention it has received.

With the sole exception of Dr. Schüle's site at Cerro de la Virgen, Orce, Granada, the impression is of a poverty of Bell Beakers in comparison to the great density around the Tagus estuary, where the concentration is the greatest in Iberia, and one of the richest in Europe (Veiga Ferreira, 1966). The comparison is best seen if we note for a moment that out of over a ton of Almerían plain pottery recovered by Santa-Olalla from the site of Tabernas, only 15 Beakers sherds were found, while at Penha Verde, with far less pottery, Dr. Veiga Ferreira found over 130 Beaker sherds.

Around the Tagus there is a remarkably high coincidence between the later VNSP sites and the distribution of comb-decorated Beakers, which Veiga Ferreira (1955) first noted when commenting upon the frequency of comb-decorated Beakers in corbel-vaulted tombs ("Tholoi"). Similar polythetic assemblages are likewise found on VNSP settlements and in the rock-cut tombs. (Interestingly enough, Leisner (1965) suggested that the rock-cut tombs were imitations of the corbel-vaulted tombs.) At Vila Nova de São Pedro itself, all the Beakers are comb-decorated, and over 90% of the Beakers from similar sites such as Penha Verde, Zambujal and Rotura are comb-decorated.

Even more interestingly, there exists a similarly high coincidence between the incised Beakers and small open settlements, caves and the simpler dolmens. Although there is some overlap between the two groups, the Tagus Beaker materials polarize in their cultural patternings, rather as Savory forsaw in 1950. While the data is most imperfectly published, we can see a bond between the VNSP II complex and comb-decorated Beakers, extending to both the settlement and burial patterns, with an equally sharp separation of the comb-decorated from the incised Beakers. Furthermore nearly all the metal "associations" are with the VNSP II – comb-decorated Beaker assemblages. We have not just a separation of two pottery styles, but distinct assemblages, complete with attendent distributions and technologies.

A case can be made for interpreting open settlements such as Casa Pia, Belem (Veiga Ferreira, 1966) or Montes Claros (do Paço and Bártholo, 1954) – where over 80% of the Beakers are incised – as "pure" Beaker ones, as Schüle does (1969), but much more significant is that no site is known with only "pure" comb-decorated Beakers as its luxury ceramic component. Despite claims to the contrary, Penha Verde is not a "pure" comb-decorated Beaker complex, but has large quantities of VNSP II material, and about 8-10% of its Beakers are incised (unpub. data). Wherever we find comb-decorated Beakers in the Tagus region, VNSP II materials accompany them in direct proportion to the richness of the site. This significantly high overlap indicates that an unusually close relationship existed between the comb-decorated Beakers and the VNSP, one best seen by viewing the comb-decorated Beakers as the last luxury decorated ceramic used by the VNSP culture; VNSP III in fact, with direct continuity between the two complexes. If we see the comb-decorated Beakers in this manner, it explains the lack of "Pure" Beaker sites with comb-decorated Beakers, the remarkable lack of single Beaker burials, and the close polythetic affinity between the two groups. Pure comb-decorated Beaker sites probably never will be discovered because they never existed, except as "mixed" with VNSP II materials.

There is therefore good reason to believe in a common copper-working tradition between the VNSP and Beaker complexes, and it is to investigate this problem that the following section is devoted. There is always the chance that we are seeing a false dichotomy caused by erratic site discovery, but this is insufficient as an excuse not to investigate the data we already have, and to appreciate the regularities that can be percieved, albeit dimly. A much fuller presentation of this argument will presented later.

THE METALS

Metals 1-4

If we turn now to the Charts (1-13) a short inspection will show that only four metals are readily distinguishable. Before moving into the analysis where we shall use these groups rather than the 17 clusters by SAM 2/2 (Diagram 7), we shall present a brief outline of each metal, which will be afterwards referred to by its number; ie. Metal 1,2, etc.
The Metals are as follows;

Metal 1
Pure copper, with a low (0.01%) trace of silver and nickel.

Metal 2
2% arsenical copper. Allowing for the usual sampling variations, the base pattern of trace elements is the same as in Metal 1, but the consistent presence of high arsenic levels (around 1.5-2.5%) is accompanied by a slight increase in the amount of silver and the appearance of low-medium amounts of nickel.

Metal 3
Tin bronze. The same underlying trace element pattern as in Metals 1 and 2, but with high and very high (over 10%) levels of tin, and the erratic but noticeable presence of lead, antimony and nickel. The majority of analyses of type 3 Metals do not have these additional impurities, which form no particular pattern and which seem to come from the added tin rather than the copper ore.

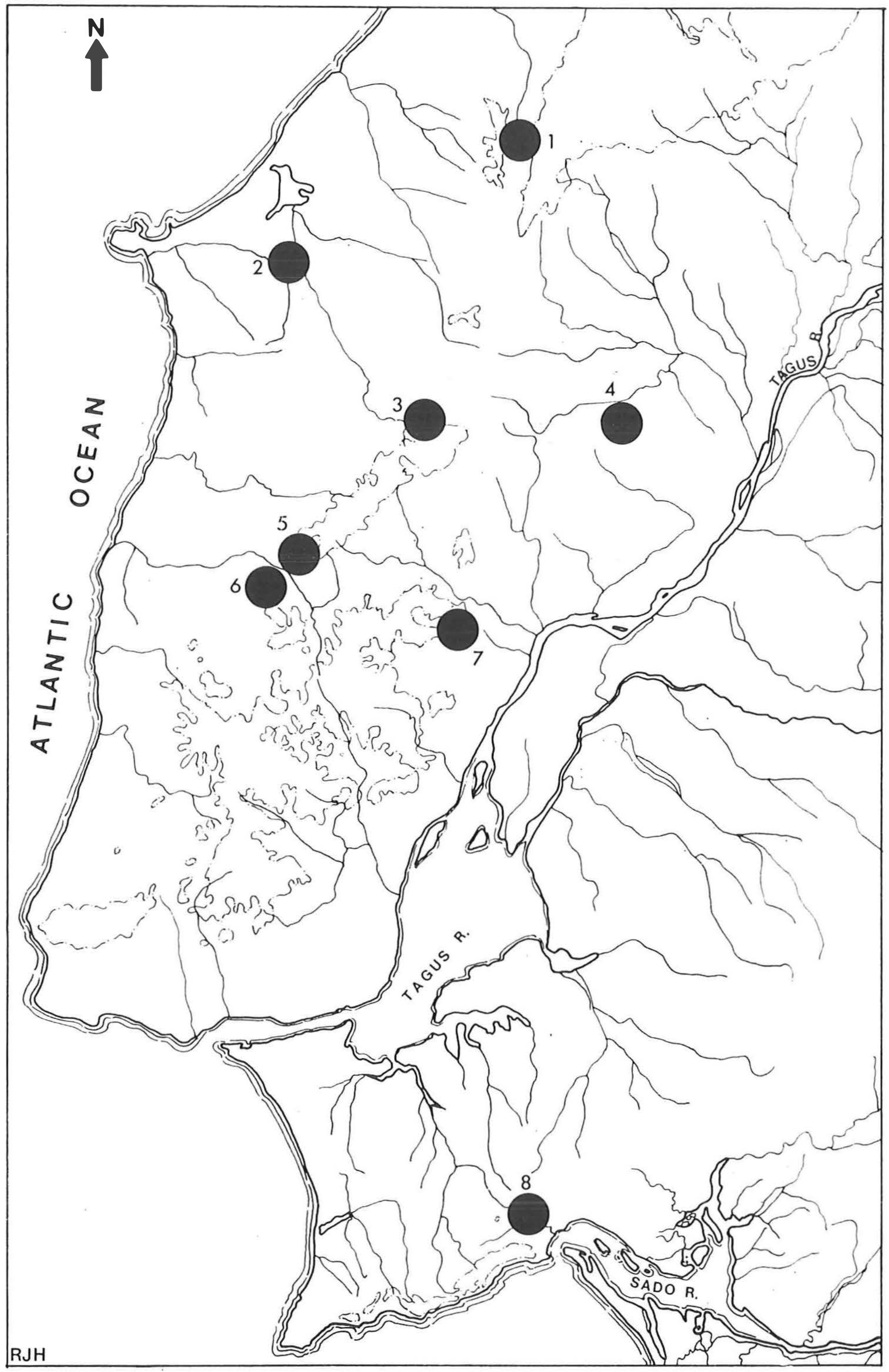
Metal 4
Tin-arsenic bronze. Really a mixture of Metals 2 and 3. The high arsenic and very high tin levels are consistently associated with each other, forming a recognisable variety. There is an accompanying increase in the random presence of lead, antimony, silver and nickel, as in the case of Metal 3.

The homogeneity of each metal group should be approximately equal, (unlike the SAM analysis groups) and therefore makes them directly comparable among themselves. Despite reducing the SAM groups so drastically, no distortions, skewings or secondary peaks can be seen, and indeed, the very "normal" appearance of the graphs indicates that we are handling populations which show the standard Gaussian distribution. So in spite of all the error sources, charts of 20 or more analyses can accomodate individual deviations without sacrificing the reliability of the whole group – which is exactly what Waterbolk and Butler claimed for the technique in 1965.

The underlying similarity of the trace element pattern, particularly in Metals 1 and 2, may be due simply to continued exploitation of the same ore lodes, whose composition changed with depth. Oxides frequently mantle sulphide ores which occur deeper down, since the uppermost level of sulphide ore bodies is often oxidised. This would explain the contemporaneity of Metals 1 and 2, their similar trace element patterns, and account for the arsenic content in Metal 2.

Regional variation

Charts 1 and 2 (Alcalá – Los Millares and El Argar – El Ofício) provide a rough guide to the degree of regional variety in the overall trace element pattern we can expect, by comparing them with Charts 3-8 (ie; Palmela, Penedo-Fórnea, Pedra do Ouro – São Mamede, VNSP, Pragança and Alcobaça), all from around the Tagus area (see Map 3). The overall homogeneity of trace element patterns, except arsenic and tin, emerges very clearly from the Tagus area. The same underlying pattern appears in the SE Spanish metals. Charts 12-13 reveal that slightly more lead and nickel occur in the Portuguese Palmela Points than in their Spanish counterparts, but there is no major variation that can be ascribed to *regional* differences rather than to other factors, such as intentional alloying. That regional variation does affect trace element percentages is certain, since the SAM 1 analyses from southern France quoted by Guilaine (1967) show the consistent presence of antimony, silver and nickel in much higher amounts than occurs in contemporary eneolithic-EBA metals from southern and western Iberia. It is just that in the cases studied here, it is not a significant source of variety.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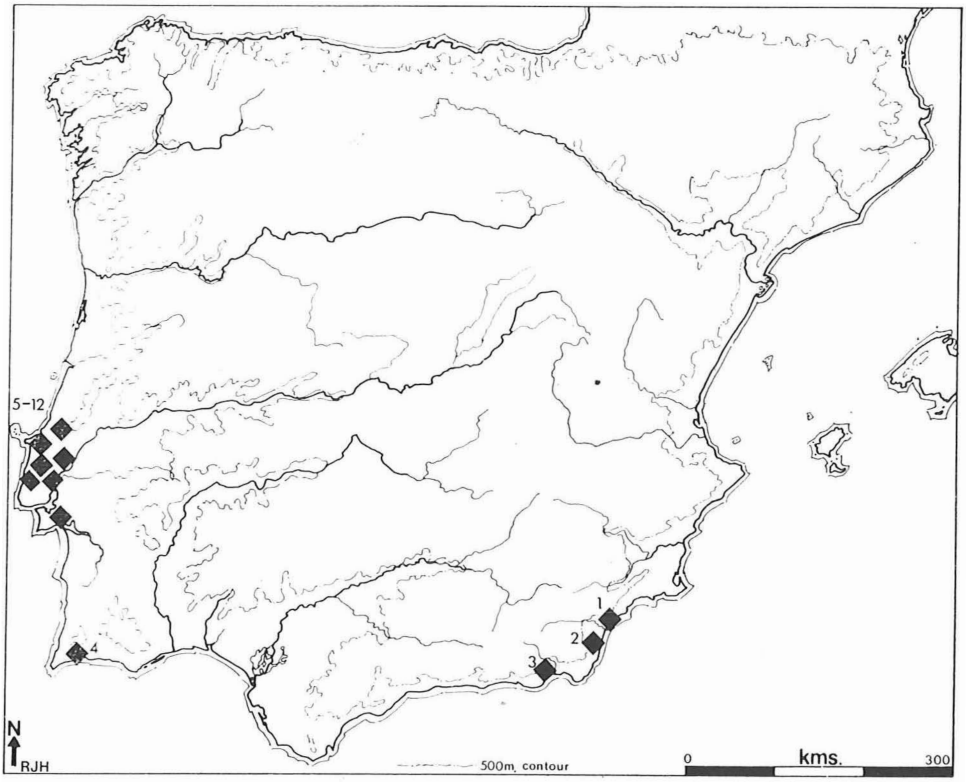
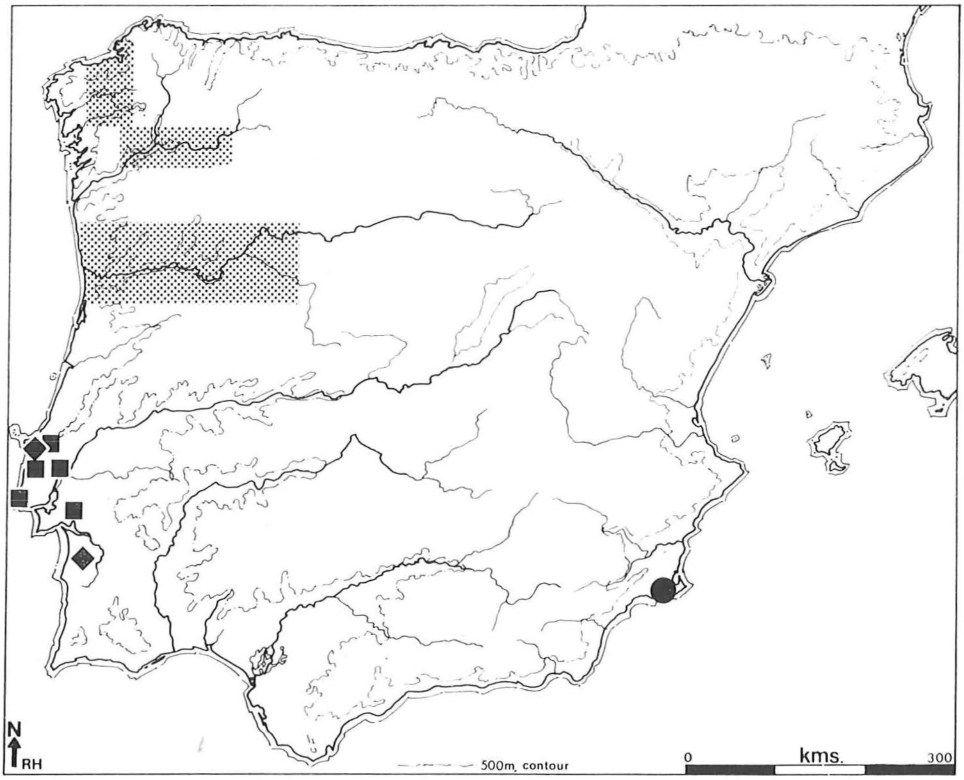


Map 4.
Location of sites used for analysis
1. El Ofício
2. El Argar
3. Los Millares
4. Alcalá
5. Grutas de Alcobaça
6. São Mamede
7. Pragança
8. Vila Nova de São Pedro
9. Castro da Fórnea, Matacães
10. Castro do Penedo, Runa
11. Pedra do Ouro, Alemquer
12. Palmela

Map 3.
Tagus Estuary Portugal. Location of sites which yielded the objects analysed by SAM.
1. Grutas de Alcobaça
2. São Mamede
3. Pragança
4. Vila Nova de São Pedro
5. Castro da Fórnea, Mataçães
6. Castro do Penedo, Runa
7. Pedra do Ouro, Alemquer
8. Palmela.



Map 5.
Ore lodes mentioned in text.
Shaded areas : major alluvial tin deposits.
circle : tin
square : gold
diamond : copper

Inter-site variation

If large-scale differences cannot be seen between the two regions under study, some local site differences can be identified, which are not wholly attributable to chronological distinctions. This is seen most clearly in Metals 3 and 4 from Pragança (Chart 7), Alcobaça (Chart 8) and El Argar-El Ofício (Chart 2).

The tin-bronzes (Metal 3) from Pragança all have a consistently high to very high proportion of tin, approaching the 1: 12 tin – copper ratio in many cases. By contrast, the inconsistent dispersal of tin in the Argaric objects ranges from a non-functional 0.1% to 10.0% or more. The reason for this distinction between contemporary metals (Atlantic and Argaric respectively) appears to lie in the differential ease of access to tin supplies. In western Spain and Portugal, (especially in northern Portugal and Galicia) great quantities of tin are ready to hand in the alluvial gravels of the streams and rivers emptying into the Atlantic. In S.E. Spain, the only known tin sources – also of Cassiterite – are around Cartagena, in Murcia (see Map 5). Allan (1970) recently published personal information received from Mr. Cunningham who actually worked for tin near Cartagena from 1927 to 1935. He goes on to say (op. cit. 27-8)

> "... Here in a zone two miles long and half a mile wide there were sixteen concessions of varying size along the crest of the hills above La Unión. The district was famous for the discovery of rich pockets of tin ore that made small fortunes for the lucky discoverers. ... Cunningham operated a small concentrating plant ... and for some years made twenty to thirty tons per month of 30% tin concentrates. At the time some of these mines were working more or less continuously, supplying Cunningham with rough concentrates.
>
> The Fortuna mine had reached a depth of over 400 ft. and several others were over 300 ft. in depth. Good gossan outcrops were frequent. An occurance in which mineralisation occurred in rich pockets up to quite important dimensions could hardly fail to have formed extensive alluvials. Traces of alluvials could hardly be excepted after 4,000 years, and any ancient work on the veins would certainly have been covered by later work. There is little official record of Cunningham's work or the activity which preceded it."

The obvious point is that tin ore *was* available in exactly that region which supported the rich Argaric culture-complex, and that it occurred sporadically and unexpectedly in small pockets. This would explain the erratic tin content of the Argaric bronzes in Chart 2, since the occasional discovery of one of the ore pockets would provide tin at some times and not at others. With such a fluctuating source the metal smiths would have had to have waited until such time as another stroke of fortune intervened, or until they acquired more tin in trade with the peoples in Portugal and Galicia. Argaric axes are easily identifiable at Vila Nova de São Pedro, by their typology and high tin content (Metal 3), while Argaric imports are also known from Galicia (ie; rivetted daggers in the hoard from Ronfeiro, Orense.). Rather scarcer are Atlantic bronzes in S.E. Spain, which, when they do occur, tend to be later than the period under discussion. (eg; The large, single-looped palstave from Solana de Peñarrubia, at Béjar-Lorca, in Murcia).

Such an explanation is more probable than the alternative ones; that erratic tin content indicates ignorance of the qualities of a tin bronze alloy (an unlikely supposition), or to a period of experimentation when metal smiths tried various percentages of tin to find the best one for their purpose. In the latter case, we would expect to see in later Argaric analyses a consistent tin bronze alloy adopted to suit particular requirements, but this is not the case. The erratic tin contents continue, as shown by other SAM analyses of later Argaric pieces.

Much the same variation occurs in the composition of Metal 4 (high tin-arsenic bronzes). In the sites around the Tagus estuary, only the caves of Alcobaça have many examples of this metal, but the tin content is consistently very high, while the quantity of tin in these group 4 metals from El Argar-El Ofício is small by comparison.

The final illustration of inter-site variation is perhaps to be seen in the presence of type 3 Metal at Pragança and type 4 at Alcobaça, neither site possessing both types. More probably this is due to the large Atlantic halberds and tanged daggers from Alcobaça which are not found at Pragança, than to inter-site variation.

Chronological variation

A. *S.E. Spain* (Charts 1 and 2)

Metals 1 and 2 predominate in the Los Millares complex, with a single example of tin bronze (Metal 3). Metals 2, 3 and 4 occur in the Argaric culture without any examples from type 1 Metal. Since there is no chronological overlap between the two cultures, it is clear that type 1 Metal (lacking significant quantities of impurities) is the oldest, and that it appears to have been used alongside the 2% arsenical copper alloy (Metal 2) for a very long time. Metal 2 continued as the major alloy into Argaric times, but now supplemented by the tin bronze and tin-arsenic bronze alloys. All three metals may have been deliberately selected for specific uses, but the sample of 36 analyses is too small to permit sub-divisions to check this. So for the S.E. of Spain, the technical progression would run chronologically thus;

Stage 1; (Millaran) Metals 1,2.

Stage 2; (Argaric) Metals 3,4.

This agrees in general terms with the regularities noted in SAM 2/2, (Diagrams 7, 11), but the numerous sub-groups are simply not recognisable, since they are assimilated into our four metal groups without any noticeable distortions.

B. *Tagus Estuary.* (Charts 3-8)

A very similar sequence of events can be seen around the Tagus, though it should be remembered that on all these sites the samples are mixed and cannot be definitely split into pre-Beaker and Beaker groups.

Metal 1 occur on all the sites, especially at Vila Nova de São Pedro, where some 40 objects at least were manufactures from this arsenic-free copper. Metal 2 is also frequent at all sites, forming the dominant alloy at Palmela, Fórnea-Penedo, Pedra do Ouro-São Memede, Pragança and Alcobaça. A wide range of pre-Beaker and Beaker objects were made from this popular metal which was not superseded until the middle of the 2nd. Millennium B.C., when tin bronze alloys mark the first real break in the metallurgical tradition. At VNSP (Chart 6) true bronze was used in the manufacture of "Argaric" type axes, and at Pragança (Chart 7) it coincides with the post-Beaker occupation of the site. Metal 4 occurs only at Alcobaça, and as we suggested earlier, it probably reflects the slightly later date of the Atlantic bronzes analysed from the caves. A provisional sequence of metals should run as follows:

Stage 1; (*circa* 2500 B.C.) Metals 1,2.
Stage 2; (*circa* 2000?-1500 B.C.) Metal 3.
Stage 3; (*circa* 1500-1400 B.C.) Metal 4.

As we shall see in the following section, only Metals 3 and 4 can be ascribed exclusively to any cultural phase (in this case the Argaric and Atlantic traditions) while Beaker metallurgy noticeably does not stand out by virtue of any special metal group, nor can it satisfactorily be separated from VNSP metallurgy except on typological grounds. The contemporaneity of Metals 1 and 2 reflects a similar situation identified in the 4th. Millennium B.C. metallurgy in the S. Caucasus where a pure copper and an arsenical copper were used side by side (Selimkhanov and Maréchal, 1965).

Functional variation

Flat axes. (Chart 9)
Metals 1 and 2 are present in equal proportions. The small number of tin bronze axes (Metal 3) are typologically later than the remainder, being classed as "Argaric". There is no clear preference for any one metal over the other for the pre-Argaric (ie; VNSP and Beaker) axes. There are no examples of Metal 4.

Chisels. (Chart 10)
Metals 1, 2 and 3 occur in the same proportion as among the axes. Chisels are usually seen as a VNSP II type, but since three specimens occur at Palmela (Leisner, 1965; Taf. 97, Figs. 98, 102, 109) as well as at VNSP, they can be interpreted a little more broadly as of general VNSP-Beaker date, and not limited to the VNSP complex. The single example of tin bronze comes from Vila Nova de São Pedro itself, and indicates either the late survival of the type until Argaric-Atlantic tin bronzes become known, or that tin bronzes could be produced in VNSP – Beaker times, albeit for small objects.

Awls. (Chart 11)
The same three metals are present as among the axes and chisels. That no specific metal or alloy was selected for their exclusive manufacture is plain enough, but perhaps awls were the tools with which smiths first tested their new alloys? As a small, utilitarian object, subjected to considerable work-stress they would be ideal experimental subjects, and quick to yield results. If the alloy were a poor one, the casting flawed, or the metal work-hardened for too long, then the awl would soom break or bend. It was also easy to manufacture, and economical in the amount of metal it needed. Undoubtedly they were variously used, since they occur in such numbers and on such a variety of sites. One possible use not often mentioned could be for pressure-flaking the vast numbers of arrowheads, sickles and knives found so abundantly around the Tagus and in S.E. Spain.

It can hardly be pure chance that the early appearance of copper awls broadly coincides with the astonishing florescence of fine bifacial flintwork in Iberia, S. France and Italy. Quite possibly the small copper awls were first used to manufacture bifacially flaked flint points in quantity from cherts and flints treated by careful heating and cooling to improve their flaking quality (Crabtree and Butler, 1964; Bordes, 1969). If so, then the same pyrotechnology used to treat the flint before working it have been used more imaginatively in metallurgy. Links between ceramic technology and metallurgy have long been recognised, (a good recent example is in Renfrew, 1969), so there is no good reason why the range should not be extended to include heat pre-treatment of flints and other stones.

Wertime (1964) pointed out that early metallurgy is frequently part of an intense interest in the geological environment where fine stones, minerals and clay were all actively sought out and exchanged. The list of known raw materials in the VNSP cultures (Appendix 4) conveys some idea of the amount of interest, where ideas could be exchanged as easily as stones. This is of course hypothetical and will remain so until micro-structural analyses are made of the VNSP flintwork. But some explanation is required to account for the proliferation of fine flintwork at the same time as copper metallurgy and copper awls appear.

Palmela points. (Charts 12, 13)
The slightly greater amount of lead and nickel in the Portuguese Palmela Points is a negligible difference between them and their counterparts in Spain.

More interesting is the complete dominance of the high arsenic alloy (Metal 2) used to the virtual exclusion of Metals 1 and 3. Over 90% of the 109 specimens are made from this alloy, indicating that only one metal was selected for the manufacture of this classic Beaker metal type. A high degree of control over the alloy composition is clear, since it is the 2% arsenical alloy which was deliberately aimed for and successfully achieved. A good number of specimens have more than 5% arsenic, but as Coghlan (1972) noted, the mechanical efficiency is not improved by the addition of arsenic above the 2% level. The 2% arsenical alloy is the most efficient and economical one, both for its ability to be work-hardened to a hardness equal to mild steel (Tylecote, 1962) and for its superior casting qualities. The small amounts of arsenic act as a mild deoxidant to remove gases from the molten metal that would otherwise be retained and flaw the casting (Charles, 1967). Such flaws are a common feature in Irish flat axes cast from nearly pure copper (Allan, Britton and Coghlan, 1970). The remarkable consistency of metal composition stands out all the more by contrast to the flat axes, chisels and awls just mentioned, but there is another point in favour of the case that the 2% arsenical alloy was intentional.

Cold hammering increases the hardness of 2% arsenical coppers nearly 100%, without seriously imparing the ductility of the metal. As the table below indicates, the mechanical strength also increases in direct proportion to the quantity of arsenic. As Tylecote observed (op. cit; 42)

"...As little as 1.04% As. will raise the strength of hammered copper in the cast or annealed condition from 28.7 to 38 tons/sq. in. This is equivalent to increasing the hardness from 124-177. Thus the enormous effect of arsenic on the hardness of a hammered copper cutting edge could not fail to have been noticed..."

Effect of Arsenic on the strength of Wrought Annealed Copper. (From Tylecote, 1962; 42; adapted from G. D. Bengough, *J.I.M.* 1910 vol. 3. 34-97)

% As.	UTS Tons / sq. in.
0.0	14.0
0.04	15.5
0.25	15.7
0.75	15.7
0.94	16.5
1.91	17.0

Now cold hammering is one of the characteristics of Beaker metalwork, and nearly every Palmela Point is not only hammered but edge-ground as well. Many of the VNSP II tool forms – curved knives, notch-hilted daggers – were never cold hammered to the same extent, nor were their cutting edges treated so carefully as on Palmela Points. Many of the VNSP copper axes seem to have been hammered at their edges to some degree, but the technique seems to have been perfected along with the increasing preference for 2% arsenical copper in Beaker times.

How the 2% arsenic content was achieved is unclear. Perhaps the ores were of this composition, or ores of a higher arsenic content were selected and the excess arsenic oxidised off under controlled conditions to achieve the 2% figure. There are several Palmela Points with high arsenic contents which perhaps reflect the original arsenic content of the ore which was later reduced. McKerrell and Tylecote wrote; (1972: 209)

> "... control of the arsenic content, by oxidative loss, is entirely feasible, and was, in all probability, the technique actually used to reduce the arsenic content of North British Halberd rivets."

These findings harmonise with our data, but more probably the high arsenic contents reflect sampling variation, since arsenic segregates strongly in copper (see Table 7 in McKerrell and Tylecote).

On account of their size and weight, Palmela Points are usually interpreted as spear or javelin heads, an idea strengthened by the discovery at Valdenabí, León, of a burial with two Palmela points embedded in the skull (Luengo, 1941). The skull has since been lost, but a two-holed wristguard which accompanied it was recorded. A more doubtful instance was claimed by Sr. Cañal in 1894, who published finds from Las Cumbres, some 15 kms. east of Carmona (Seville). He wrote (op. cit.: 61)

> "...One of the skulls found ... had three copper spearheads embedded in its upper part."

A drawing of one of the "spearheads" shows it to be a typical Palmela point, rather larger than average size. If the word "clavadas" (lit; nailed) had not been used, one would have been tempted to believe that an ordinary burial of a warrior on top of his spears had been mistakenly identified, but in the light of the Valdenabí find, we should probably accept the description as assurate.

Other functions could be as knives or razors, since many Palmela points have oval or even round blades (eg. El Acebuchal (Bonsor, 1899)). The four from Puentes de García Rodríguez (La Coruña) have an uneven keeled section which may indicate wear on that side. Quite often the fine cold working on the edges is asymmetrical, showing traces of grinding and sharpening, as on the two points from Cañada de Rosal (Sevilla) (Harrison, 1974).

CONCLUSION

With the recognition of only four metals we can gain a clearer appreciation of the technology of copper working around the Tagus estuary. The main technical innovation was the appearance of tin bronze alloys of Atlantic and

Argaric traditions. But prior to this, no major technological discontinuity between the VNSP and Beaker cultures can be identified on the basis of the more than 400 SAM analyses. We can see the same 2% arsenical alloy in use in VNSP times to manufacture awls, flat axes and chisels as in the Beaker period for the production of Palmela Points. Even tin bronze is represented in both cultures, as shown by the VNSP chisel and a few rare Palmela Points. All the techniques used in Beaker metal manufacturing were already known to the VNSP smiths: cold hammering (on the flat axes), arsenical and tin bronze alloys were in use; even the same metal (presumably from the same ore sources) was used. Whatever we may believe about the typological development of certain artefacts, the apparent continuity of metallurgical knowledge and skills strongly suggests that Beaker metallurgy is merely a slightly more developed from of VNSP metallurgy, continuing on as before but with an increasing preference for the arsenic alloys. The increasingly deliberate control in ore selection or alloying was accompanied by more extensive and refined cold working to take full advantages of the properties of the arsenical inclusions. Thus a gradual preference for consistent production of arsenical alloys developed at the same time as Beaker pottery became popular.

The absence of carbon-14 dates hinders an accurate estimate of the time-depth involved in the pre-Atlantic traditions, but a guess-date of 2,500-1,500 B.C. ought to convey the right order of magnitude.

The continuity of metal-working and settlement and burial patterns around the Tagus contrasts with S. E. Spain where no such pattern can be distinguished. Only around the Tagus estuary can Beaker metallurgy have any real background, and it would not be hard to see comb-decorated Beakers as the last phase of the VNSP culture.

February 1974

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B.R.G.K.	Bericht der Römisch-Germanischen Kommission
B.S.P.F.	Bulletin de la Société Préhistorique Française
C.I.P.P.	Comision de Investigaciones Paleontologicas y Prehistoricas
C.S.G.P.	Comunicações dos Serviços Geologicos de Portugal
O.A.P.	O Archaeologo Portugues
P.P.S.	Proceedings of the Prehistoric Society
S.A.M.	Studien zu den Anfängen der Metallurgie
S.E.A.E.P.	Sociedad Española de Arqueologia, Etnografia y Prehistoria, Actas y Memorias
T.A.E.	Trabalhos de Antropologia e Etnologia

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APPENDIX I: BEAKER COPPER SMELTING AND WORKING

Crucibles for copper smelting occur in Beaker levels at Rotura (Ferreira and Travares da Silva, 1970), and copper slags of Beaker date occur at Zambujal where a circular copper smelting furnace has been excavated by Dr. Schubart and Professor Sangmeister. At El Acebuchal, where great quantities of Beakers were found by George Bonsor in the 1890's, there are quantities of slag, copper droplets and ores that may well be of the same date as the Palmela Points, awls and tanged daggers found there. Near Madrid, at the settlement of El Ventorro, crucibles were found decorated in the Ciempozuelos Beaker style, associated with a pure Ciempozuelos domestic Beakers assemblage recovered from oval "fondos de cabanas" which appear to be hut remains (Harrison, Quero and Priego, 1974).

So far no Beakers have been directly associated with the cushion stones which seem curiously rare in the peninsula in comparison with northern Europe. Two such stones which probably qualify as metal working implements come from Gruta 1, São Pedro do Estoril, where many Beakers were also found (Leisner *et. al.* 1964. Est. D Figs, 15-16). Both stones are of highly polished basalt, in contrast to the use of softer amphibolite for the adzes and axes, and are described as possibly "hammers, polishers, or hammerstones" (*op. cit.* p. 27)

Their use as either hammers or hammerstones is highly improbable since both have extremely finely polished edges, without any of the usual signs of erosion or abrasion which hammering and beating produce. We can see dozens of abraded hammers and hammerstones in the Lisbon museums, and not a single one has the high quality finish of the São Pedro do Estoril stones. Neither are they much more likely to have been polishers, since the ends and sides are straight and even, with neat, well-defined corners: all features uncommon to most polishers which habitually wear into gently rounded profiles, with wide-angled facets and no sharp edges. Polishers are often rounded river cobbles such as were found at Penha Verde (unpub. M.S.G. Lisbon).

A far more plausible explanation is that they are metalworking stones, where a hard, resiliant stone is required, one well finished on all surfaces, and of sufficient weight to make an impression upon the metal being worked. The neatly squared corners, ever so slightly rounded and polished are also indespensible features for a metalsmith, since they can be used to raise up flanges or to beat out small irregularities. In short, all the features which make the functions suggested by Dr. Leisner unsuitable support the new identification.

APPENDIX II: CHARTS 1-13
(For site locations, see maps 3 and 4)

Notes on the Charts

1. Alcalá (Algarve, Portugal) and Los Millares (Almería, Spain) (Leisner and Leisner, 1943)

Although these two sites are separated from each other by over 500 miles, their analyses are combined, since they are so similar in metal composition. It was done only because there were too few analyses from each site to warrant separate charts.

2. El-Argar and El Ofício, Almería. (Siret, 1887)

The Argaric type-sites, lying close together, and each indistinguishable from the other in terms of metallurgy.

3. Palmela ("Quinta do Anjo," Setúbal) Leisner, 1965)

VNSP – Beaker rock-cut tombs. The materials from all four tombs are combined since fully half of the finds are without exact tomb provenance.

4. Castro da Fórnea, Matações; Castro do Penedo, Runa. (Spindler, 1969; Spindler and Gallay, 1973)

Two fortified VNSP settlements with Beaker occupation. Approximately 1 km. apart, and combined for analysis.

5. Pedra do Ouro, Alemquer. (Barbosa, 1956; Leisner and Schubart, 1966) and São Mamede, Obidos.

Two VNSP settlements. Abundant Beakers from Pedro do Ouro. Combined to make up a large enough sample for analysis. They are not distinct from each other in terms of their metallurgy.

6. Vila Nova de São Pedro, Santarem. (Jalhay and do Paço, 1945)

Type-site for the VNSP culture. Massively fortified citadel and settlement site.

7. Castro de Pragança.

Defended settlement, with occupation from VNSP until Iron Age times.

8. Cuevas de Alcobaça. (Natividade, 1901)

A group of caves clustered in a small valley, with materials from LN to full Atlantic Bronze Age times. Combined to form sample.

9. Flat Axes from Portugal.

Mainly from around the Tagus estuary.

10. Awls. (No more details given in SAM for these particular specimens)

Mainly from around the Tagus estuary.

11. Chisels.

All from around the Tagus estuary region.

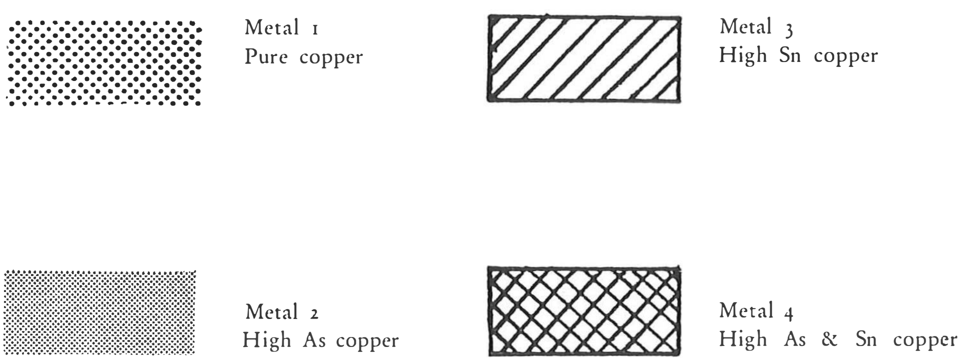
12. Palmela Points, Portugal.

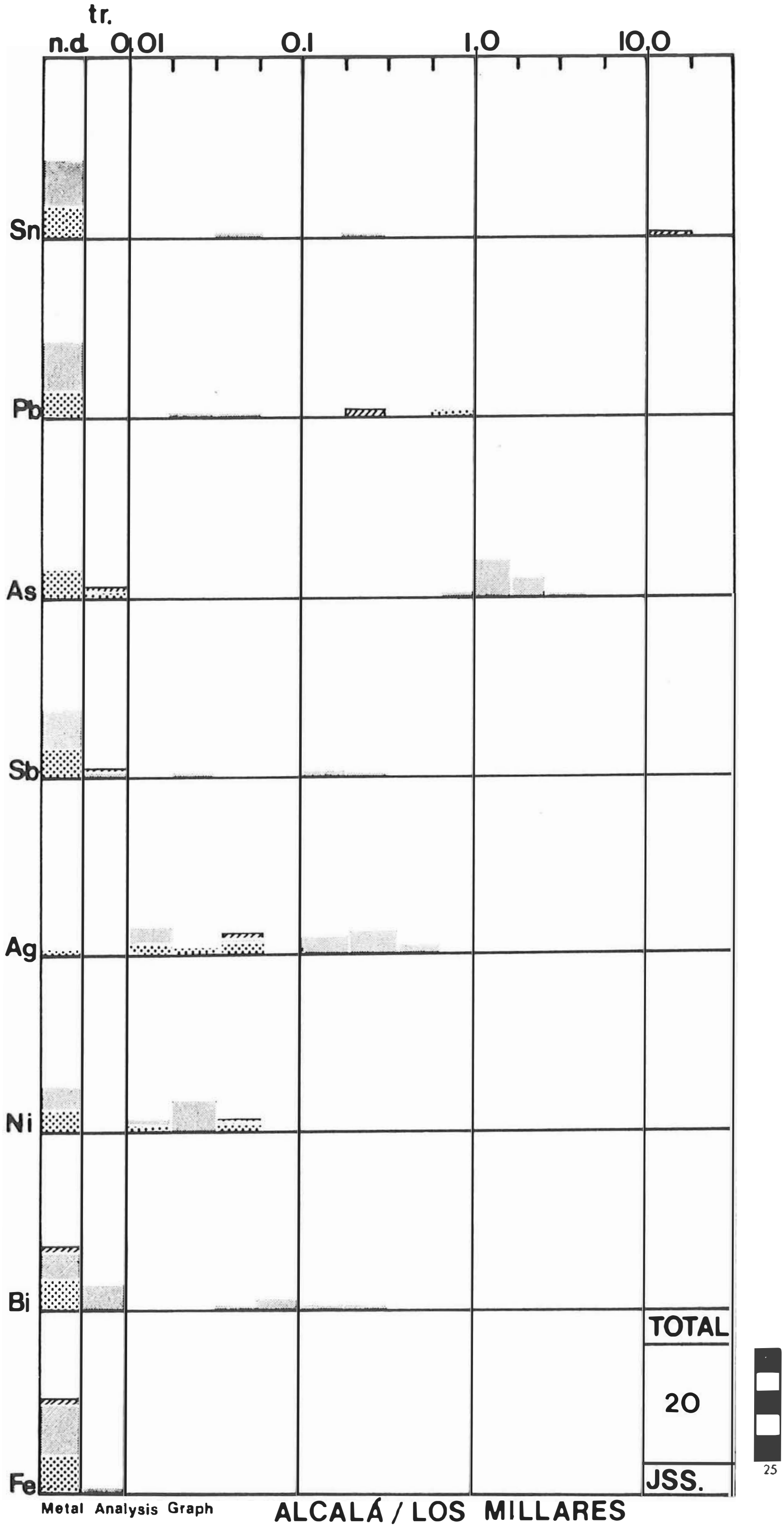
All over Portugal, but especially around the Tagus estuary.

13. Palmela Points, Spain.

From all over Spain, but especially concentrated in the Western half.

Key to the charts

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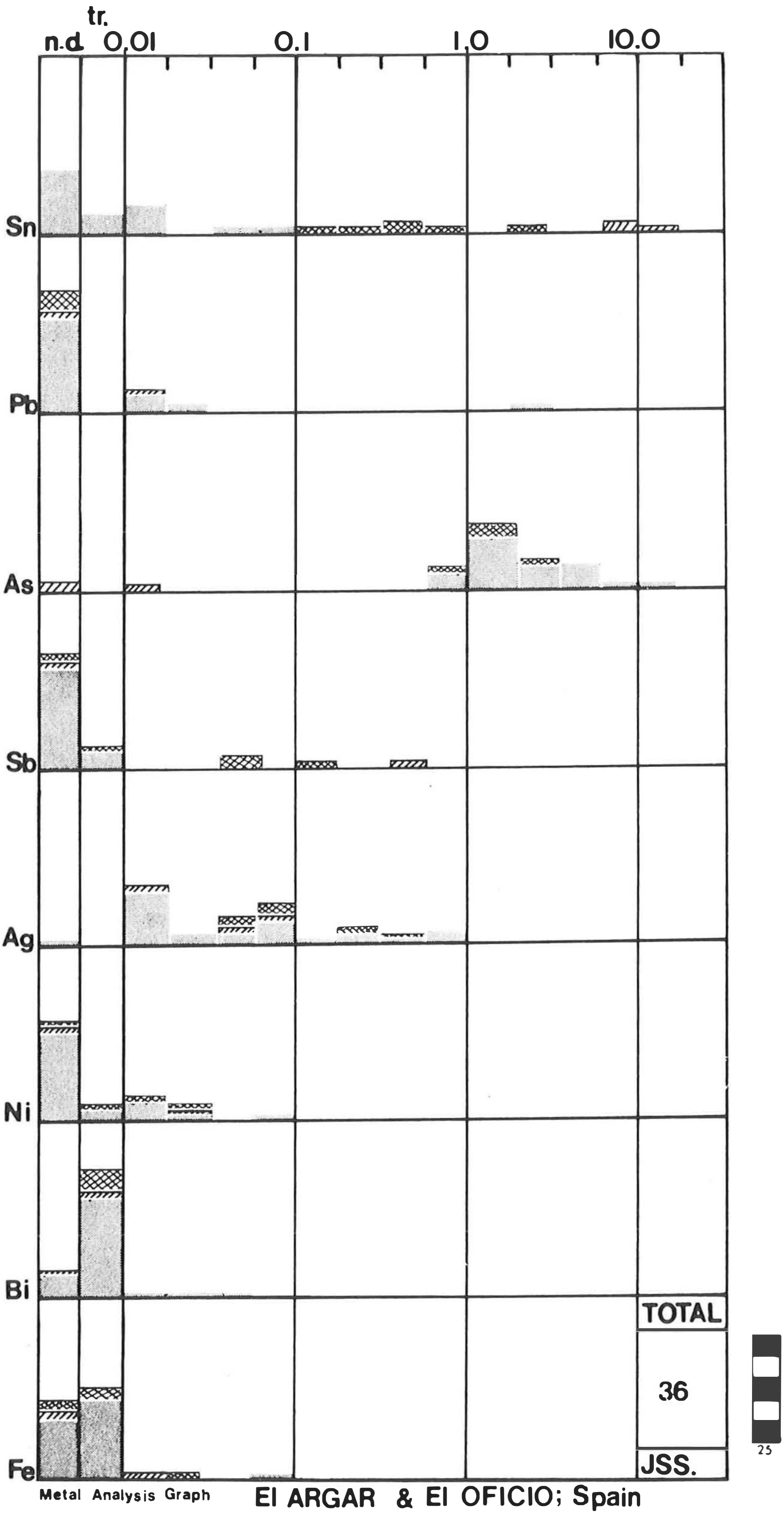
JSS.
Metal Analysis Graph
ALCALÁ / LOS MILLARES
25

Chart 1



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10.0
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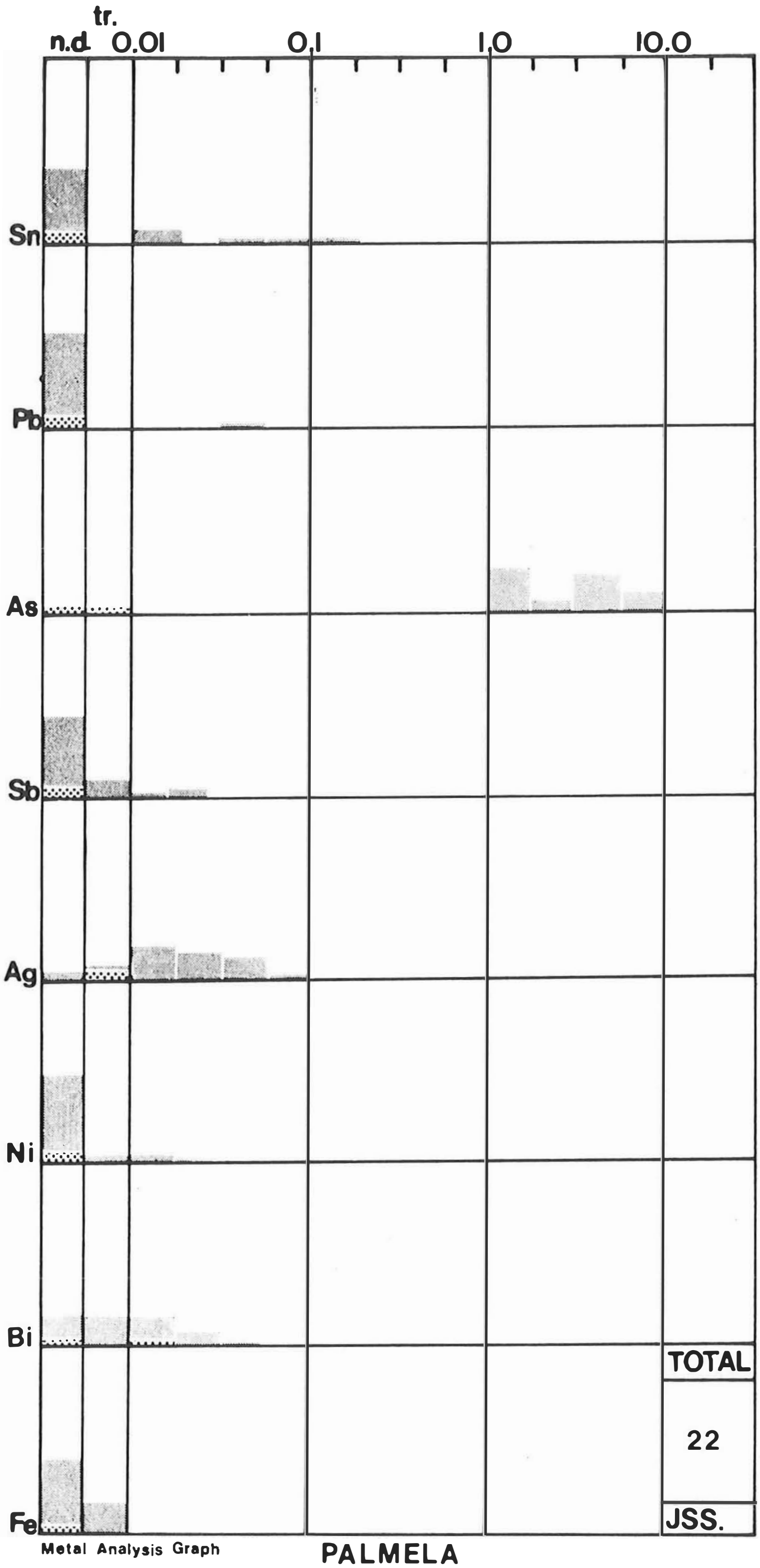
Sb
Ag
Ni
Bi
Fe
TOTAL
36
JSS.
25
Metal Analysis Graph
El ARGAR & El OFICIO; Spain

Chart 2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Ni
Bi
Fe
TOTAL
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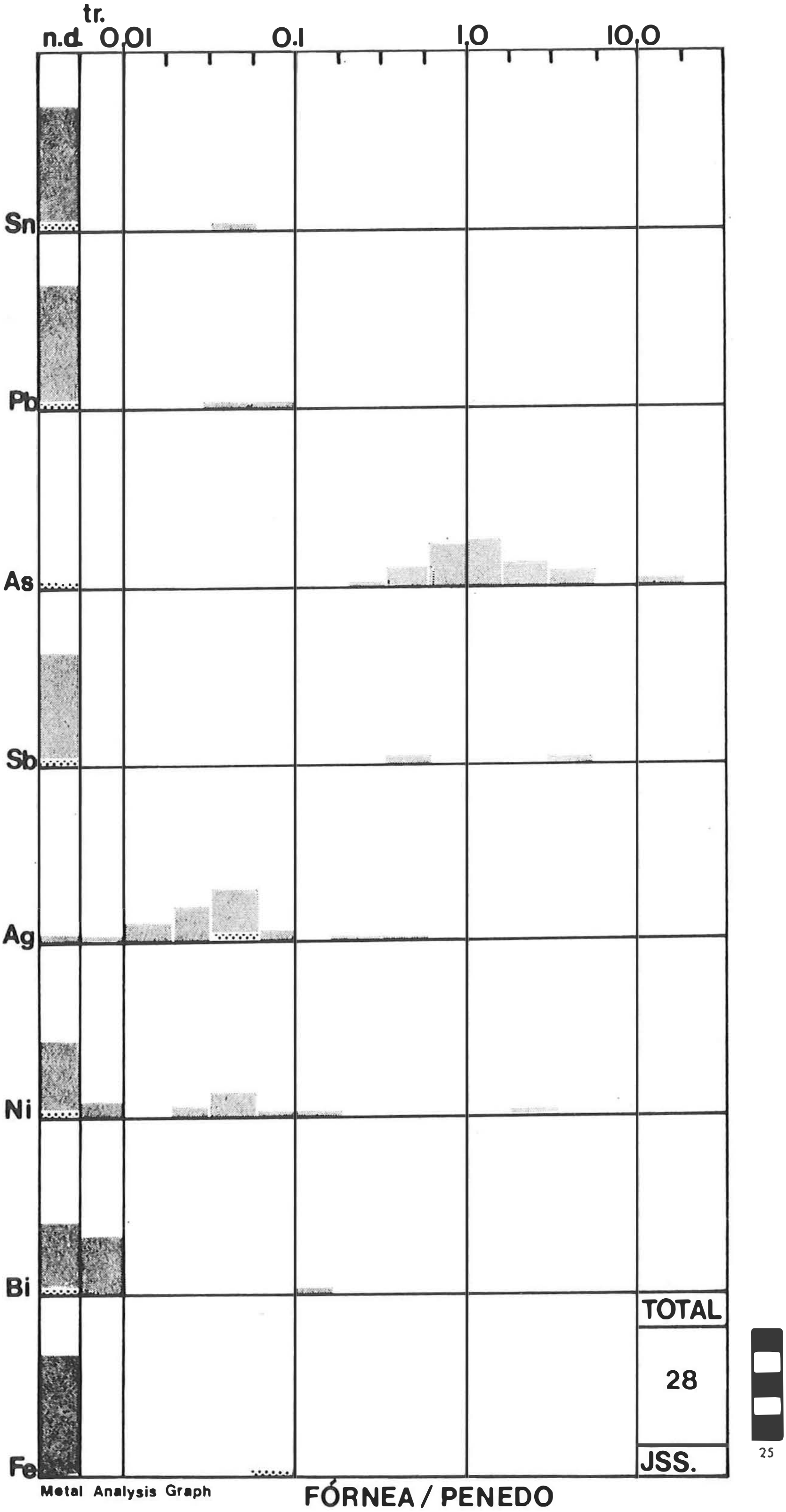
JSS.
Metal Analysis Graph
PALMELA

Chart 3



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10.0
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As
Sb
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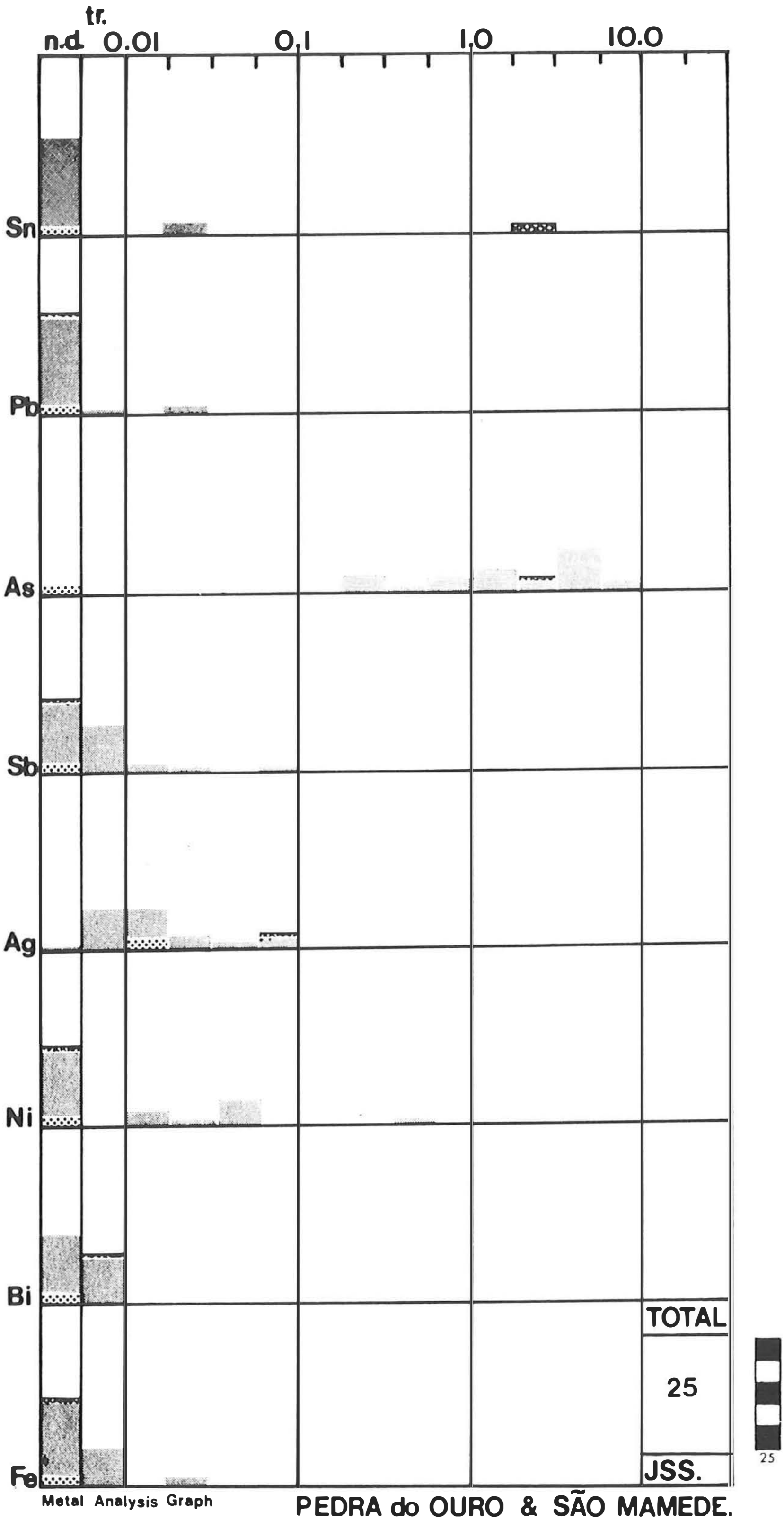
Ni
Bi
Fe
TOTAL
28
JSS.
25
Metal Analysis Graph
FÓRNEA / PENEDO

Chart 4



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10.0
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Pb
As
Sb
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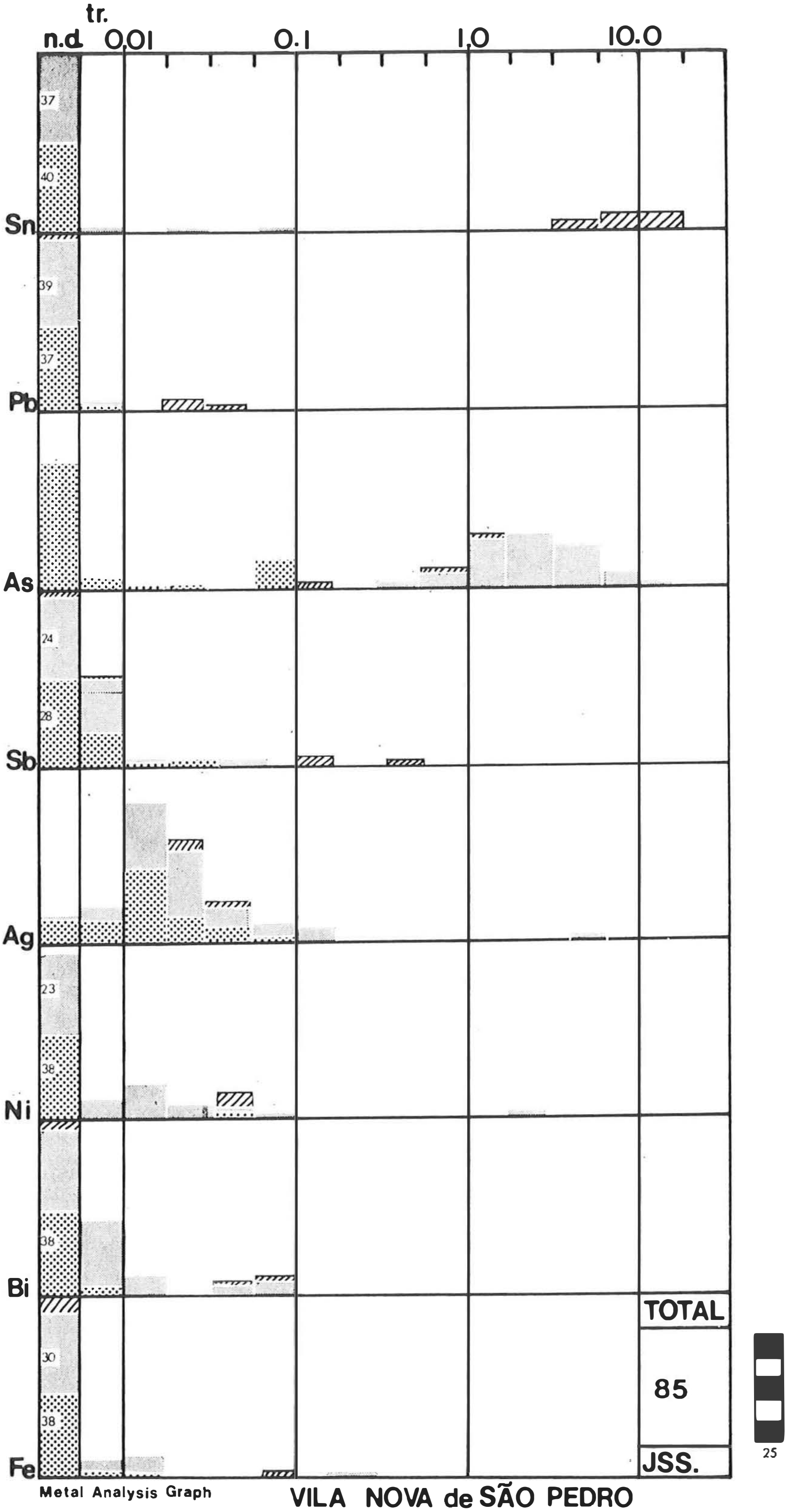
Ni
Bi
Fe
TOTAL
25
JSS.
25
Metal Analysis Graph
PEDRA do OURO & SÃO MAMEDE.

Chart 5



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Sb
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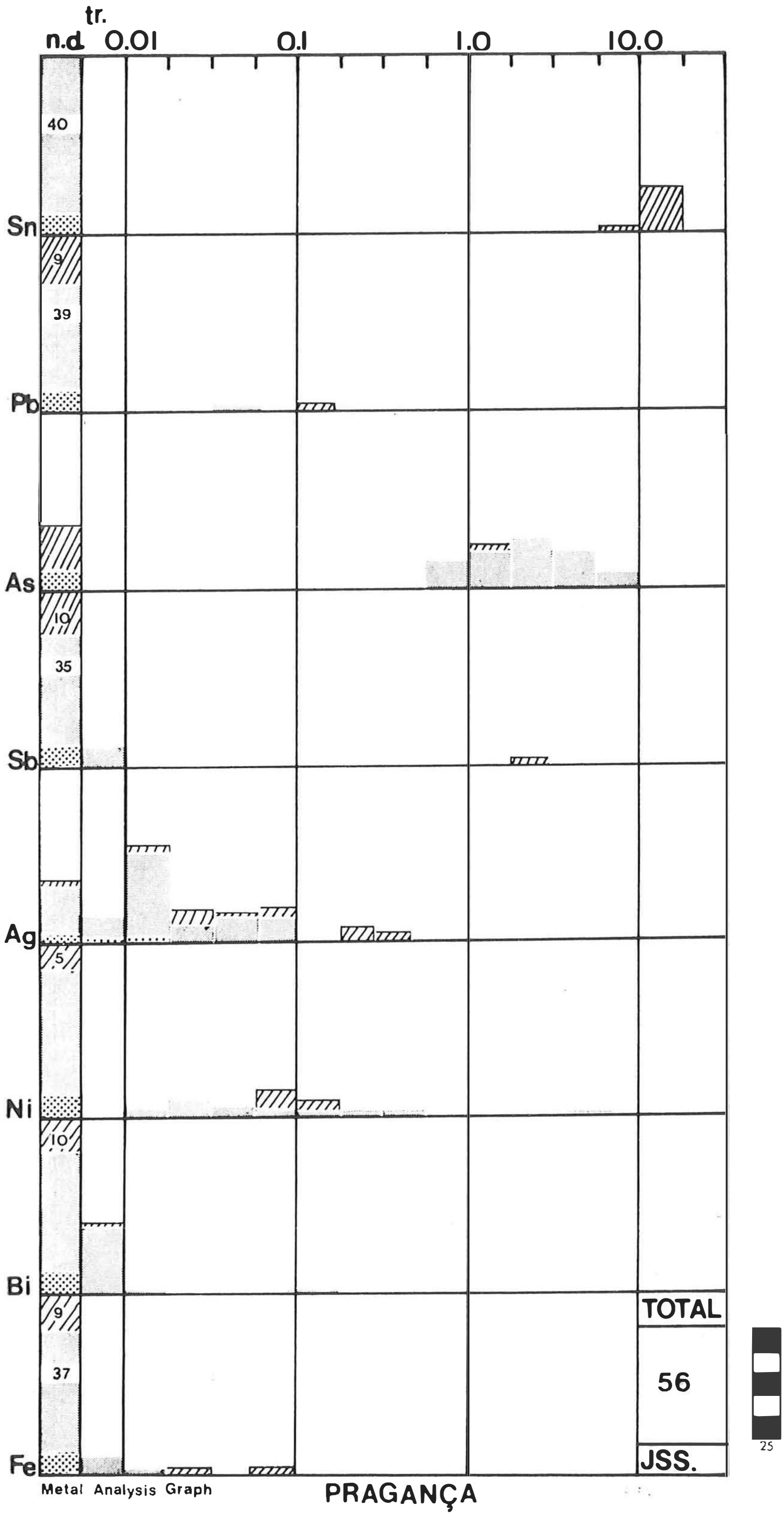
Ni
Bi
Fe
37
40
39
37
24
28
23
38
38
30
38
TOTAL
85
JSS.
25
Metal Analysis Graph
VILA NOVA de SÃO PEDRO

Chart 6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Ni
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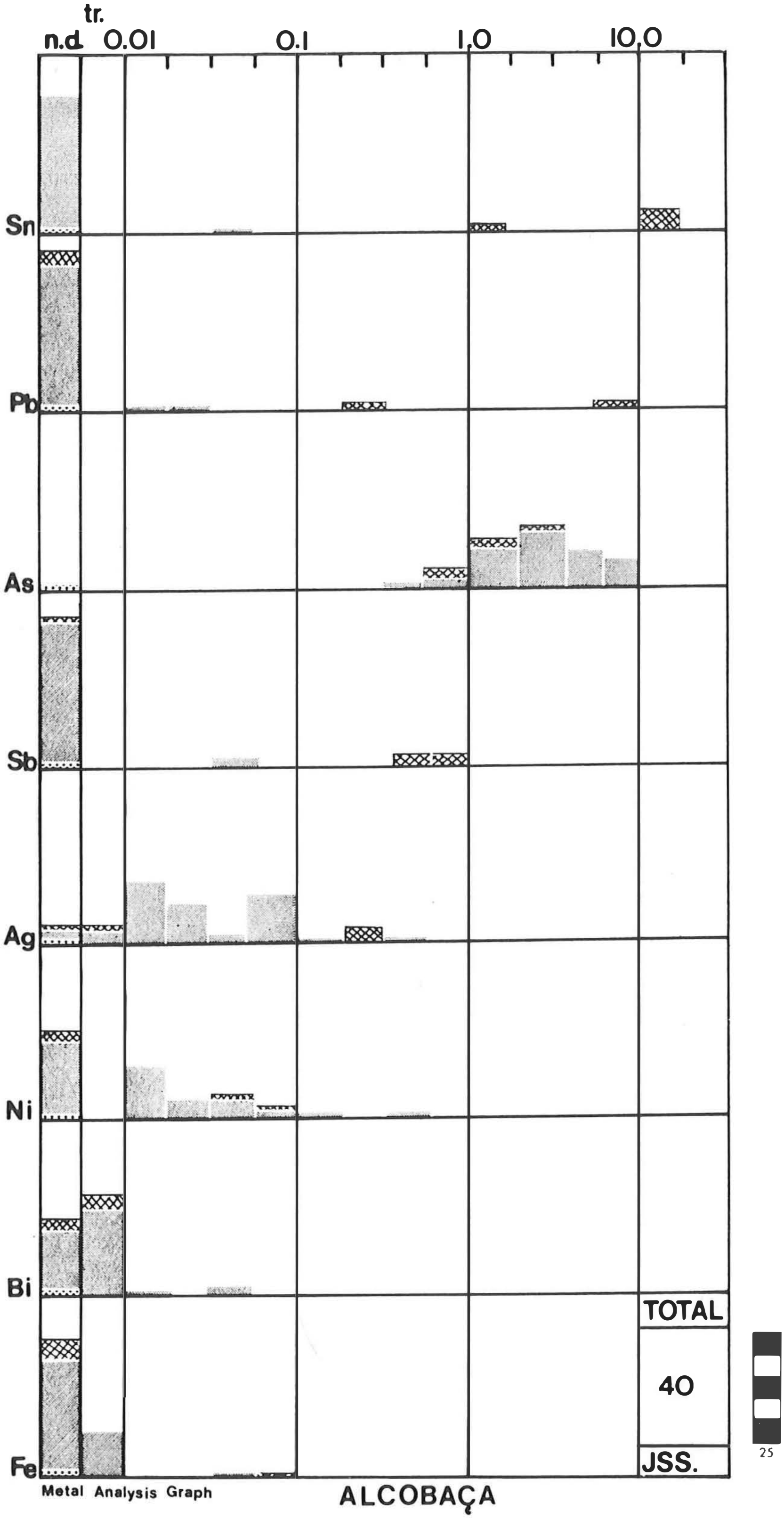
Bi
9
37
Fe
TOTAL
56
JSS.
Metal Analysis Graph
PRAGANÇA
25

Chart 7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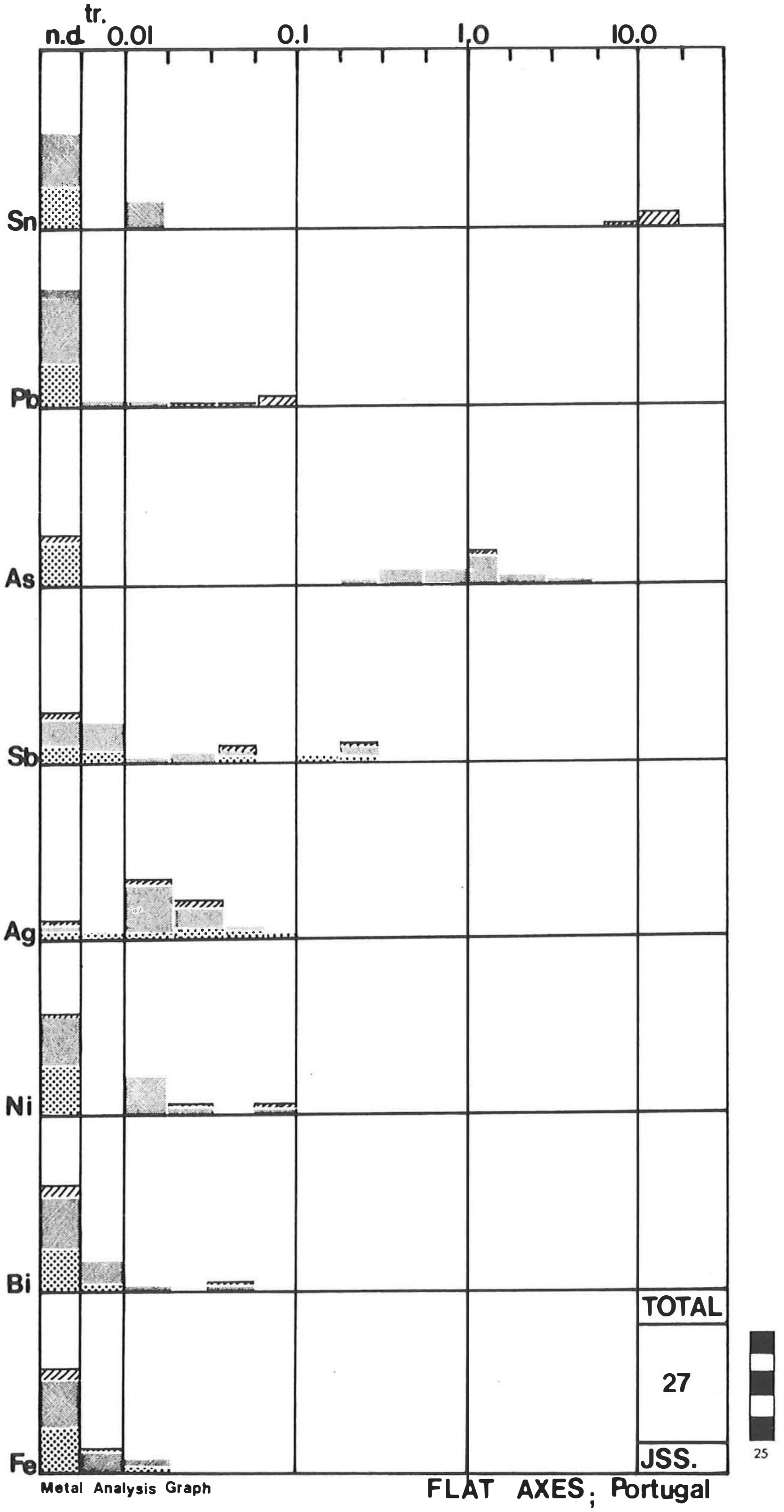
As
Sb
Ag
Ni
Bi
Fe
TOTAL
40
JSS.
25
Metal Analysis Graph
ALCOBAÇA

Chart 8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tr.
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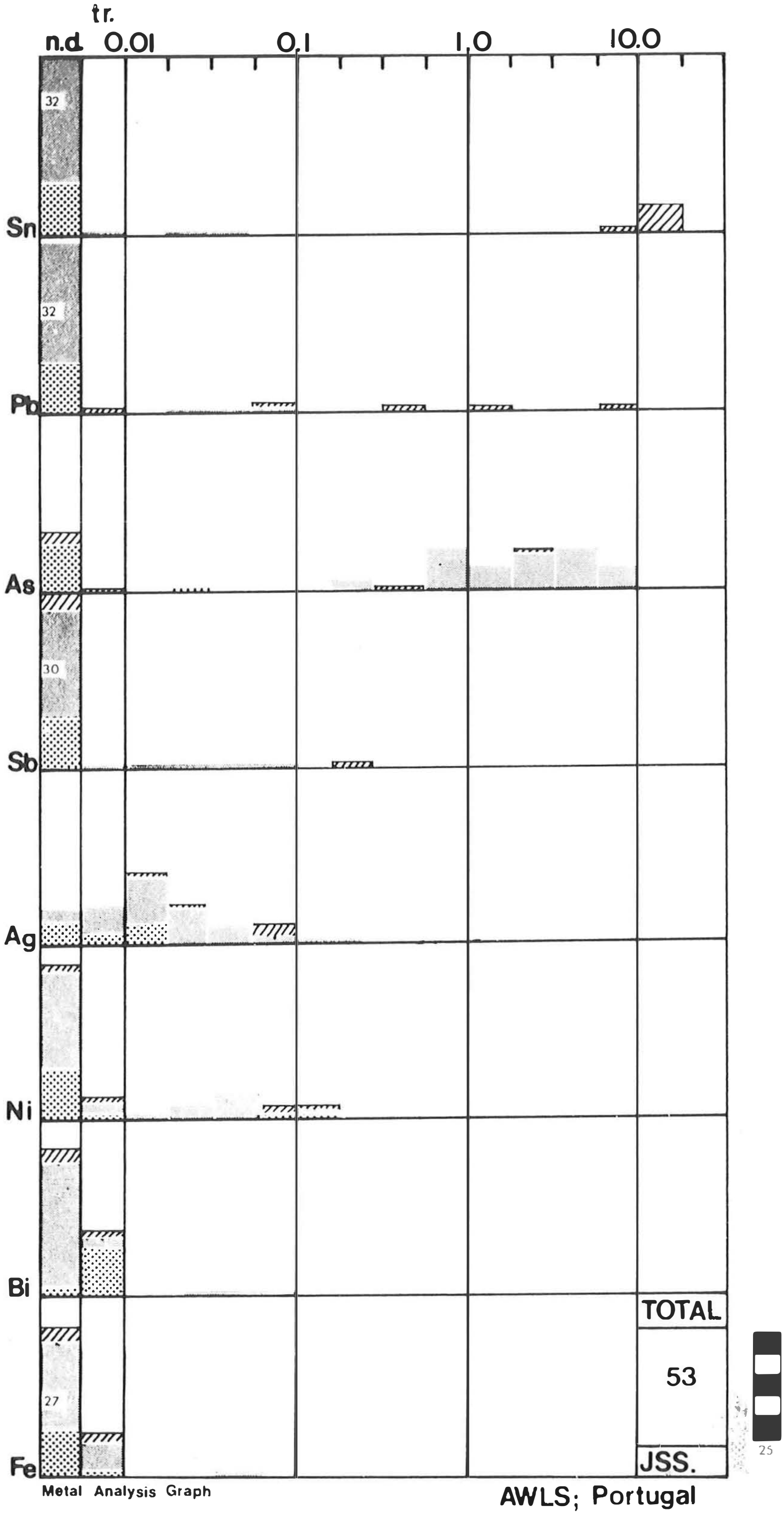
1.0
10.0
Sn
Pb
As
Sb
Ag
Ni
Bi
Fe
TOTAL
27
JSS.
25
Metal Analysis Graph
FLAT AXES; Portugal

Chart 9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n.d.
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10.0
32
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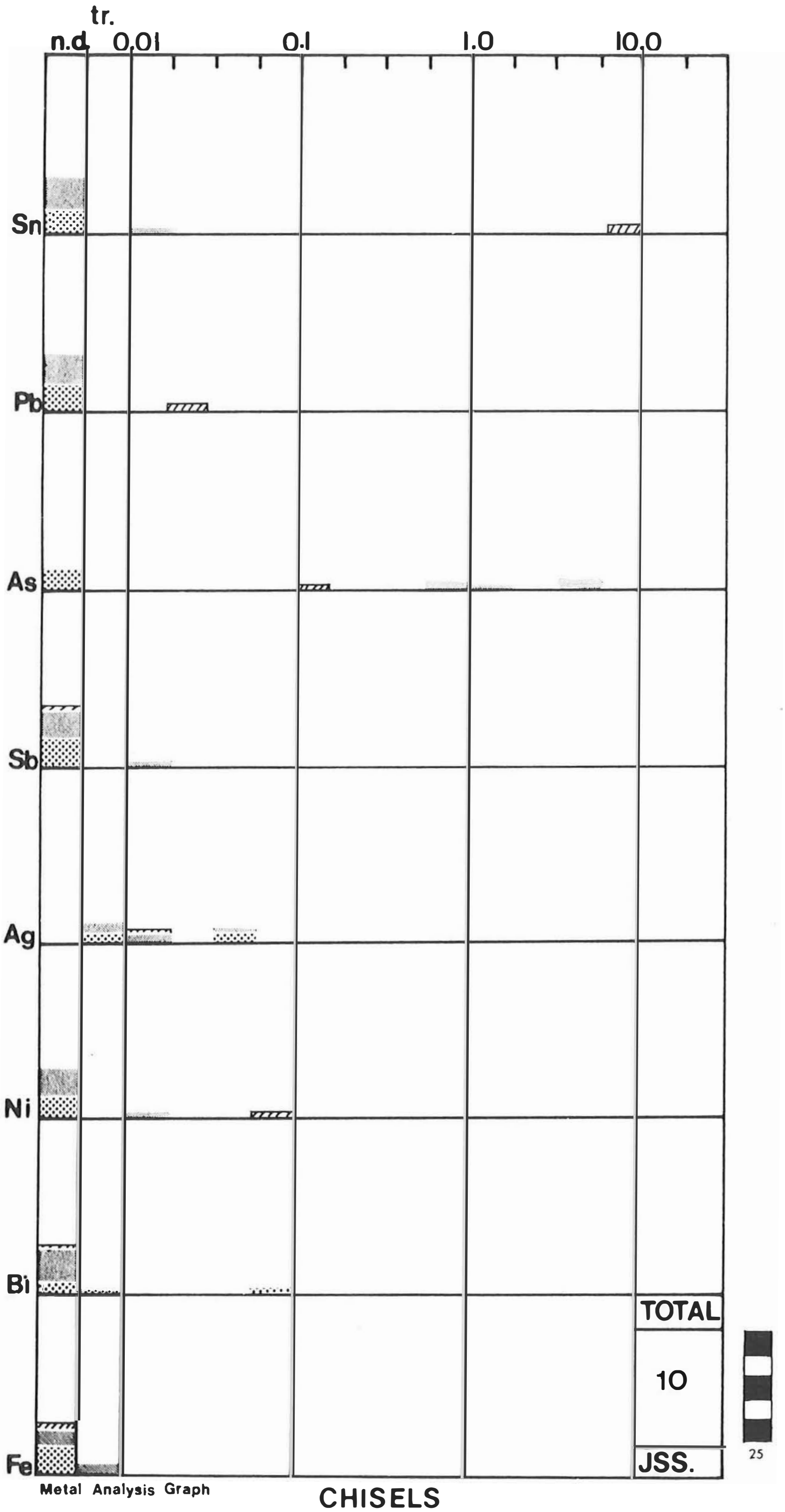
32
Pb
As
30
Sb
Ag
Ni
Bi
27
Fe
TOTAL
53
JSS.
Metal Analysis Graph
AWLS; Portugal

Chart 10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10.0
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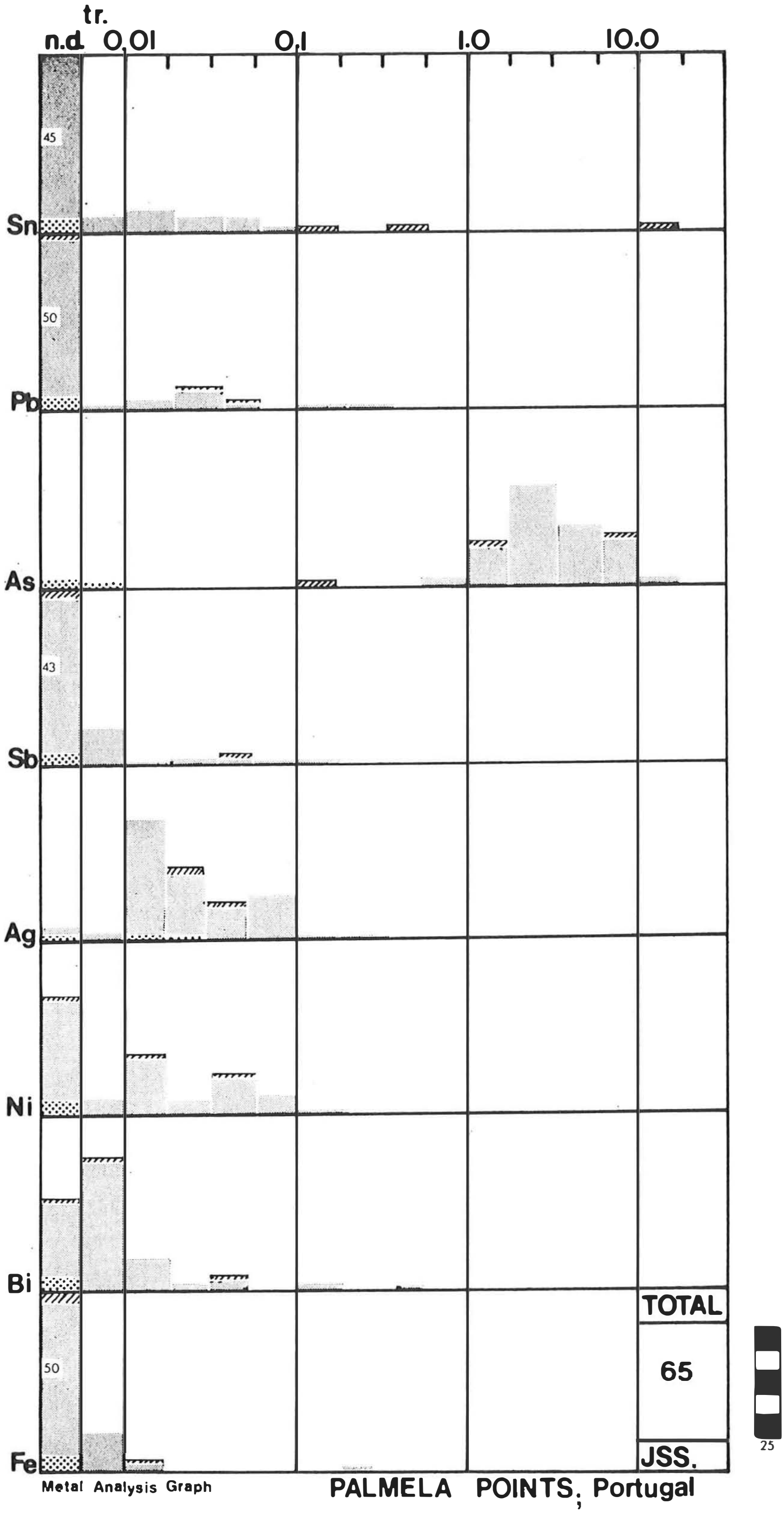
As
Sb
Ag
Ni
Bi
Fe
TOTAL
10
JSS.
25
Metal Analysis Graph
CHISELS

Chart 11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10.0
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Pb
As
Sb
Ag
Ni
Bi
Fe
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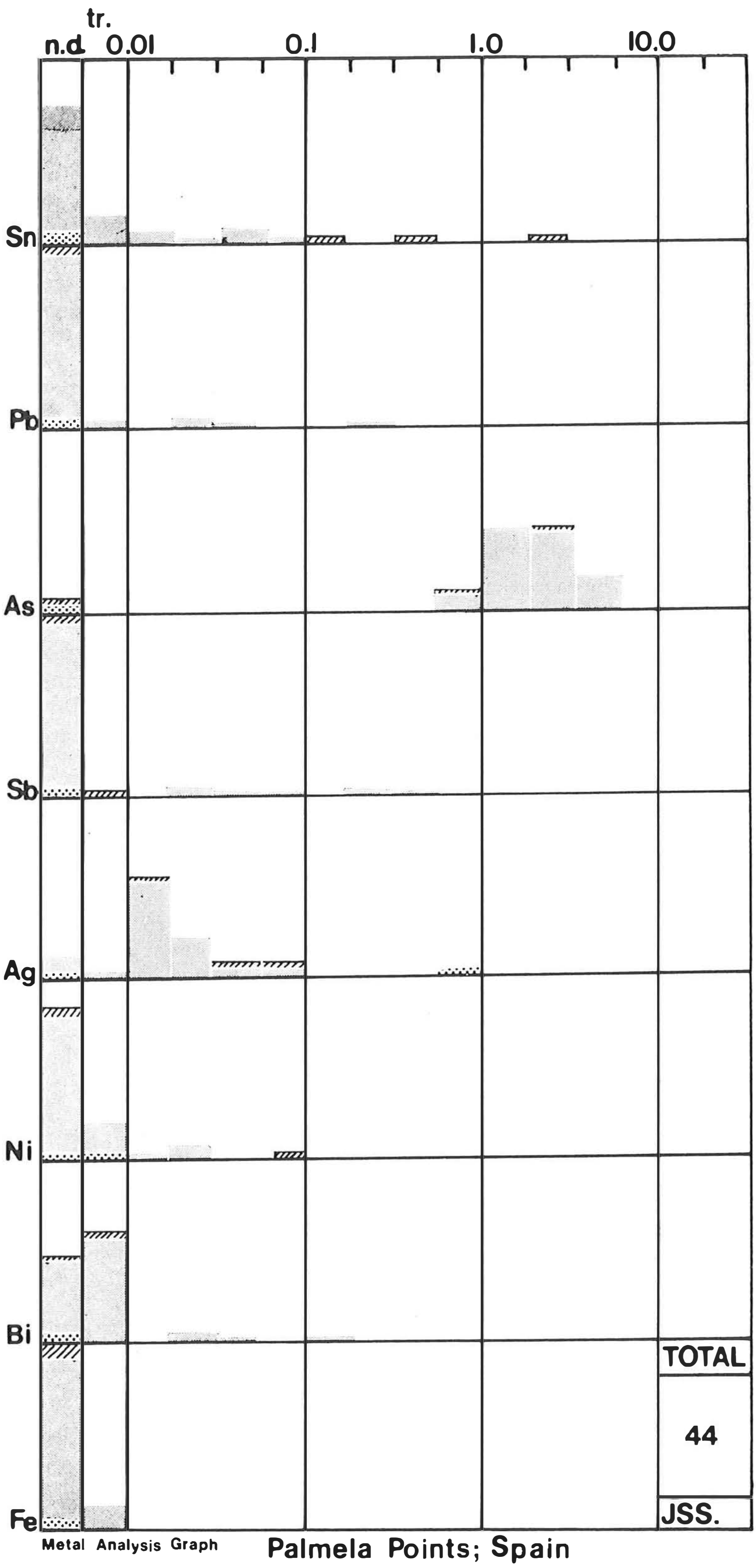
50
43
50
TOTAL
65
JSS.
Metal Analysis Graph
PALMELA POINTS, Portugal

Chart 12


tr.
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Sn
Pb
As
Sb
Ag
Ni
Bi
Fe
TOTAL
44
JSS.
Metal Analysis Graph
Palmela Points; Spain

Chart 13

APPENDIX III: NOTE ON THE AVAILABLE METALS IN THE TAGUS ESTUARY REGION

Copper

Jalhay and do Paço (1945:29) recovered over 13 kgs. of Limonite ore with Malachite encrustations from inside the Citadel of Vila Nova de São Pedro, and confirmed that it was not found locally. From wherever the ore did come from (Prof. Amilcar Mario de Jesús suggested the Alentejo), it would probably have yielded a relatively pure copper, possibly even the same type as our Metal 1.

The only known copper resources in the entire region occur near Óbidos (carbonate ores) and at the mines of Lousal and Caveira near Grândola (Veiga Ferreira, 1966:87). These last are of great interest as major sources of native copper, which may well have been exploited in VNSP and Beaker times. Not too distant are the very rich tombs at Palmela, and the settlements of Rotura and Chibannes, all with an abundance of copper.

Clearly, some trade or exchange network was established to provide the metal found on so many sites in the region, but in the absence of more data, the mechanics remain obscure.

Gold

Blance (1971: Maps 2, 3) locates at least 5 sites where gold could have been panned from alluvial deposits, all of which are not now commercially valiable. Possibly tin was recovered from the same alluvials as the gold, but the major deposits are farther north, in the Duero and Minho drainages (Map 5).

APPENDIX IV: LIST OF RAW MATERIALS KNOWN FROM VNSP SITES

Stones	*Ores*	*Other*
Limestone	Limonite	Shells
Soft Sandstone	Malachite	Jet
Sandstone	Copper	Amber
Granite	? Native Copper	Ivory
Basalt	? Gold	Mother of Pearl
Amphibolite	Manganese Ore	? Red Coral
Schist	Red Ochre	? Carnelian
Alabaster		
Callaïs		
? Jadeite		
? Nephrite		
Serpentine		
Flint		
Chert		
Rock Crystal		
Agate		
Hyalin Quartz (Milky White)		