Notes on the composition of pre-European copper and copper-alloy artefacts from the Transvaal

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SYNOPSIS

Seven copper artefacts (five ingots and two ornaments) found at prehistoric sites in the Transvaal were submitted to analysis. All the artefacts showed a high copper content and a relatively low level of impurities. A little-known ingot type from the Limpopo Valley ('nail' ingot) is described, and its analysis is given.

The analysis of two copper ornaments that come from sites dated to the 5th Century A.D. and the 11th Century A.D. showed the constancy of the composition of copper articles over long periods.

The well-known 'Blaauwberg Ingot' was re-analysed, and the results showed that this ingot cannot be regarded as a true bronze.

Analytical values for the composition of three brass artefacts from Bambandyanalo (Mapungubwe), Northern Transvaal, are given.

Some aspects of pre-European bronze manufacture and brass smelting, and of early metal trade from the East Coast into the interior of South Africa, are discussed.

SAMEVATTING

Sewe koperkunsprodukte (vyf gietblokke en twee ornamente) wat op prehistoriese plekke in Transvaal gevind is, is ontleed. Al die kunsprodukte het 'n hoë koperinhoud en 'n betreklike lae peil van onsuiwerhede gehad. 'n Taamlik onbekende tipe gietblok uit die Limpopovallei ("spykergietblok") word beskryf en sy ontleding word aangegee.

Die ontleding van twee koperornamente afkomstig van terreine uit die 5de en 11de eeu n.C. het gedui op die konstantheid van die samestelling van koperartikels oor lang tydperke.

Die bekende "Blaauwberg-gietblok" is weer ontleed en die resultate het getoon dat hierdie gietblok nie as 'n ware brons beskou kan word nie.

Analitiese waardes vir die samestelling van drie geelkoperkunsprodukte vanaf Bambandyanalo (Mapungubwe), Noord-Transvaal, word aangegee.

Sommige aspekte van die voor-Europese vervaardiging van brons en geelkopersmelting en die vroeë metaalhandel vanaf die Ooskus na die binneland van Suid-Afrika word bespreek.

INTRODUCTION

The recent Symposium on Ancient Mining and Metallurgy in South Africa, held in October 1973 in Johannesburg, has shown both the achievement and the shortcomings in these fields. As U. S. Küsel[1] pointed out, very little work has been done on the analysis and the micrography of pre-European metals since Professor G. H. Stanley laid the foundations of South African prehistoric metallurgy more than forty years ago. However, much material has in the meantime accumulated in South African museums, university departments, and local collections, waiting for investigation, interpretation and, of particular importance, for publication.

Many pre-European metal artefacts are preserved in the Archaeology Department of the University of the Witwatersrand, where, in addition to much material from recent excavations, the collections of the now defunct Archaeological Survey are kept. The collections contain a fairly representative range of iron, copper, tin, and brass artefacts, a number of which were recently submitted to analysis. The results of the analyses, together with some comparative results from the work of G. H. Stanley and other investigators, are given in Tables I to IV. (The numbers attached to various artefacts are the relevant numbers of the catalogues of the Archaeology Department of the University of the Witwatersrand.)

COPPER INGOTS OF THE SOUTH AFRICAN IRON AGE

Ingots generally are defined as 'masses of cast metal' (O.E.D.). The ingots described here and listed in Table I are of five different types: block ingots, hemispherical (bun) ingots, rod (nail) ingots, and two particular types, the Musuku and the Marale[2, 3]. No samples of the Rhodesian/Congo types—'cross' and 'capital I' shapes—have so far been found south of the Limpopo.

Block ingot 21/39/5, belonging to the Rooiberg collection and described by M. Baumann[4], was found at Smelterskop, near Rooiberg. The ingot has a slightly irregular, but basically rectangular, shape (approximately 50 mm by 35 mm by 20 mm). It appears to be a piece cut off from a larger copper bar. However, it is unlikely to be from a modern copper bar since the silicon content is very high (1,25 per cent); otherwise, the amount of impurities in this ingot is low (less than 0,1 per cent).

Professor Stanley analysed a hemispherical copper ingot from Pietersburg and found that the ingot had a copper content of 99,95 per cent.[5] Unfortunately, no other details are given for the specimen. It is likely that the 'bun' shape resulted from the melting of copper in a small clay pot or a hemispherical potsherd. The 'bun' type of copper ingot is very common in English specimens of the Roman period[6], and tin ingots from Rooiberg also have this shape.

Musuku and Marale ingots attributed to prehistoric Bantu copper workers in the Northern Transvaal have rather odd shapes that cannot be defined easily — so the Musuku are generally described as 'miniature top hats' and the Marale as 'miniature golf clubs'. Characteristic of both types are the excrescences resembling pegs or studs sprouting from ridges on the 'top' surface. The explanations given for the curious shapes of these ingots vary from those involving 'symbols of fertility' or 'a sacred

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TABLE I

ANALYSIS OF COPPER INGOTS FROM NORTHERN AND EASTERN TRANSVAAL

Catalogue No. Archaeology Department, University of the Witwatersrand	1/70	49/36/10	3/41/2	—	21/39/5	28/40
Site	Soutpansberg	Soutpansberg	Pilgrimsrest area	Phalaborwa	Rooiberg Smelters Kop	Schroda Limpopo Valley West of Messina
Description	Musuku 'Top Hat' Ingot	Marala 'Club' Ingot	Marala 'Club' Ingot	Marala 'Club' Ingot	'Block' Ingot	'Nail shaped' Ingot
Weight (grams)	2740	852	1093		239	15,4 (average)
Constituents:	%	%	%	%	%	%
Copper	Balance	Balance	Balance	99,38	Balance	98,18
Iron	0,01	0,92	2,35	0,45	0,01	0,006
Nickel	0,005	0,07	0,32	0,04	0,001	0,005
Tin	0,006	0,005	0,002	—	0,05	0,003
Lead	0,001	0,001	0,001	—	0,03	tr.
Arsenic	tr.	tr.	tr.	—	0,001	tr.
Silicon					1,25	tr.
Sulphur						1,06
Phosphorus						0,08
Analyst	McKechnie Brothers (S.A.) (Pty) Ltd, Germiston.			G. H. Stanley[5]	McKechnie Brothers, Germiston.	Metal Sales Co. (Pty) Ltd, Johannesburg.

cactus ceremonial' to those dealing with 'value patterns' of a barter currency, where the number of pegs indicates the trade value[2, 7]. The most likely explanation seems to be that given by Professor Stanley, who suggests that the copper bodies of the Musuku and Marale are the 'left-overs' of casting heads, and the pegs the remnants of long rods poured into holes drilled into the soil at the bottom of the moulding cups[8].

The analysis of the Musuku shows high copper values in each case. Two Musuku specimens analysed by Professor Stanley[5] gave copper values of 98 per cent and 98,5 per cent respectively. Similar high values have been found for the Marale and Musuku ingots listed in Table I. Both types contain substantial amounts of iron and some nickel, but are practically free from other metallic impurities.

In the Limpopo Valley, still another type of ingot is found, resembling copper nails, about 50 mm long and 5 to 6 mm in diameter, ending in a thick, roundish head. A hoard of 35 such copper nail-ingots (catalogue No. 28/40) is preserved in the Archaeology Department of the University of the Witwatersrand. The label attached to one of these 'nails' reads:

Copper ingots for wire making cast in holes in mounds. Venda Kopje opposite Schroda across Limpopo, S. Rhodesia, August 1937.

A note in G. A. Gardner's book, *Mapungubwe*[9] refers to these ingots:

> [On Venda Kopje across the river, about two miles from Mapungubwe, west of Messina] rods of copper were common and had been cast in a wet sandheap into which sticks had been thrust, the molten copper then poured in, and, overflowing, producing large-headed, nail-like objects.

I. M. Allen, who reported on two specimens of this type exhibited in the Rhodesian National Museum[10], submitted one of the specimens to H. H. Coghlan, the well-known English authority on primitive metallurgy, for examination. Coghlan found the copper of the specimen 'extremely pure, much purer than in the usual native smelt' and concluded that these objects were made from native copper (metallic copper) probably used by Lemba coppersmiths.

The high purity of these 'nail-ingots' has been confirmed by the analysis of a specimen from the hoard preserved at the University of the Witwatersrand (Table I). The copper content (98,18 per cent) of the nail-ingots is similar to that found in a number of Musuku and Marale ingots (Table I). The metallic trace impurities are low, but non-metallic impurities (sulphur and phosphorus) are relatively high.

It is not necessary to postulate, for the making of the ingots, the use of native copper, which is rare in nature and occurs only in small amounts in the Messina area. It appears that such nail-ingots were made by the process used by the BaVenda or BaLemba of the Northern Transvaal. H. Stayt[2] gives some notes on this process, recording that cobbled ore (probably malachite) was heated in a kiln charged with charcoal and dry leaves. The reduced copper was re-smelted in potsherds and poured out into holes drilled into the ground with sticks.

COPPER ORNAMENTS OF THE SOUTH AFRICAN EARLY AND MIDDLE IRON AGE

The copper ingots described so far may not be older than one or two centuries because the 'ancient' smelters of Messina and Phalaborwa were still working in the mid-19th Century, just before the arrival of the European settlers in the Northern and Eastern Transvaal[11]. However, some copper ornaments found at excavation sites have been dated to the 5th Century A.D. (Broeder-

TABLE II
ANALYSIS OF COPPER ORNAMENTS

Catalogue No. Archaeology Department, University of the Witwatersrand	24/73D		19/70 (L 125)
Site	Broederstroom site 24/73 near Hartbeespoort Dam, Transvaal.		Bambandyanalo K2 site (near Mapungubwe Hill) Soutpansberg District, Northern Transvaal.
Description	Chain formed by eleven links		Finger ring
Weight (grams)	10,8		26
Analysis	1	2	
Sample taken	Unpickled	Pickled	Pickled
Constituents:	%	%	%
Copper	Balance	Balance	Balance
Tin	0,0018	0,0029	0,0048
Lead	0,0025	0,0035	0,0012
Iron	0,40	0,05	0,0016
Aluminium	Present	Trace	—
Nickel	0,040	0,042	0,017
Antimony	0,0011	< 0,0009	< 0,0009
Arsenic	< 0,0009	< 0,0009	< 0,0009
Silicon	Present	0,005	—
Zinc	< 0,001	< 0,001	< 0,0010
Bismuth	< 0,0009	< 0,0009	< 0,0009
Analyst	McKechnie Brothers S.A. (Pty) Ltd, Germiston, Transvaal.		

stroom near Hartbeespoortdam)[12] and to the 11th Century A.D. (Bambandyanalo K2 site, west of Messina)[9] (Table II). They thus belong to the South African early and middle Iron Age, which extends approximately from the 4th Century A.D. to the 15th Century A.D.

At Broederstroom a beautiful little copper chain (catalogue No. 24/73) has been found, of which the analysis is given in Table II. The chain links, made of an almost pure copper, contain some iron and nickel but otherwise have a very low content of impurities.

From the famous Bambandyanalo K2 site comes the solid spiral-wound copper finger ring, whose composition is also given in Table II. The analysis of the ring, which was found just above bedrock at a depth of 7 ft, shows again a very low level of impurities and a correspondingly high copper content. It appears that the smelting process of the pre-European South African copper workers was as well designed and controlled as that of the ancient smelters of Sumeria, Egypt, and Cyprus, where practically pure copper was manufactured more than 4000 years ago[8].

BRONZE ARTEFACTS FROM PRE-EUROPEAN SOUTHERN AFRICA

There are numerous reports on bronze artefacts found at prehistoric sites, one of the earliest being given by H. Lichtenstein, who travelled amongst the Bechuanas in 1803-1805[13]. Lichtenstein gave one of the massive copper armlets worn by the Bechuanas to Dr Klaproth, an outstanding German chemist, for examination. Klaproth reported that 'this metal consists of 93 parts copper and 7 parts tin and is therefore very similar to the Chaldaean bronze'.

G. Caton-Thompson found a number of ancient bronze articles at Zimbabwe and other Rhodesian ruin sites. The analysis of these objects showed an average tin content of 10,1 per cent, a value typical for true bronzes[14]. Some bronze artefacts were also found at archaeological sites in Natal, e.g. a bracelet from Brotherton Shelter, described by P. Beaumont[15].

It is, of course, possible that bronze ornaments or the alloys used for them were obtained by barter and resmelted by the prehistoric South African metal workers. Stone crucibles and claysherds with remains of copper-tin smelts sticking to their walls have been found at sites at Zimbabwe[14], Rooiberg[16], and in the Orange Free State[17].

Jan van de Capelle, an official of the Dutch East India Company, reported in 1723 that the natives living inland of Delagoa Bay (perhaps in the Eastern and Northern Transvaal?) alloyed copper with tin[18]. Robert Moffat in 1827 was shown, by a Hurutshe coppersmith from Kurrechane, how to smelt copper and tin in a crucible for making wire[19].

It is likely that ancient trade routes, however tenuous, existed between the interior of the Transvaal and the East Coast of Africa, and perhaps also to the countries to the west and north. Reports of the art of bronzemaking in far-away countries may have reached the people of the Central Transvaal. Apparently some of the metal workers there tried to make bronze, but were unfortunate in the choice of ores, which contained much nickel, arsenic, and iron, and in the proportioning of the metals in the smelt. This is the conclusion reached in the interpretation of the analysis of samples of copper-tin alloys from the Rooiberg area. A number of these samples contained less than 1 per cent tin, a content deriving most probably from impurities in the ores used.

Four samples analysed by Stanley[8] and Wagner[16] showed a copper content of 76 to 84 per cent and a tin content of between 1,5 and 3,5 per cent — values very different from standard bronze compositions, which vary from 5 to 15 per cent tin. Furthermore, these samples have a very high arsenic content (11 to 19 per cent). Arsenic was occasionally used to harden bronzes, but in African primitive metallurgy it is almost certainly an impurity derived from pyrites, copper—nickel ores, etc. An arsenic content of more than 10 per cent could make bronzes rather brittle and therefore useless.

TIN—COPPER ALLOYS FROM ROOIBERG

There were, up to now, two analysed specimens from Rooiberg—the well-known 'Blaauwbank ingot' and the 'Frobenius pellet', which were generally regarded as true bronzes (Table III).

The 'Blaauwbank ingot' was found on a small slag heap on the farm Blaauwbank near Rooiberg Mine. The ingot, whose shape somewhat resembles a slightly bent finger, is now in the Archaeological Collection of the University of the Witwatersrand. The label attached to the ingot gives some details and values of the analysis (first published in 1912 in a report by T. G. Trevor[20]). From there, this analysis has found its way into many of the publications on South African pre-European metallurgy and has since been used as the main evidence for prehistoric bronze smelting in South Africa. However, this so-called bronze appears, as Stanley remarked in 1912, to be 'a most peculiar product', and re-analysis of this ingot was thought advisable. The results of the original analysis and of the recent re-analysis by atomic-absorption spectroscopy on two samples are given in Table III. The results disagree completely. It appears from the recent analysis that the Blaauwberg ingot falls into the range of the alloys of low tin content (1,5 to 3,5 per cent) mentioned earlier in this paper. The arsenic content is fairly high (approximately 3 per cent). The ingot is not a uniform product as the different zinc contents of the two samples, one drilled from the head of the ingot and the other through the centre, show.

The 'Frobenius Gusstropfen' is a small copper—tin pellet that was found by Professor L. Frobenius in 1928 at the Smelterskopje site near Rooiberg[21]. The analysis of this pellet is given in Table III. The pellet has a high iron content, but is otherwise relatively free from impurities. The tin content is unusually high (21,2 per cent). The material forming the pellet may have flowed out through a crack in the smelting crucible before the bronze was properly alloyed, but it represents a near approach to true bronze.

TABLE III

ANALYSIS OF COPPER-TIN ALLOYS FROM ROOIBERG (TVL)

Catalogue No. Archaeology Department, University of the Witwatersrand	21/39 (L 6)			
Site	Blaauwbank near Rooiberg Tin Mines, Waterberg District, Transvaal			Smelterskopje, near Rooiberg Tin Mines
Description	Unformed slug			Pellet
Weight (grams)	86			
Analysis	1	2	3	
Sample taken	Cut from surface	Core drilled from head	Core drilled through centre	
Constituents:	% (approx.)	%	%	%
Copper	80	Balance	Balance	74,07
Tin	7	1,45	1,56	21,23
Lead	—	< 0,01	—	0,43
Iron	{5	0,63	0,63	3,52
Aluminium		Traces	—	—
Nickel	3	0,04	0,04	0,25
Antimony	—	0,08	0,09	—
Arsenic	2	3,06	2,97	—
Silicon	3 (gangue)	0,02	—	—
Zinc	—	0,58	0,02	traces
Bismuth	—	0,01	—	—
Analyst	G. G. Hewitt 1910.	McKechnie Brothers S.A. (Pty) Ltd, Germiston		E. H. Schulz, Dortmund (Germany)
Literature	G. Trevor[20], p. 272			Leo Frobenius[21], p. 288

TABLE IV

ANALYSIS OF BRASS ORNAMENTS FROM BAMBANDYANALO SITE (NEAR MAPUNGUBWE HILL), SOUTPANS DISTRICT, NORTHERN TRANSVAAL, AND FROM ZIMBABWE, RHODESIA

Catalogue No. Archaeology Department, University of the Witwatersrand	19/70 (L 134)	19/70 (L 10)	19/70 (L 17)	—
Site	Bambandyanalo 'Treasure Pot'	Bambandyanalo 'Treasure Pot'	Bambandyanalo 'Treasure Pot'	Zimbabwe (Rhodesia) Acropolis
Description	Bangle made from spiral wire	Fragment from spiral wire 1 mm dia.	Bangle made from rod 4,5 mm dia. B.W. Gauge No. 7	Brass wire A 4 — No. 39
Constituents:	%	%	%	%
Copper	66,9	64,6	65,3	63,8
Tin	0,01	0,01	0,01	Nil
Lead	0,71	0,58	0,56	—
Iron	0,03	0,04	0,03	0,04
Aluminium	Trace	Trace	Trace	—
Nickel	0,03	0,02	0,03	Nil
Antimony	0,004	0,003	0,003	
Arsenic	0,004	0,003	0,004	
Magnesium	Trace	Trace	Trace	
Silicon	< 0,01	< 0,01	< 0,01	
Cadmium	0,04	0,036	0,024	
Zinc	Difference (32,26)	Difference (34,7)	Difference (34,03)	36,1
Bismuth	0,01	0,01	0,01	
Analyst	McKechnie Brothers S.A. (Pty) Ltd, Germiston, Transvaal.			
Literature				G. Caton-Thompson[14] p. 211.

From the evidence available so far, it does not seem that there was much skilled smelting and working of bronze in the Transvaal before the arrival of the Europeans. If bronze was manufactured at all intentionally it was done on a small scale and in a haphazard way. However, the Rooiberg area, where nearly all the tin used in prehistoric South Africa was mined, and where much smelting of metals was done, is archaeologically not well explored, and more intensive excavations there could still give a new picture of pre-European copper and bronze technology.

BRASS ARTEFACTS FROM BAMBANDYANALO AND ZIMBABWE RUINS

Three artefacts, labelled 'Treasure Pot Bambandyanalo', were analysed. The artefacts were presented to the Archaeological Survey in the 1930s and are now part of the Department of Archaeology's collection. It is known that these objects were found by G. A. Gardner, or one of his assistants, when he excavated at Bambandyanalo in 1934-36[22], but no information on the exact locality, associations, or age is available.

The 'Treasure Pot' contained, besides a few rusted iron objects and many glass beads, a number of non-ferrous artefacts, among them a solid bangle, several armlets made from spiral wire, and numerous fragments of wire. The analysis of three of these artefacts showed that they were made from brass (Table IV). Their copper and zinc contents correspond closely to the composition of standard brass (one-third zinc, two-thirds copper). Metallic impurities are low, with the exception of lead (0,56 to 0,71 per cent). The intentional addition of lead to brass was fairly usual in the past, e.g., substantial amounts of lead are found in English medieval brasses[6] and in the brass statuettes of West Africa (Benin)[23]. It is also known that the BaLembas of the Soutpansberg (living near the Mapungubwe sites) added lead, obtained from the Portuguese, to their copper to make a softer material for wire-drawing[2]. The uniformity of the composition of the three artefacts analysed and their similarity to a specimen of brass wire found at Zimbabwe (Table IV) are remarkable.

In reporting the finds of pre-European metal objects, one of the most interesting problems is always whether they were locally produced or imported. In the case of brass artefacts, the indigenous manufacture of brass from ore can almost certainly be excluded. Brass making by the old pre-industrial 'calamine process' was a rather sophisticated method, unknown in the primitive technology of Southern Africa. Even more difficult is the extraction of pure zinc metal from an ore. In Europe, commercial quantities of zinc were not available before the 18th century, although they were available somewhat earlier in China and perhaps in India[24].

However, there is some evidence that rough zinc ingots have been dug up at old African villages in the Pilansberg area. T. G. Trevor reported on such finds and he exhibited also, at a meeting of the Chemical, Metallurgical & Mining Society, a zinc ingot weighing 15 lb, found in a cave near Chuniespoort, Transvaal[25]. Unfortunately, no detailed information on these ingots is available. It is possible that imported zinc metal and locally produced copper were melted together by primitive African smiths. An interesting indication of the presence of a copper alloy is given by the analysis (X-ray fluorescence scan) of the vitreous glaze sticking to a stone crucible found at an Iron Age site at Harrismith (O.F.S.). The level of intensity for the copper, zinc, and tin present in this glaze is given as very strong[17]. Another possibility for the making of brass ornaments by primitive South African smiths was, of course, the re-smelting of bartered brass ingots or other brassware.

Not much definite information is available on the trade and barter of brass in pre-industrial Southern Africa. One of the difficulties in the interpretation of early reports is the ambiguity of the word *brass*. Whereas in modern usage *brass* means an alloy of copper and zinc containing approximately 30 per cent zinc, up to the 18th century *brass* was a general name for all alloys of copper with tin or zinc and other base metals (O.E.D.). The missionary-traveller, R. Moffat, wrote in 1827 that he had seen a smith in Bechuanaland making 'brass' out of copper and tin[19].

However, it is likely that the brass (geelkooper) mentioned in a report (1723) by Van de Capelle, an official of the Dutch East India Company at Delagoa Bay, was true brass. The report states: 'The Ronga chose to sell their ivory and amber to the English, whose brass goods they preferred to the heavy copper brought by the Dutch'[26]. This report by Van de Capelle also gives an interesting hint on how English brass could have come to the Northern Transvaal. The Ronga, a group of the Tsonga people, lived in the area extending inland from the East Coast (Delagoa Bay). In his book *The Copper Miners of Musina*, Van Warmelo draws special attention to the VaRhonga, 'the people living in the south east' (of the BaVenda). 'These folk were of great service to the Venda country, for they were smiths, artisans and craftsmen from the earliest days'[27]. BaVenda people lived at or near Mapungubwe, so a trade connection from there to the East Coast is quite likely. There are, of course, also early links between Mapungubwe and the Zimbabwe and Khami cultures to the north—another route by which brass could have found its way to the 'Treasure Pot' of Bambandyanalo.

The available evidence on the origin and the age of the Bambandyanalo brass artefacts is rather scant and circumstantial, and does not allow one to draw any safe conclusions, but there is a possibility that these artefacts were made from brass rods or other brassware brought, perhaps in the 17th or 18th century or even later, by barter from the East Coast to the BaVenda people and their neighbours living near the Limpopo.

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Courses on X-ray spectrometry and X-ray powder diffraction

Two two-week courses on the above topics are to be held at the State University of New York, Albany.

The first will deal with X-ray spectrometry and will run from 26th May to 6th June, 1975. The course will be instructional and will develop the basic theory and techniques starting from elementary principles. The first week will cover basic principles and techniques, and the second week will continue with further fundamentals and practical applications. Emphasis in the second week will be placed on advanced principles and techniques, absorption-enhancement corrections by mathematical methods, computer automation of modern X-ray spectrometers, and energy-dispersive methods.

The second course, that on X-ray powder diffraction, will run from 9th to 20th June, 1975. The course will be tutorial in nature, and will develop the basic principles and practical applications starting from elementary considerations. The first week will cover principles and practice of instrumentation, specimen preparation, identification of powder patterns including complex phase identification, and practical considerations on the use of the several indices with emphasis on computer retrieval and computer-assisted identification. The second week will cover qualitative identification of powder patterns in greater depth, quantitative analysis of polycrystalline mixtures of two or more phases, the rudiments of crystallography, powder-pattern indexing, and other topics in depth.

No previous knowledge or experience is required for either course. Equal time will be devoted to lectures, and to laboratory problem-solving sessions. The registration fee for each course is $345,00 for either week, or $650,00 for the entire two-week session, payable in advance. For further information and to register, communicate with Professor Henry Chessin, State University of New York at Albany, Department of Physics, 1400 Washington Avenue, Albany, New York 12222, U.S.A.

Book review

Fox, W. *Tin: The working of a commodity agreement.* London, Mining Journal Books, 1974.

This book is a comprehensive and detailed account of the history of the various commodity agreements on tin from the turn of the century until the present.

The author, through his many years of experience and involvement in the politics and mechanics of tin control, brings an unrivalled insight to the subject. In particular, he describes recent changes in the technical, economic, and political context of mining in each of the major producing countries, and analyses the history of the international attempts to stabilize the world price of tin as a raw material. The geographical and economic aspects of the industry are also covered.

It is a book to be read by all those concerned with the mining, marketing, and consumption of tin, and indeed those concerned with the pricing and marketing of all metals and other commodities in the future.

D.A.V.

Papers of interest

The following papers may be of interest to readers:

The control of maintenance in a large telecommunications transmission network, by S. V. W. Clarke. *Trans. S. Afr. Inst. Elect. Engrs.*, Nov. 1974.

Some applications of ergonomics in the South African mining industry, by C. H. van Graan. *S. Afr. Mech. Engr*, Nov. 1974.

NIM reports

The following reports are available free of charge from the National Institute for Metallurgy, Private Bag 7, Auckland Park 2006.

Report No. 1679

The detection of noble-metal impurities in refined noble-metal solutions by thin-layer chromatography.

Rapid semiquantitative thin-layer chromatographic techniques have been developed for the determination of noble-metal impurities during plant-scale purification of individual noble metals. Silica gel G was used as the adsorbent, and, where reversed-phase elution chromatography was employed, silica gel containing a binder was used. Impurities in rhodium, iridium, and ruthenium solutions were separated by the use of 5 N hydrochloric acid as the stationary phase and a mixture of tri-n-butyl phosphate and toluene as the eluant. Impurities in gold and palladium were separated by the use of tri-n-butyl phosphate and iso-octyl thioglycolate, respectively, as the stationary phase, and hydrochloric acid solutions as the eluant. After separation, the impurities were located by spraying with rubeanic acid solution, and were determined by visual comparison with standard plates.

The determination of impurities in platinum solutions failed, owing to the lack of a selective extractant for these solutions.

Report No. 1684

The application of three-phase liquid-liquid extraction to the separation and concentration of noble metals.

The procedure for a three-phase extraction system using the reagent diantipyrylmethane is described. The third phase, which is organic and of low volume, is formed beneath the normal organic phase of the conventional two-phase extraction system. The noble metals are extracted in the form of their thiocyanate complexes into the third phase from hydrochloric acid solutions.

Platinum, palladium, ruthenium, and gold are extracted quantitatively, the extraction of rhodium is 91 per cent, and iridium is not extracted. Nickel, aluminium, and chromium are not extracted to any extent, and iron and copper are coextracted.

This procedure affords a rapid means for the concentration of the noble metals, which can subsequently be determined direct by conventional techniques.