THE BEGINNING OF THE USING OF ZINC IN CHINA.

BY H. T. CHANG

In my work, Lapidarium Sinicum,[1] the chapter on brass is specially devoted to this inquiry. Recently Dr. Read of the U. S. Bureau of Mines wrote to Dr. Ting, suggesting the question whether "The knowledge of zinc-smelting in India is previous to that developed in China." Therefore I have asked Mr. P. L. Yuan to translate the chapter on bronze into English in complete version. Now I wish again to point out the fact that the knowledge of zinc-smelting in China was developed independently and not obtained from any another country outside.

Prof. P. Neogi of Government College at Bajsahn said that according to "Sanskrit books of the twelfth and thirteenth centuries," India was the first country to discover the processes of smelting zinc. Prof. Neogi also said that in the seventh century there were already records of zinc-smelting, only that zinc was not regarded as a metal. In the fourteenth century its metallic property became more known and not until sixteenth century every one knew that it is a kind of metal.

But, Dr. Laufer deeply believes that it is the Arabs who first developed the process of zinc-smelting. In his book, Sino-Franica, he did not prove by any records that the process of smelting zinc in China is derived from India.

Now if we want to investigate the history of the using of zinc in China alone, it is best to search for evidences after the Three Dynasties (三代 2205-255 B. C.). The Three Dynasties were in the Bronze Age of full development. But what they used was the so-called Chingt'ung or Hsiang-t'ung, an alloy of copper and tin. According to the six varieties recorded in the chapter on K'aokungchi (考工記) of Chowli (周禮), their percentages are recalculated as follows:

Variety of tool	Percentage of Cu.	Percentage of Sn.
Bells and Tripods (鎛 鼎)	83	17
Wedged axe - (斧 斤)	80	20

1. Memoir Ser. B, No. 2, Geol Surv., China.

Weapon axe	(戈 戟)	75	25
Large knives	(大 刃)	67	33
Arrow Heads	(削殺矢)	60	40
Mirrors	(鑒 燧)	50	50

In the later part of Chow (周) and in Chin (秦) times the alloy of copper was still made with tin. Such books as Hsuntsu (荀子), Yuehchueshu (越絕書) Hanfeitsu (韓非子) can well prove this fact, and it need not be repeated again.

In Shihouchi (食貨志 Memoir on Manetary System) of Hanshu (漢書 History of The Han Dynasty) it is recorded :

> "Chin Dynasty consolidats the whole nation and the quality of its coins is as same as that made in the Chow Dynasty".

Evidently there is no proof to show the use of zinc before the times of Chow and Chin.

It was until the comparatively recent dynasty of Ming (明) that zinc was dwelt upon in the clearest manner. Some passages can be cited here.

In Wulihsiaochih (物理小識 Notes of Sciences) :

> Both the alloy of copper with Wochien (倭鉛 zinc) and that of copper with Lukanshih (爐甘石 smithsonite) have the same yellow color.....The brass made from smithsonite is malleable in the fire. That made from Wochien should be taken out from the furnace and pounded after it becomes cold. In making coins with Wochien (zinc) in the proportion of 6 parts of Wochien to 4 parts of copper their color is black, and they are easily broken when dropped."

In Pentsaokangmu (本草綱目 Plant Medicine) by Li-shih-chin (李時珍) :

> "The different pieces of Lukanshih have various sizes, looking like a sheep's brain, and feeling greasy like Kaolin. The red copper where in combination with Lukanshih will become yellow. The present brass is made in this way."

In Fangyüchiyao (方輿記要 Essential of Geography) by Ko-tsu-yü (顧祖禹) :

> "Ning Chou (會州), Yunnan, produces smithsonite. In the time of Chiaching (嘉靖) it was mixed with copper to make coins."

It is also said in Wulihsiaochih:

> "Wochien is not obtained from a lead ore, but by smelting smithsonite."

This shows at that time people already knew that smithsonite is a zinc ore.

In Tienkungkaiwu (天工開物) the constitution of alloys are stated as follows:

Composition / Alloys	Copper	Tin	Zinc
Huangtung (黃銅) (Yellow Copper)	60 %		40 %
Hsiangtung (響銅) (Bronze proper)	80 %	20 %	
Tichitung (低器銅) (Ordinary vessel)	50-40 %		50 60 %
Huohsutung (火煆銅) (Copper-after heat treatment)	70 %		30 %

It is also said in the same book :

> " There is no such term as *Wochien* in old books. It is a new term for the metal that is smelted from smithsonite. It occurs along the Tai Hong Shan (太行山) in Shansi, and also somewhat less in Ching Heng (荊衡 Hupeh and Hunan). Every ten catties of smithsonite are put into a clay crucible which is then covered tightly with mud. The mud is left to become dry and it will not crack while subjecting to red heat. Layers of coal are laid below the crucible. Start the fire with log and thatches. The smithsonite in the crucible melts and becomes solid after being left in cold air. Break the crucible, and obtain the substance. For every ten catties of ore, two catties are lost. What is left is zinc. If this were not collected by copper, it would volatilize in the fire. Because it looks like lead, but more brittle and hard, it is called Wochien.

From there we can well understand the process of zinc-smelting and its utility in the Ming dynasty.

To advance the subject a little further, we can not help to trace back a little earlier to the Sung (宋) Dynasty (960-1278 A. D.). The term Lukanshih was not coined by the Ming people. In Tsaohuachinan (造化指南 the Guide to Creation) it is said:

> "Lukanshih is affected by gold and silver. Only after three thousand years it can become a mass and be used in alchemy.

In Waitanpentsao (外丹本草) by Tsue-fang (崔方):

> "Use two catties of copper and one catty of Lukanshih and melt the mixture. One gets one and half catties of T'oushih (鍮石)."

The two books mentioned immediately above are the works by the

alchemists of Taoism. The first one, i.e., Tsaohuachinan, is said to be the sayings of one of their Saints (土宿昆元眞君) and they were noted down by Pao-pu-tsu (抱朴子). But the book was reexamined by Li-shih-chin (李時珍) in the Ming Dynasty, who regarded it to be a work compiled by the priests of Taoism of the Sung and Yuan dynasties.

Probably in the Sung Dynasty, smithsonite was already used in smelting. It was first used for making alloys with copper, and surely it was discovered by the alchemists of Taoism. They called Lukanshih (爐甘石) also by the term Lushiensheng (爐先生). Since it was often seen in the furnace (Lu 爐), therefore the prefix, Lu (爐), was here used. Pao-pu-tsu was an alchemist in the Ch'in Dynasty (晋朝). In his book, "Paoputsu," there is no such term yet. Therefore the Taoist's book "Guide to the Creation" can not be said to have been noted by him.

Then if one goes to search in the official history, he will get more evidences. In the Shihouchih (食貨志) of the Sung Dynasty :

> "At first, Tsai-ching (蔡京) advocated the use of mixed-tin money. For making every 1,000 coins, there were used eight catties of copper, four catties of "black tin" (*Heihsi*) and two catties of "white tin" (*Peihsi*) and the term "white tin" here used is meant by zinc."

After a long research I found out in the book, Yü-pien (玉篇), lead was called "black tin" (*Heihsi*). But according to the present usage, lead (*Chien*) is called black lead (*Heichien*) and zinc is called "white lead" (*Peichien*).

In the time of Sung, lead was also called "black lead", for example in Shihouchih :

> "Hsü-Yen (徐鉉) used all the "black lead", which was left by the mints in the Southeast provinces, to make red paints."

Here "black lead" is surely the lead of to-day. Thus "black lead" and "black tin" were the same thing. "White lead" and "white tin" surely could also be the same, and both were zinc.

In Paochuanlun (寶莊論) :

> In gold alloys, there are *Peihsiking* (white-tin-gold) and *Heihsiking* (black-tin-gold)."

In Tangjehuatsu (唐日華子) :

> "There are seventeen varieties of silver alloys such as *peihsiyin* or "white-tin-silver" and *heihsiyin* or "black-lead-silver" etc."

The fact that *Peihsi* (*white-tin*) was always distinguished from *heichien* (black-lead) is just as same as the present usage of "white lead" and

"black lead".

Formerly the words, lead and tin, seem to be used very loosely. For example, in Hsuehwen (說文) "lead is a greyish gold (metal)" In its notes by Huai-nan-tsu (淮南子) "Greyish gold is tin". So lead and tin were both described as a greyish metal.

Hufen (胡粉) was a powder of lead, but was called tin powder in medical books. So far all the quotations show that lead and tin were interchangeably used in ancient times. Therefore we can conclude that what was called "white tin" was "white lead" or zinc.

Again the analysis of the Sung coines[1] gives the following percentages :—

Coins	Time (A.D.)	Percentage of zinc
Shuen-hua (淳化)	990-994	1.08
Chih-ping (治平)	1064-1967	1.00
Shih-ning (熙甯)	1068-1077	1.40
Yuang-feng (元豐)	1078-1085	2.18
Yuang-yu (元祐)	1086-1093	1.26
Chao-sheng (紹聖)	1094-1097	13.16
Ta-kuan (大觀)	1107-1110	0.97
Cheng-ho (政和)	1111-1117	2.14

We have no check on the accuracy of the analysis. But anyway they suffice to show that there is zinc in the coins. The high percentage (13%) of zinc in the Chao-sheng coins may somewhat startle the reader, but it is surely not due to unintentional mixture. Its complete analysis may be given here.

Cu	55.49 %
Pb	25.80 %
Zn	13.15 %
Sn	3.07 %
Fe	1.49 %

Thus the composition confirms the statement quoted above from Sungshih (宋史), i.e., *heihsi* (黑錫 lead) is one half of the amount of copper and *peihsih* (tin) is one half of the amount of *Heihsih* (lead).

During the reign of Chao-sheng, Tsai-ching was the prime minister.

1. Science, China Vol. 6 No. 11

The "mixed-metal" coinage he proposed to make was then the mixing of zinc.

In Shihuochih of Sungshih :

> "In the third year (1017) of Tien-hsi (天禧) it was decreed that criminals against the use of Tungt'oushih (銅鍮石) were to be exampted from capital punishment. Since the reign of Hsi-ning (熙寧) the officers had strictly enforced the law to prohibit private smelting. All the wares of T'oushih were made and sold by the government only."

T'oushih was a brass, an alloy of copper and zinc. Then brass wares must have been prevailingly used. Also in Laushuhanpichi (老學庵筆記) by Lu-you (陸游) :

> "Copper has yellow color. Bells, tripods, etc. made in old times are all wares of "yellow copper". Now as we obtain them from excavation, they naturally have a dark color due to long period of tarnishing underground. But it is of no reason why the wares made and used for religious worship at present should be colored with dark tint which is obtained by burning a painting medicine (Chemical)."

This quotation can be viewed from three different points : (1) Lu-you must have seen much more brass than bronze ; (2) it can be well understood that those brass wares which were not used for religious worship must have been of yellow color, (3) the painted vessels were the imitations of old bronze, but the real material was a brass. Therefore we can be sure that in the Sung Dynasty brass coins and vessels could not be made without zinc.

Only at that time technical knowledge was not so far advanced to determine the exact percentage which, therefore, could not be uniform in all cases.

In Weiluch (稗略) by Kan-ssu-sun (扈似孫) the following passage was quoted from the Jihhuatse (日華子) of the Tang Dynasty.

> "Silver has the *peihsiyin* and *heichienyin* varieties."

This shows that in the Tang dynasty there was already such a term as *peihsi*. Because of the white color it was mistaken for silver and therefore it was called *peihsiyin*. If the term *peihsi* were derived from the same term used in the time of Tang, then we can say zinc was already used in the Tang dynasty (620-905 A.D.)

Now how was the actual condition in the time of Sueh (隋 589-618 A.D.) and in the beginning of Tang? In Shihuochih (食貨志) of Suehshu (隋書) :

> "*Hsila* (錫鑞) is cheap. Many are after its profit. Coins made by private

persons can not be restricted "

In Shihuochih of Tangshu (唐書) :

"In the time of Yuan-tsung (玄宗) there are in the whole country ninety nine mints ; each mint makes 3,300,000 coins, using 21,200 catties of copper, 3,700 catties of *la* and 500 catties of tin."

What is *La* then ? After a laboreous research it is found that the Sung coinage was made after the method of Tang. In Shihhuochih of Sung-shih (宋史) :

"By inquiry there is found a man, Ting-chao (丁謂), an official in the court of Nan Tang (南唐), who knows Yao Shin (饒信) and other localities producing copper, lead and tin. Then this official is given full power to call men to mine the metals and to inquire the old casting methods. The only method found best is that used at Jung Ping (永平) which seems to be the same method of mixing metals of Kai-yuan (開元) of the Tang Dynasty. Then Ting-chao returned to the court to make report".

This is to prove that the Sung Dynasty copied the method of Tang. Since Sung has been proved to have used zinc, then Tang ought to have used it too. What were called changes made by Tsai-ching (蔡京) are simply the changes of terminology (*heihsi* and *peihsi*), the addition of more amount of zinc and calling the coins Chiahsichien (夾錫錢).

From what has been discussed above, we can understand that *la* used by Sueh and Tang must contain some zinc or might be a zinc-bearing material.

Again in Chungshanching (中山經) Shanhaichiing (山海經): "Huan Shan (黃山) produces many *peihsi*". The Comment made by Kuo-pu (郭璞) tells "*peila* is *peishi*". This proves that *peishi* and *peila* were the same thing. *Peihsi* used in the Sung time has already been proved to be zinc. Therefore *peila* must also contain zinc. But in the Tang Dynasty *la* was used in much larger amount than tin. Therefore *la* was not a pure zinc. probably lead had been also counted under the term *la*.

To trace another step further back, we are to inquire how zinc was used in the Han Dynasty (201-220 A.D.) and generally, the further we trace backward, the lesser is the record and the more difficult is the research.

Between the Western Han and the Eastern Han, there was a period of Hsing Mong (新莽 9-22 A.D.) which deserves much of our attention. Because Wang-mong (王莽) was a man to make redical changes. The monetary system of the Western Han suffered most changes on his account. In Hsihuochih (食貨志) of Hanshu (漢書) :

"When Wang Mong was a regent, he changed the rules of Han and made coins of copper mixed with *tienhsi* (連錫)".

The word *lien* did not exist before Han. Also in Hanshu the word *lien* is used :

> "All the finds of gold, silver, copper, *lien*, *hsi*, (tin), tortoise shield, and bivalved shells come from the oracular signs (占)"

In Hsichi (史記) :

> "Changsha (長沙) has the occurrence of *lienhsi*. In Shuowen (說文), the word *lien* has the redical, 金 (King, metal). Lien (鍊) is one of the copper family."

Aside from these, it is very scarcely seen even in the books written in the Han Dynasty. The so-called *lien* stated in Hsichi (史記) is probably a local term for a metal that was produced specially in the south-western part of the country at that time.

In ancient days, besides Hsu-shen (許愼 see Hsueh-wen), Yinshao (應劭) said : "Lien is somewhat like copper". Mong-kang (孟剛) said "Lien is another term for tin." Li-chih (李奇) said "Chianhsipu is called Lien". All these, however, show that there is no definite metal so far has been recognized. By all investigations, it can be concluded that lien could not be other than zinc. In the Han Dynasty there were still many bronze (Chingtung). Its color is nearly as whitish as tin. If the old authors, Hsu, Ying, and Mong did see the actual substance, the color of *lien* must be whitish and somewhat like the zinc ore.

Not only the term *hsila* (錫鑞) in Tangshu and Suehshu are used in the same sense as *lienhsi* in Hsichi and Hanshu, the two words *lien* and *la* are phonetically related. With all probability, *la* is phonetically derived from *lien*. Since *la* was a zinc material, most probably *lien* had been the same. This is a proof from etymology and phonetics.

In Erhya (爾雅) *hsi* is called *yin* (鉛). Kuo-pu called *peila* (白鑞) in his notes. The *yin* in Erhya and *Peihsi* (白錫) in Shanhaiching are both called *peila* by Kuo-pu. Then *yin* and *peihsi* must be the same thing.

The word *yin* (鉛) has its radical 引 (yin) which means to pull; same is with the word *lien* (連). The *lien* might also be *peihsi*. This is a proof from the meaning of the word.

In Tienkungkaiwu (天工開物) :

> "Lukanshih comes from Ching Heng (Hupei and Hunan)"

In Pentsaokangmu (本草綱目) :

> Lukanshih is abundantly produced in Hsiang Tung (湘東) (Eastern Hunan)."

In Hsichi :

"Changsha produced *lienhsi*".

The localities are also the same. This is a proof from the geographical positions.

As I have already quoted from Hsichi, *lien* was produced in Changsha. I happened to think of the modern dialect in the southwestern China. At the present time in Yunnan, zinc is called *lien* (鏈). Therefore both kinds of *lien* may be the same thing, i.e. zinc (if we regard the written words are coined after the spoken language, then it is not improbable that the written word 連 (*lien*) has been subjected to changes during the history).

From all what has been said we can understand that *lien* (of the Han Dynasty) was most probably a zinc.

In the Chinese Magazine, Science, Vol. 6, No. 11, there are tables of analyses of Chinese old coins, the Wuchuchien (五珠錢 five-cent piece) contains 2.9 % of zinc. This was not a coin of Wang-mong ; it might be one of the Eastern Han.

I have mentioned that the first people who used Lukanshih to make brass was a Taoist. In Hankuangyi (漢官儀 Official Statues of Han) :

> "Wang-mong usurped the reign, abolished the Wuchu coinage. He started a smaller coinage system and called the coins *Peihsuchchenjen* (白水眞人)".

This name is characteristic of the Taoist's idea. In all probability, the method of making Wong-mong's coins was derived from the alchemist of Taoism.

Generally speaking, the metallurgical process in China was developed in the earliest time by the Tan-tsao (丹竈 alchemist) group of the Taoists. In the Chin Dynasty there was an alchemist called Pao-pu-tsu (抱朴子 a man of third century) who had never said anything about zinc. In the Western Han (201-9 B.C.) Lao-chin (裴欽) and Huei-nan-wang (淮南王) made some alloys for medicine. Later on, people often mistook them for gold. In Menghsipitan (夢溪筆談) by Sun-kuo (沈括) :

> "At Pa Kung Shan in Shou Chou (壽州) flat and round pieces of gold are often found in the soils and gullies, with the words 劉主 (Liu-chu) stamped on them. People say that they are the medicine of Huei-nan-wang, and called them Yintsechin (印子金 stamped gold). In Hsiang Sueh (湘鄂 northern Hupeh) gold is dug out from the soil ; its shape likes the foot of horse. It is so soft that it can be cut by knife and powdered by stone. It is said that they were made by Lao-chin for mixing medicine."

Lao-chiu was a man of Han-kao-tsu's time (201-192 B.C.) Huei-nan-wang was a man of Wu-ti's time (139-84 B.C.). In the year Yuan-shao of Wu ti, Huei-nan-wan raised a rebellion and was disposed from his principality. At that time such false gold was very common. In King-ti's time (155-138 B.C.) a decree was issued for the capital punishment of molding false gold (as recorded in Hanshu). This false gold must have been of yellow color.

In Huei-nan-tsu : "Longing for the false gold of Tang Yang." Evidently it was the Tauyang copper (丹陽銅 an allow). This alloy was made by San-mo-chuin (三茅君) of Toaists for the people in famine in Tan Yang. Lately people used zinc power (爐粉) to polish copper and called it the method "*Tanyang*". (in Hsishanfutan 席上腐談 of the Sung Dynasty). Although the method of making Tanyang copper has lost, probably it was the beginning of making brass.

Thus the use of zinc in China is very far back in history. In comparing with India, we note that the Sung Dynasty had the clearest record to show the use of zinc; the Sung Dynasty belonged to the eleventh century. It was in twelfth and thirteenth century that India began to have any record of it. Then we can say that Chinese method was not derived from India. If we recognised that in the seventh century India already had the method of zinc-smelting, Chinese history as far ack as that of Wang-mong in the very beginning of Christian era shows the use of zinc in coinage. Besides, the use of zinc in China was developed by the Taoists whereas that in India, by Buddhists. The Taoists could not have received anything of Buddhists. It is clear that there is no relation whatever in the smelting of zinc in China and in India.

Furthermore, the false gold of early part of the Western Han Dynasty has been made according to the advices of the alchemists of Taoism. Considering from technical point of view, the false gold-making could not have no relation with zinc-smelting ; this was taken place in 200 B.C. At that particular time at least there was not known any communication with Turkestan and the far west. Not only the Buddhism had not yet come to China. Even there was also no communication with Persia and Arabia. So it can be said that the zinc was used in China earlier than in India and that

probably it was independently discovered by the Taoists.

First it was used in coins. Why ? Because at that time the alchemist expected to become rich by making gold. The *Tanyang* was used to relieve the people from suffering famine. The use in coinage bears the same purpose. Zinc was not used in making vessels before the Sung time. It has two evidences. First of all there is no record to prove the use of brass before Tang. Secondly a positive proof is obtained from the analyses of Dr. Chikashige of Japan who showed that the vessels made before Tang has the same proportion as that recorded in Kokungchi of Chowli already referred to in the first part of this paper :

Contents of zinc in vessels and tools before Tang.		Contents of zinc according to records in Kokungchi.	
Bells	19 %	Bells and Tripods	17 %
Arrow-heads	13-17 %	Wedging Axe	30 %
Weapan Axe	16-22 %	Weapon Axe	25 %
Mirrors	26-31 %	Large Knife	33 %
		Cutting Knife	40 %
		Mirrors	59 %