THE TUNGSTEN INDUSTRY
OF THE PEOPLE'S REPUBLIC OF CHINA

by

Ku Yuan-Kuo

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Signed: ______________________
Ku Yuan-Kuo

Golden, Colorado
Date: April 25, 1975

Approved: ______________________
Alfred Petrick, Jr
Thesis Advisor

Approved: J. Paul Mather
J. Paul Mather, Head
Department of Mineral
Economics

Golden, Colorado
Date: April 25, 1975

ABSTRACT

Chinese production of tungsten is estimated to be about 17.6 million pounds per year, 25 to 30 percent of the world's supply. Chinese tungsten production has declined since 1963 mainly because of political change, lower ore grades, and deeper mining. China has 77 percent of the known world tungsten reserves. The tungsten mining industry is still unadvanced compared to other western producing countries.

Assuming application of western technology, the Chinese tungsten industry could deliver tungsten at an estimated f.O.b. price of U.S. $21.20 per short-ton unit. This is lower than the price of domestic tungsten in the United States (about $24.42 per short-ton unit) and even lower than the Brazilian price ($33.80 per short-ton unit) This indicates that the Chinese tungsten industry has the capability of supplying tungsten to the world market, as well as to the United States at very competitive prices.

Chinese tungsten supply to Communist countries has decreased since 1962. The major importers of Chinese tungsten were USSR, Czechoslovakia, and Poland. This has not improved

relations with these countries. Export of tungsten concentrates to the USSR from China was resumed in 1970 and has increased to 5.7 million pounds in 1971.

Supply to Western countries has been higher than to Communist countries since 1966. Although China decreased the supply of tungsten to the world market, total supply to the western countries was still higher than to the Communist countries until 1970. After 1970, with a new supply policy, tungsten to the Soviet Union and to other Communist countries increased sharply and will possibly exceed or equal to the supply to western countries. One of the major obstacles for tungsten supply to the western countries is the unfavorable import tariff levied on tungsten concentrates from China.

Domestic consumption of tungsten in China will continue to increase due to the high priority given the steel industry by government. Stockpiling will continue because of government policy toward preparations for war. This policy will continue until border agreements between the Soviet Union and China are signed and honored.

The tungsten supply policy will depend in part on government attitude toward the United States. Due to the high price of tungsten during the years between 1969 and 1970 in the world market, China significantly increased her supply of tungsten to Sweden, Japan, United Kingdom, and France. However, because of strategic reasons and increased domestic consumption, China was not able to increase the supply of tungsten to the high levels of 1962.

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INTRODUCTION

China is believed to have the world's largest and richest tungsten deposits. Most of these deposits are located in the Nanling Region of southern China which includes the southern Yunnan, northern Kwangsi, northern Kwangtung, southern Hunan, and southern Kiangsi Provinces. The objective of this study is to evaluate the importance of these deposits to world tungsten supply and their influence on world tungsten prices. To achieve this objective, it is necessary to examine the resource base and the historical record of production and pricing. Of particular interest is the attitude of China's governmental policy toward domestic tungsten needs and stockpiling. In addition, the costs of Chinese tungsten, using latest technology, is compared to other world producers.

The Chinese tungsten industry began in 1915; the first shipment of ore to United States was in that year. The ore contained up to 78.80 percent WO_3 with practically no detrimental impurities.

The tungsten deposits of southern China are represented by three mineral systems--the pegmatite system, the wolframite-quartz system, and the scheelite-quartz system. They occur in mountainous areas characterized by large granite batholiths associated with intense and complex sedimentary structures. Veins occur in both the granite and sedimentary rocks. Wolframite and scheelite are the principal ore minerals; cassiterite, bismuth minerals, molybdenite, and chalcopyrite are also of economic importance.

According to the U.S. Bureau of Mines, tungsten production of China has decreased since 1963. It is believed only 15.4 million pounds have been produced since 1971. One of the reasons for low production is due to China's primitive mining methods and processing of concentrates. Mining methods in the industry prior to 1949 were simple and crude; hand drilling and black power were universally used and concentrates were obtained by hand crushing, jigging, sluicing, drying and packing. The Chinese tungsten industry expanded during the First Five Year Plan (1953-1957) for economic development. Tungsten was exported to the Soviet Union in exchange for machine tools, mining, and metallurgical equipment. Because of the withdrawal of Soviet experts from China in 1960, modernization of the mining industry, as well as other national industries, encountered difficulties because of lack of equipment and trained personnel. As a result, the "self-reliance policy" for national industrialization was initiated. Tungsten supply to other Communist countries decreased sharply since 1962, whereas the supply to western countries increased. In 1970, tungsten exports to western countries was approximately 4.29 million pounds; supply to Communist countries is estimated at only 0.99 million pounds.

Because of adverse relations with the Soviet Union and armed conflicts along the border of the two nations in 1969, tungsten production was stockpiled for defense purposes. Increased domestic consumption of tungsten, government stockpile policy, declining grade, and deeper mining are forcing China to modernize the tungsten industry. High investment and labor costs, and fluctuations of world price of tungsten may alter the country's competitive position with other tungsten producing sources.

According to a 1973 report of the National Material Advisory Board (NMAB), by 1990, the United States, one of the world's largest tungsten consumers, is likely to be producing less than 25 percent of its present volume. In addition to rapidly increasing U.S. demand for tungsten, world demand will double within the next 15 years. China's renewed trade relations with United States began in 1973; as a result, 80,000 pounds of tungsten were exported to the United States. Future tungsten supply will probably rely heavily on China.

This study includes a cost analysis of a 300-ton-per-day mine and mill complex in southern Hunan Province. The reasons for the cost analysis are the following:

(1) To show evidence that China is able to influence world tungsten price and supply in the world market after modernization of her tungsten industry.

(2) With 77 percent of the world tungsten reserves, China, after modernization of her tungsten industry, is likely to be one of the world's lowest cost producers. Such low cost Chinese production is an additional uncertainty facing the world tungsten industry.

(3) The writer believes that because of increased domestic consumption, lower ore grades, deeper underground mining, and increasing competition among major tungsten producing nations, China must modernize her tungsten industry within the next five years.

The cost model is based on application of western technology. This was done because of limited data from China. The model uses information available from a U.S. Bureau of Mines study (Larson,* 1971), updated and adapted to location in China. Cost estimates on Chinese tungsten production have never been done by western Chinese experts.

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* Please refer to Bibliography

Although the information on China's reserves are old, they are the only official government announcement which can be trusted. They provide good information on the grade of ores and tungsten distribution which is very important and helpful for the cost estimating purposes.

Because official data from People's Republic of China are rare, this study must depend on publications of the U.S. Bureau of Mines, the United Nations Conference on Trade and Development (UNCTAD), Chinese publications, and personal contacts with Chinese experts.

I. GEOLOGY SUMMARY

The most important tungsten region of China is in the Nanling area of the southern Hunan, southern Kiangsi, northern Kwangtung, northern Kwangsi, southeastern Yunnan, and western Fukien Provinces (Fig. 1) Geologically, the area is one of intensely and complexly folded mountains trending east northeast to northeast. Tectonism occurred principally during (1) the Caledonian (late Silurian to early Devonian), (2) the Anguanian (late Triassic), and (3) the Yenshanian (phase A-Late Jurassic, and phase B-between the Cretaceous and Eocene) The area is disturbed by intense folds and high-angle longitudinal thrusts and transverse faults striking northwest. Three sets of shear joints, striking north northwest, northwest, and west northwest, are well developed. Tungsten mineralization is closely related to the transverse faults and to the joint systems.

According to Dr. K. C. Hsu (Hsu, 1943) the geological formations (Table 1) of the Nanling region consist in part of pre-Devonian metamorphic rocks (phyllites, slates, mica schists, and mica-quartz schists).

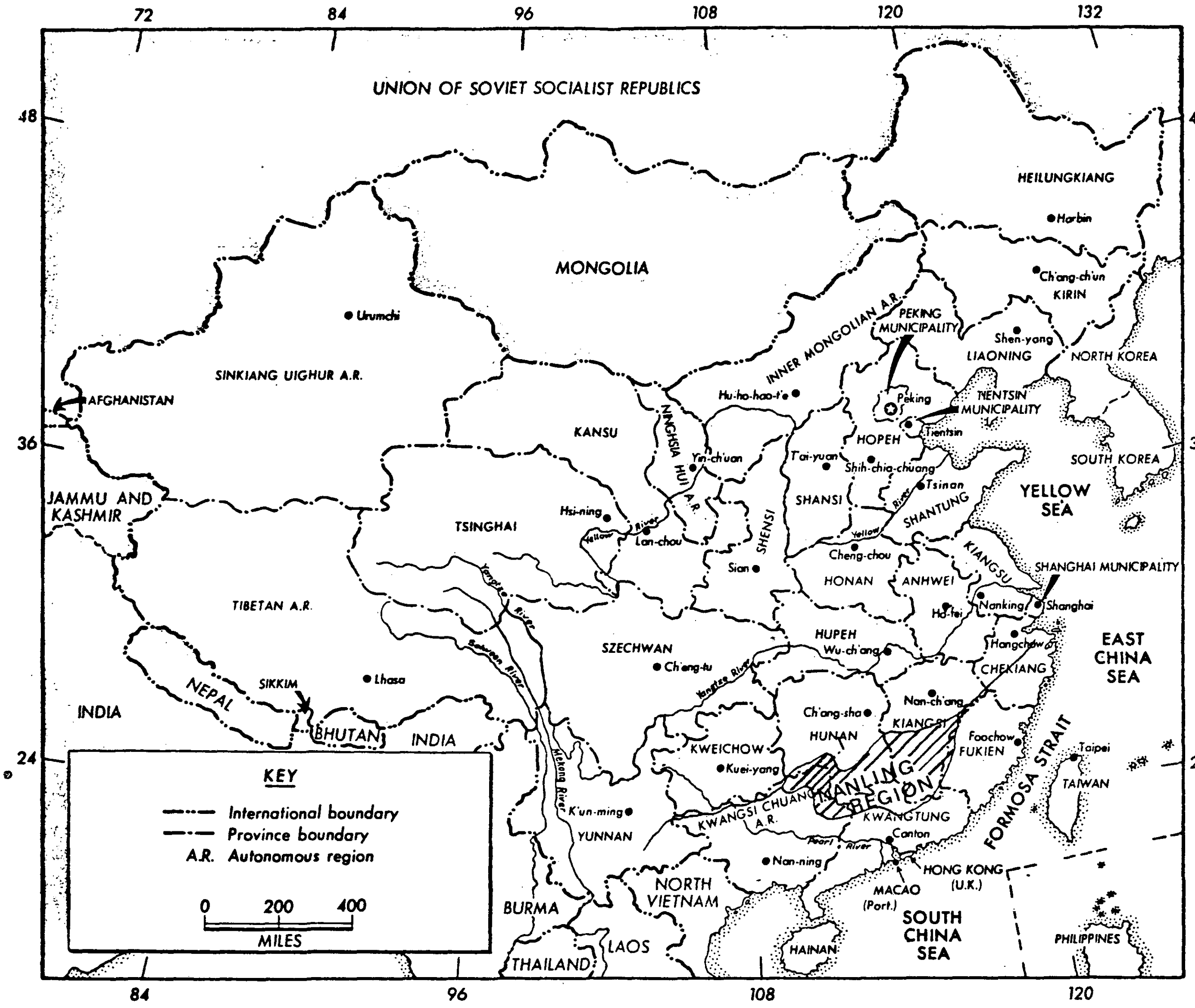

Figure 1. People's Republic of China
(Adapted from area handbook for the People's Republic of China, 1972, pg. 1)

TABLE 1

Stratigraphy of Southern Kiangsi (Nanling Region)

AGE	FORMATIONS	THICKNESS (in meters)
Lower Pleistocene	Red Clay	15
Late Tertiary	Kanhsien Gravel Unconformity (Nonlingian)	
Early Tertiary	Yutu Red Beds Unconformity (Yenshanian)	500
Cretaceous	Loyao Red Beds Unconformity (Yenshanian)	600
Late Jurassic	Granite and Tungsten Deposits	
Lower Jurassic	Anyuan Coal Series Unconformity (Anyuanian)	400
Lower Triassic	Tieshihkow Series Disconformity (Hercyrian)	300
Upper Permian	Loping Coal Series Disconformity (Hercynian)	100
Middle Permian	Yangsin Limestone	220
Lower Permian	Chuanshan Limestone	170
Middle Carboniferous	Huanglung Limestone	180
Lower Carboniferous	Tseshui Coal Series	150
Lower Carboniferous	Changtung Shale	250
Devonian	Shiashan Sandstone Unconformity	700
Pre-Devonian (Sinian-Cambrian to Silurian)	Metamorphosed argillaceous and arenaceous sediments	3000

Data Source: Hsu, 1943

Devonian rocks consist mainly of thick-bedded, hard sandstone. Lower Carboniferous beds are represented by shales, sandstones, and impure limestones; the upper part includes minor anthracite coal beds. The Middle Carboniferous consists mainly of limestone. The Lower Permian section is represented by bluish-gray fossiliferous limestones. Middle Permian strata consists of fossiliferous limestones and shales. A disconformity separates the Middle and Upper Permian. The Upper Permian coal-bearing series includes beds of anthracite coal. The Lower Triassic sequence consists of shales and sandstones. The Lower Jurassic incorporates mainly conglomerates, sandstones, shales, and layers of bituminous coal. The Cretaceous "Red Bed" series consists of red sandstones, conglomerates, shales, tuffs, and local rhyolite flows. Tertiary "Red Beds" are comprised of conglomerates, conglomeratic sandstones, and sandy shales. Granitic intrusions (Late Jurassic) of the area do not penetrate Cretaceous strata. At the Cretaceous-Granite contact, arkoses sandstones and conglomerates with granite pebbles, vein quartz, and greisen are evident.

Most of the tungsten deposits occur either in granite or in flanking sedimentary rocks. Those in the granite are considered pre-Cretaceous or post-Lower Jurassic in age. The region comprises 1400 square miles which include about

20 percent of the Nanling granite complex. Tungsten occurs as veins within the granitic masses that intruce formations ranging up to Triassic in age. The veins on the average contain 30 percent quartz, 38 percent orthoclase and microline, 25 percent plagioclase, 7 percent biotite, and accessory muscovite, apatite, magnetitie, and titanite. Deposits are in pre-Devonian sedimentary rocks; very few in Devonian sandstone, and none in Carboniferous to Triassic strata. Some veins occur in Lower Jurassic sandstones, phyllites, slates, argillites, mica schists, quartzites, and graywackes.

II. TUNGSTEN DEPOSITS

Tungsten deposits are widely scattered over the earth in many countries. Most of the important deposits of the world are in quartz veins that contain wolframite, huebnerite, ferberite, and some scheelite. The second important deposits are contact metamorphic scheelite. Placer deposits are less important--they contain wolframite and scheelite.

World

The various tungsten deposits of the world can be classified as follows: (Hsu, 1944):

(1) Pyromesomatic scheelite deposits - Scheelite is the only mineral, temperatures of formation from 500 to 800 degree Centigrade, contact metamorphic deposits. Important locations of the deposits are southern Hunan in China, California and Utah in the U.S.A., and in Finland.

(2) Tungsten-bearing pegmatites - Wolframite or scheelite, little ferberite or hubnerite, temperatures of formation range from 575 to 1000 degrees Centigrade, pegmatoid deposits The deposits are located in Burma, southern Kiangsi in China, and in the U.S.A.

(3) Hypothermal Tungsten deposits - (a) Hypothermal Wolframite: mainly wolframite with or without little scheelite, temperatures of formation range from 300 to 500 degrees Centigrade, Quartz vein deposits. (b) Hypothermal scheelite: scheelite is the principal mineral, wolframite is entirely absent. The principal gangue mineral is quartz. (c) Hypothermal replacement tungsten deposits: these types of deposits are in non-calcareous rocks, contain mainly scheelite or wolframite with little ferberite or hubnerite, quartz vein deposits. The deposits are located mainly in Kiangsi, China, in Bolivia, Portugal, Australia, Malaysia, and in Burma.

(4) Mesothermal tungsten deposits - (a) Mesothermal hubnerite or wolfrmaite: chiefly hubernite or wolframite, some shceelite, quartz vein deposits. (b) Mesothermal scheelite: scheelite is the only mineral, quartz deposits. Temperatures of formation range from 200 to 300 degrees centigrade. (c) mesothermal replacement tungsten deposits: Mostly scheelite, some carry wolframite. These deposits are found in Colorado, U.S.A., and In Kiangsi, China.

(5) Epithermal tungsten deposits - (a) Epithermal ferberite or hubnerite: Chiefly ferberite or hubnerite, with or without scheelite, quartz vein deposits. (b) Epithermal scheelite: scheelite only, quartz vein and replacement deposits. Temperatures of formation range from 50 to 200 degrees Centigrade Example localities include those of Nevada and Colorado in the United States.

(6) Placer tungsten deposits - mostly wolframite and scheelite. In the United States placer deposits can be found in California.

(7) Tungsten deposits of hot spring origin - tungsten is predominantly in association with manganese and iron-oxide; no definite tungsten mineral identified. This deposit can be found at Searles Lake, California.

Tungsten Deposit in China

The tungsten deposits of southern China may be categorized as the (1) Pegmatite System, (2) Wolframite-Quartz System, and (3) Scheelite-Quartz System. Most veins strike north 70 east to south 70 east, and usually dip from 70 to 90 degrees. Vein thicknesses vary from 0.1 to 0.6 meters and extend in length from a hundred to several hundred meters.

Following Mo Chin-Sun (Mo, 1957), the tungsten deposits in southern China are divided as follows:

(1) Pegmatite System: This ore system has limited industrial value because of its restricted distribution and low tenor. The pegmatites range from simple to complex. Mineralogically the simple types consist chiefly of feldspar and quartz and with or without minor amounts of muscovite. They occur also as irregular masses within the batholiths. Complex pegmatites consist mainly of feldspar and quartz associated with variable amounts of green and brown micase, fluorite, and tourmaline. Molybdenite, cassiterite, and wolframite are frequent associated minerals and are usually related to hypothermal wolframite-quartz veins.

Quartz-Microcline Type: The deposits are pneumatolytic and reflect high-temperature hydrothermal mineralization. Important minerals as quartz, microcline, orthoclase, muscovite, zinnwaldite, garnet, beryl, tourmaline, topaz, fluorite, molybdenite, cassiterite, and wolframite are present. Biotite granite is generally the intrusive related to these deposits. The ore-bodies occur as veins, bags, or irregular concentrations. Granite, partly metamorphic sandstone, and shale are the major rock varieties in the mining districts.

(2) Wolframite-Quartz System: This type of ore system is the most important in China. About 70 percent of China's tungsten is produced from Wolframite-Quartz veins. The deposits are in intensely folded and faulted Paleozoic sediments intruded by Late Jurassic granites. The tungsten deposits usually occur near the margins of large intrusives. The veins are formed by filling well-developed joints in the granite or in adjacent metamorphosed argillaceous sediments. Wolframite is the principal ore mineral. Veins range from 0.1 to 0.6 meters in width, and extend hundreds of meters in length. The average grade of the ore varies from 1.5 to 4 percent WO_3.

Four types of ore deposits are recognized within this series - greisen, feldspar-quartz, quartz, and stibnite-quartz.

(a) Greisen* type: These deposits involve pneumatolytic-hydrothermal mineralization. The intensity of mineralization increases with the degree of alteration. Greisens occur as massive bags, chimneys, and dense parallel stringer veins. Quartz, zinnwaldite, muscovite, fluorite, tourmaline, topaz, monazite, cassiterite, molybdenite, arsenopyrite, ilmenite, wolframite, and scheelite are present. Only wolframite and cassiterite in the greisens are of economic importance. The width of greisen zones range from centimeters to several meters. Quartz veins are closely spaced in granitic masses though sometimes the entire granite body is greisenized.

(b) Feldspar-quartz type: The type involves high temperature hydrothermal mineralization. Large amount of flesh-colored feldspar (mostly orthoclase) is present in massive form. Major tungsten deposits are found in granitic rocks. The larger

*Results from alteration and mineralization of granites; occurs as zones along the sides of small but numerous quartz veins or stockworks; also due to closely spaced veins, the whole surface of the granite body appears to be greisenized.

veins are 1,000 meters in length and several meters wide; spacing between veins is about 12 meters. Quartz, orthoclase, muscovite, zinnwaldite, fluorite, topaz, cassiterite, molybdenite, and wolframite occur in the deposits. Wolframite is the chief ore mineral; molybdenite is subordinate. The tungsten content is usually high; the grade of ore increases as the intensity of greisenization increases. The main forms of the ore bodies are single veins, parallel stringers, and vein zones. Mining districts are for the most part in the granitic rocks; some are in partly metamorphic sandstones and shales.

(c) Quartz type: This type involves high-temeprature hydrothermal mineralization. Abundant minerals as quartz, acid plagioclase, beryl, fluorite, bismuthinite, chalcopyrite, arsenopyrite, pyrrhotite, molybdenite, sphalerite, galena, scheelite, and wolframite are common. The ore-bodies occur as single-bag veins, parallel stringers, or stringer-vein zones. The biggest vein zones range from 1,000 to 1,500 meters in length and about 500 meters wide. The thickness of individual veins is about 70 centimeters. Wolframite is the chief ore mineral and is usually of high-grade; reserves are extensive.

(d) Stibnite-Quartz type: This type reflects low-temperature hydrothermal mineralization. Wolframite associated with stibnite characterizes these deposits. Such minerals as stibnite, quartz, chlorite, fluorite, and plumose wolframite are associated. Granodiorite intrusions are related to the deposits. Veins are the only forms of the ore bodies. Country rocks include sandstones, shales, and limestones. Stibnite is the chief mineral; wolframite occurs in limited amount.

(3) Scheelite-Quartz System: Scheelite deposits were discovered in southern China during 1957 and have since proven to be of considerable economic importance. The most important deposit area is in southern Hunan. The deposits occur as well-developed replacement beds in skarns intercalated with hornfels within the lower part of Upper Devonian limestones. The ore concentrations may be subdivided into three types according to their mode of occurrence:

(a) Skarn type: This type involves contact metamorphic and high temeprature hydrothermal metasomatic mineralization. Garnet, diopside, and quartz are the major skarn minerals. Scheelite is predominant; other associated minerals include molybdenite, pyrrhotite, and fluorite and small amounts of galena and chalcopyrite. The ore-body generally occurs in bedlike or lenticular form. The bedlike deposits have the greater economic importance and greater reserves. The intrusive rocks are mainly granite; country rocks are limestones and shales.

(b) Barite-Quartz: This type involves moderate temperature hydrothermal mineralization. The deposits occur as veins in shear fractures of anticlinal structures developed in sandstones, shales, and limestones. Scheelite is the principal mineral; other minerals include quartz, barite, fluorite, and calcite.

(c) Stibnite, native Gold-Quartz: This type deposit reflects a low-temperature mineralization environment. The orebodies occur as irregular lenticles along the bedding planes or slates and phyllites of Precambiran age. Scheelite is the primary mineral and is associated with stibnite, native gold, pyrite, and quartz. These deposits are widely distributed in certain areas of southern China.

III. TUNGSTEN RESERVES

World

The world reserves of tungsten are estimated at about 175 million short tons (Table 2) About 77 percent of the world known reserves are in China. The United States, the world's largest consumer of tungsten, is not self-sufficient; it only has 5.2 percent of the world reserves. The principal reserves of tungsten ore in the United States are located in the following states: California, Nevada, Idaho, North Carolina, Montana, and Colorado. The average grade of ore ranges from 0.3 to 1.0 percent of WO_3.

North and South Korea are estimated to have 7 million short tons of WO_3, or about 4 percent of the world's reserves. The tungsten major reserves are located in the San Dong Mine, South Korea. The chief tungsten mineral there is scheelite, averaging 1.7 percent of WO_3. In North Korea tungsten reserves are found mainly in Paeknyon Mine and Kichu Mine.

Bolivia's tungsten reserves are estimated at 5.5 million short tons of WO_3 or 3.2 percent of the world's total reserves. The principal mines are in the Department of La Paz. With

TABLE 2

World Tungsten Reserves

Country	Short tons of WO_3
China	134,500,000
U.S.A.	9,000,000
Korea	7,000,000
Bolivia	5,500,000
Burma	4,800,000
Brazil	2,500,000
Portugal	2,000,000
U.S.S.R.	1,700,000
Australia	1,600,000
Malaysia	1,400,000
Canada	1,000,000
Spain	650,000
Peru	550,000
Thailand	500,000
Argentina	500,000
England	400,000
Indochina	300,000
France	150,000
Japan	100,000
Mexico	100,000
Southern Rhodesia	100,000
Total	174,350,000

Data Source: Mineral facts and problems, 2nd ed. (Stevens, 1965) wolframite as the most common mineral, the ore contains 2 to 4 percent of WO_3.

Burma has about 2.8 percent of the world tungsten reserves. The largest reserves are located at Mawchi Mines, in the Karenni State. Wolframite, cassiterite, and lesser amounts of scheelite occur in quartz veins. Average WO_3 content is about 1.3 percent.

Tungsten reserves in Brazil are estimated at 2.5 million short ton of WO_3, or 1.4 percent of the world reserves. Scheelite and wolframite are the chief minerals. The reserves are found in northeastern and southeastern Brazil.

Portugal has the largest tungsten reserves in Europe, with a total amount of 2 million short tons of WO_3, or 1.1 percent of the world's reserves. Most of the deposits are in the northeastern part of the country. Wolframite, hubnerite, and scheelite are found.

Russia has long been an importer of tungsten from China and North Korea. 1.7 million short tons of WO_3 were estimated as domestic reserves, which comprise only 1.0 percent of the world total reserves. Hubnerite and wolframite are the chief tungsten minerals.

Total reserves in Australia are estimated to be 1.4 million short tons of WO_3. Important areas for tungsten are Queensland, New South Wales, Victoria, and Tasmania. Wolframite and scheelite are the common minerals. According to the U.S. Bureau of Mines, early in 1969 King Island scheelite announced plans for a 10 million dollars expansion program, average 0.8 percent of WO_3.

Tungsten reserves in Malaysia were estimated at about 1.4 million tons of WO_3, or 0.8 percent of the world total reserves. Scheelite and wolframite are the principal minerals.

The tungsten reserves in Canada were estimated to contain 0.6 percent of the world total reserves. Scheelite often occured as a by-product of gold mines and is found widely in Canada.

Other nations such as Spain, Peru, Thailand, Argentina, England, Indochina, France, Japan, Mexico, and Southern Rhodesia account for a total of 1.9 percent of the world known reserves of tungsten deposits.

China

China has the world's richest and most extensive tungsten reserves. Most of the Chinese reserves are in the provinces of Kiangsi, Kwangtung, Hunan, Yunnan, Fukien, and Sinkiang. Total reserves in China were estimated as 2,282,977 short tons (Table 3) The total reserves in the Yunnan province are unknown at present. Important tungsten minerals are wolframite and casserites, to a lesser degree. Important scheelite deposits are found in southern Hunan. Most of the tungsten depositsoccur either in granite or in sedimentary rocks; placer deposits are of less importance in China.

TABLE 3

Estimated Reserves of Tungsten in China (in short tons containing 60% WO_3)

Province	Ore Reserves	Percent of Total
Kiangsi	1,815,158	79.51
Kwantung	373,571	16.36
Hunan	56,328	2.47
Kwangsi	27,964	1.22
Sinkiang	9,480	0.42
Fukien	476	0.02
Total	2,282,977	100.00

Data Source: Chen, Y.H., 1941.

Kiangsi Province

The most important area for tungsten deposits which account for 79 percent of the Chinese total reserves, is located in the southern part of Kiangsi. The principal districts for tungsten reserves are Taiho, Sueychuan, Shungyiu, Nankang, Kanhsien, Shangyu, Chungyiu, Tayu, Lungnan, Chiennan, Hweichang, and Anyuan. (Fig. 2) Total reserves in Kiangsi are estimated at about 1.8 million short tons. Wolframite is the chief tungsten mineral, the average grade of ore ranging from 1.2 to 0.7 percent of WO_3. Veins are mainly of massive quartz with some mica-accessory minerals (cassiterite, bismuth, molybdenite, and chalcopyrite are locally of economic importance) (Table 4) The veins occur in granite and sedimentary rocks and were formed mainly by filling regular and parallel fissures.

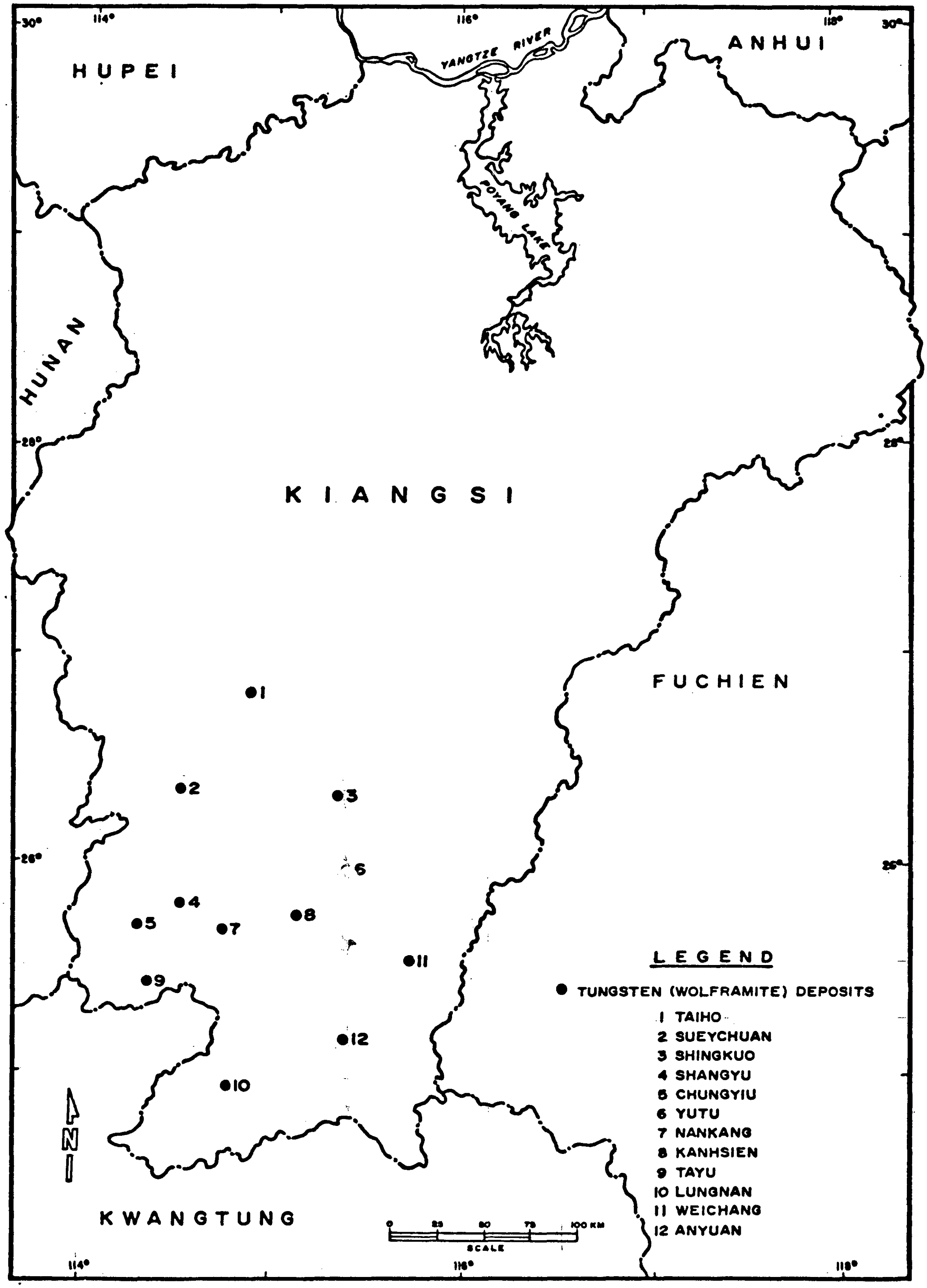

FIG. 2 - DISTRIBUTION OF TUNGSTEN DEPOSITS IN KIANGSI PROVINCE, CHINA

TABLE 4

Tungsten Reserve in Kiangsi, China

Location	Mineral	Percent of WO_3	Ore Reserve (short ton)	Data Source
Chiennan, Tachishan	Wolframite iron, scheelite	1.0	115,301	K.C. Hsu
Lungnan, Kueimeishan	Wolframite, manganese, iron	1.0-1.1	236,554	K.C. Hsu Y. Ting
Tayu, Hsihuashan	Wolframite, manganese, iron, tin, molybdenite	0.75	251,545	K.C. Hsu Y. Ting
Tayu, Tungping	Wolframite, iron, tin, bismuth glance.	0.4-0.5	58,753	Y. Ting
Tayu, Shenglungkou	Wolframite, manganese, tin, molybdenite	0.7	90,278	K.C. Hsu Y. Ting
Tayu, Hsiotungkeng	Wolframite, manganese, iron, molybdenite	0.5	24,802	K.C. Hsu Y. Ting

Table 4 continued

Location	Mineral	Percent of WO_3	Ore Reserve (short ton)	Data Source
Tayu, Hungshuichai	Wolframite, manganese, iron, molybdenite	0.6	41,667	K.C. Hsu Y. Ting
Tayu, Ilojoong	Wolframite, manganese, iron, molybdenite	0.4	12,897	K.C. Hsu Y. Ting
Tayu, Chiulungnaw	Wolframite, manganese, iron, molybdenite	0.35	14,220	K.C. Hsu Y. Ting
Tayu, Piaotang	Wolframite, manganese, iron	0.4	31,526	K.C. Hsu Y. Ting
Tayu, Talungshan	Wolframite, manganese, iron, molybdenite	0.6	14,550	K.C. Hsu Y. Ting
Tayu, Chungyiu-Nankang (mines between)	Wolframite, manganese, iron, tin.	0.2-0.95	261,245	Y. Ting
Chungyiu, Kweitzupei	ditto	0.14-0.6	26,455	Y. Ting
Shangyu, Chungshao	ditto	0.13-0.6	15,432	Y. Ting
Shangyu, Changtianwu	Wolframite, manganese, iron, bismuthite	0.24-0.46	47,399	Y. Ting

Table 4 continued

Location	Mineral	Percent of WO_3	Ore Reserve (short ton)	Data Source
Yutu, Shangping	Wolframite, manganese, iron, tin.	0.7	51,808	K.C. Hsu
Yutu, Yeachyantan	Wolframite, manganese, iron, bismuthite, tin.	0.9	14,220	K.C. Hsu
Anyuan, Penkushan	Wolframite, manganese, iron molybdenite,	1.2	248,128	K.C. Hsu
Hweichang, Tiehshanlung	Wolframite, manganes, iron, bismuthite	0.6	22,046	K.C. Hsu
Hweichang, Shihkungshan	ditto	0.5	5,401	K.C. Hsu
Hweichang, Wangsha	Wolframite, manganese, iron, scheelite.	0.7	14,550	K.C. Hsu
Taiho, Hsiolung	Wolframite, manganese, iron, pyrite, scheelite	1.1	61,729	K.C. Hsu
Shingkuo, Fushyhshang	Wolframite, manganese, iron, molybdenite, bismutite	0.5	9,370	K.C. Hsu

Table 4 continued

Location	Mineral	Percent of WO_3	Ore Reserve (short ton)	Data Source
Shingkuo, Yangshang	Wolframite, manganese, iron.	0.5	1,102	K.C. Hsu
Kanhsien, Guootzyyhuan	Wolframite, manganese, iron, molybdenite.	0.65	9,700	Y. Ting
Kanhsien, Borshyq	Wolframite, manganese, iron, scheelite, bismuthite.	0.8	22,377	K.C. Hsu
Kanhsien, Pichiashan	Wolframite, manganese, iron, scheelite.	0.7	2,535	K.C. Hsu
Kanhsien, Shiahkeng	Wolframite, manganese, iron, molybdenite, bismuthite	0.8	3,858	K.C. Hsu Y. Ting
Kanhsien, Niulankeng	ditto	0.55	31,967	K.C. Hsu Y. Ting
Kanhsien, Tungfootour	Wolframite, manganese, iron.	0.8	16,314	K.C. Hsu Y. Ting
Kanhsien, Laikeng	ditto	0.75	8,708	K.C. Hsu Y. Ting

Table 4 continued

Location	Mineral	Percent of WO_3	Ore Reserve (short ton)	Data Source
Kanhsieh, Kaopai	Wolframite, manganese, iron, scheelite, tin, molybdenite.	0.5-0.7	4,850	K.C. Hsu Y. Ting
Sueychuan, Liangbigchou	Wolframite, manganese, iron molybdenite, scheelite.	0.6	8,818	K.C. Hsu
Tayu, Yatzunaw	Wolframite, manganese, iron, tin.	0.6	25,353	Y. Ting
Hweichang, Aishang	Wolframite, manganese, iron, scheelite.	0.7	9,700	K.C. Hsu
Other	N.A.	N.A.	110,230	
		Total	1,815,158	

Data Source: Chen, Y.H., 1941

Kwangtung Province

Tungsten reserves in Kwangtung, second to Kiangsi, were estimated as 373,571 short tons (Table 5) Geographically, the deposits are located in five regions: (1) northern region, (2) Western Region, (3) Central Region, (4) Eastern Region, and (5) Coastal Region (Fig. 3) Geology is almost the same as Kiangsi and wolframite is the chief ore mineral. The grade of the ore is about 1.0 percent of WO_3 in most of the mines.

(1) Northern Region: Deposits are found in Wuyuan, Lochang Kokkang, Yingfa Shihhsing, Yuyuan, Linshon, Yingtak and Namhung.

(2) Western Region: Tungsten deposits are located in the districts of Yuanfu, Engping, Loting, Fuangchuan, and Sinhsing.

(3) Central Region: Deposits are found only in Tsunghua and Chinshing.

(4) Eastern Region: Deposits are mainly found in Meihsien, Fungshun, Hsingning, Wuhua, Chihchin, Hoyuan, Linping, and Hoping.

(5) Castal Region: Most tungsten deposits are found in Chacyuang, Chacan, Chiehyang, Taishan, Haifung, Weiyuang, Paoan, Tungwen, Sinhue, Diannpa, Chungshan, Kowloon, Lufung, and Yuangkiang.

TABLE 5

Tungsten Reserves in Kwangtung, China

Location	Minerals	Percent of WO_3	Ore Reserves (short ton)	Data Source
Shihhsing, Shihgushan	Wolframite, manganese, iron	1.0	18,629	C.S. Wang
Shihhsing, Lobahyumeitzyy	Wolframite, manganese, iron, scheelite.	1.0	15,432	C.S. Wang
Shihhsing, Shyqrenjiang	Wolframite, manganese, iron, scheelite.	1.0	32,408	C.S. Wang
Shihhsing, Syhchyanchieh Hokoushang	Wolframite, manganese, iron, scheelite.	1.0	2,205	C.S. Wang
Wungyuan, Shuitung Mongtousia	Wolframite, manganese, iron, molybdenite.	1.0	138,890	C.S. Wang
Seante, Bapaoshang	ditto	1.0	18,519	C.S. Wang
Lochang, Tiehtingtou	ditto	1.0	25,353	C.S. Wang

Table 5 continued

Location	Minerals	Percent of WO_3	Ore Reserves (short ton)	Data Source
Chungshan, Talinshan	Wolframite, manganese, molybdenite, pyrite, bismuth.	1.0	11,905	B.C. Chang
Other	N.A.	N.A.	110,230	S.L. Fong
		Total	373,571	

Data Source: Chen, Y.H., 1941

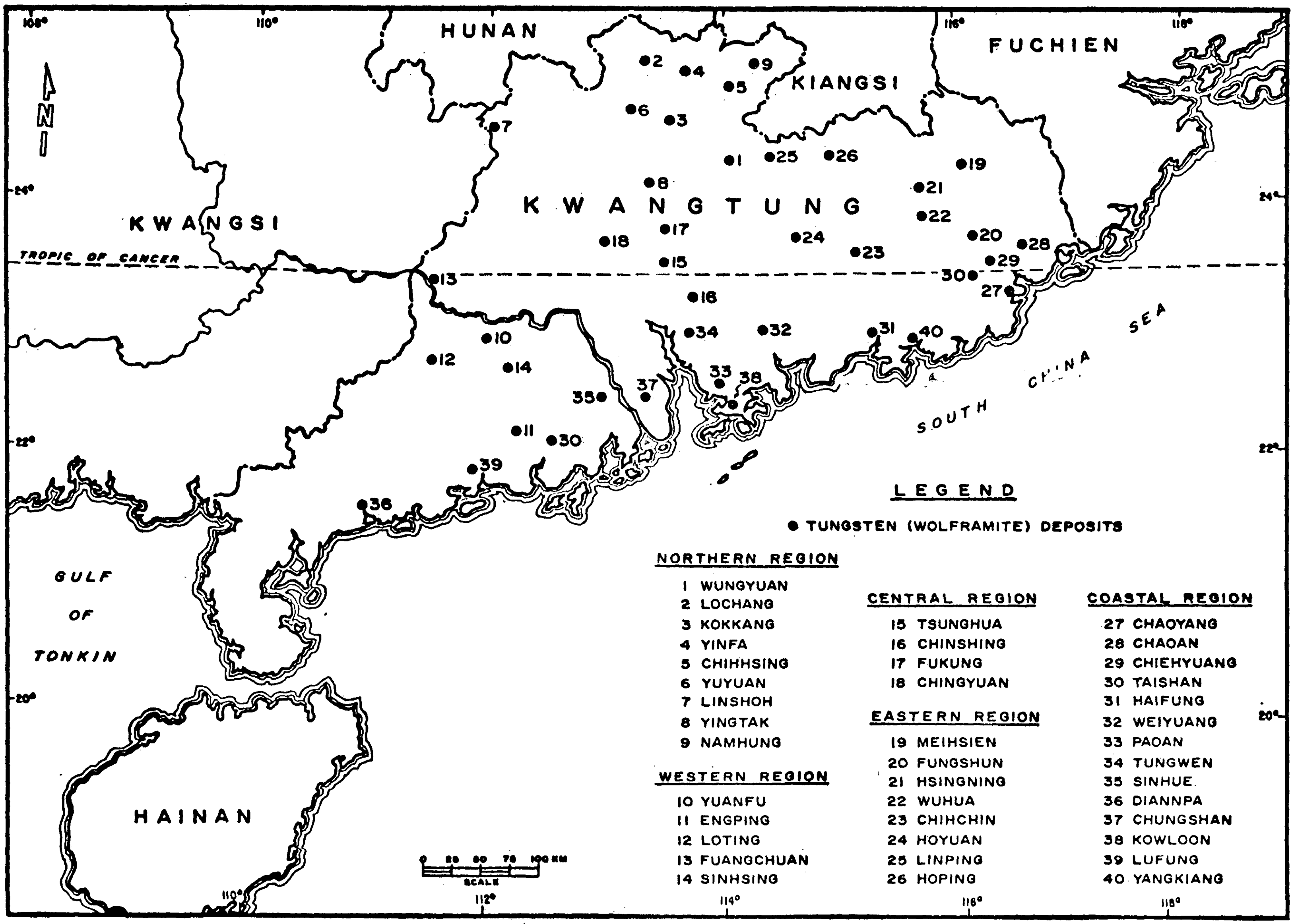

FIG. 3 - DISTRIBUTION OF TUNGSTEN DEPOSITS IN KWANGTUNG PROVINCE, CHINA

Hunan Province

The southern part of Hunan is estimated to have total reserves of tungsten of about 56,328 metric tons (Table 6) Important deposits are found in Tzuhsing, Chaling, Wuhsien, Hucheng, Kueitung, and Linwu (Fig. 4) Wolframite and scheelite are the chief minerals. Scheelite deposits are particularly important in southern Hunan and they are reported as high-grade ore. The veins generally strike NW-SE and dip 60 degrees, and they range from 0.2 to 2 meters in thicknesses. Two types of quartz veins are recognized--those occuring in the granite itself and those in the quartzose sandstone near the contact with granite mass.

Kwangsi Province: In Kwangsi tungsten reserves were estimated at 27,964 metric tons. Most of the tungsten deposits are located in the eastern part of the province which is part of the Nanling Region. Kunghsien is the most important area for tungsten deposits; other areas are Chuanhsien, Kuanyang, Fuchuan, Temghsien, Pingyang, Wuming, and Nantan (Table 7) Wolframite and tin are the chief minerals found in the mines. The richest deposits in this province are found in Shinntu. (Fig. 5).

TABLE 6

Tungsten Reserves in Hunan, China

Location	Minerals	Percent of WO_3	Ore Reserve (short tons)	Data Source
Paiyunsien, Jucheng	Wolframite manganese, iron.	N.A.	7,716	Geol. Survey of Hunan
Chingtung, Kueitung	Wolframite, manganese, iron, molybdenite.	N.A.	2,756	ditto
Tengfusien, Chaling	Wolframite, manganese, iron, tin, bismuth.	N.A.	7,937	ditto
Tengfusien, Chaling	Wolframite, manganese, iron, tin, bismuth.	N.A.	7,937	ditto
Yingtsuiyan, Wuhsien	Wolframite, manganese, iron.	N.A.	13,228	ditto
Hueyjaoau, Wuhsien	ditto	N.A.	6,173	ditto
Yaokangsien, Tzehsing	ditto	N.A.	17,416	ditto
Laitzuling, Linwu	ditto	N.A.	1,102	ditto
		Total	56,328	

Data Source: Chen, Y.H., 1941.

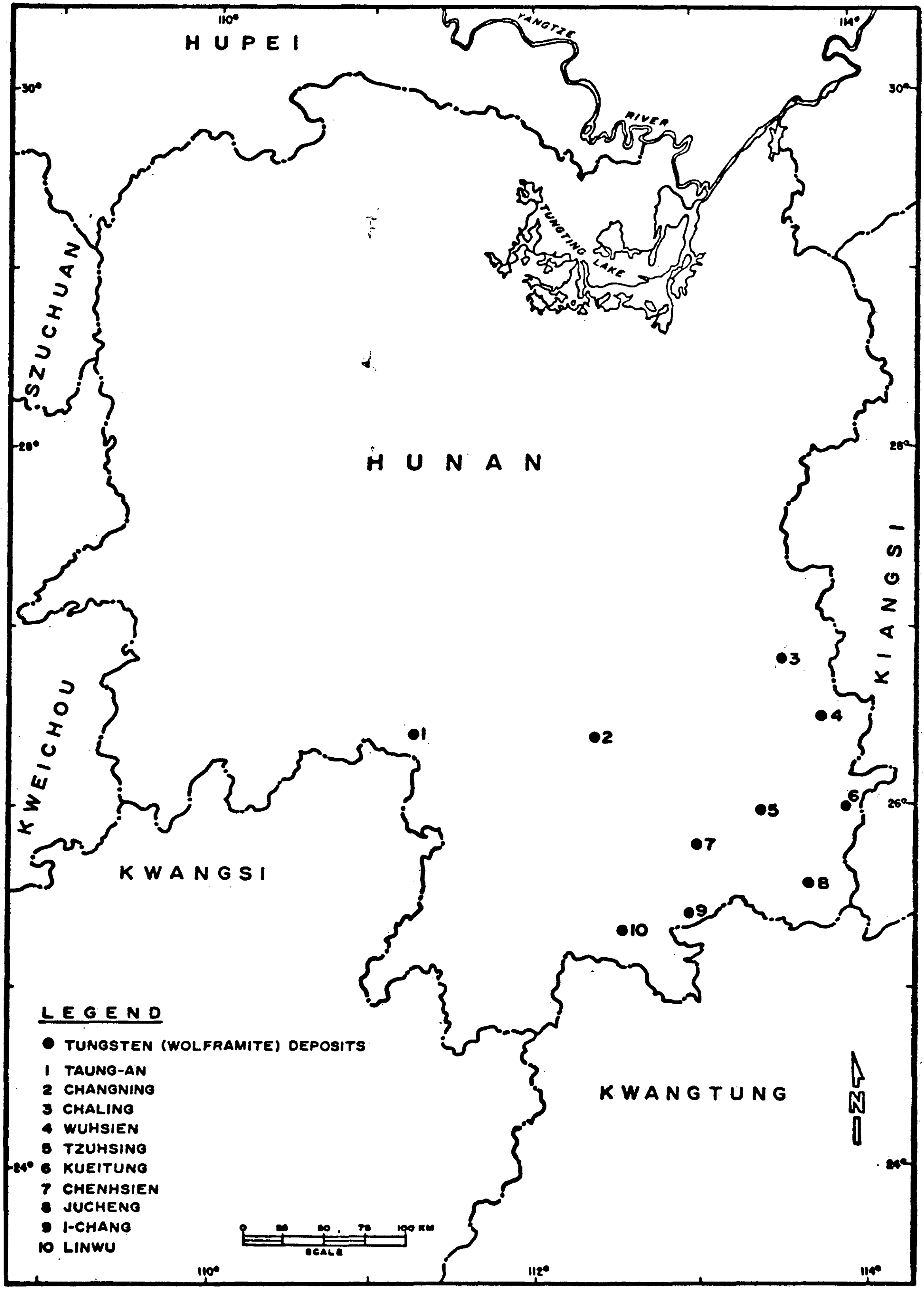

FIG. 4 - DISTRIBUTION OF TUNGSTEN DEPOSITS OF HUNAN PROVINCE, CHINA

TABLE 7

Tungsten Reserves in Kwangsi, China

Location	Minerals	Ore Reserves (short ton)	Data Source
Limuhsiang, etc., Kunghsien	Wolframite, manganese, iron.	16,044	C.K. Chang
Chehoshiang, Hueilotsuen, Nantan.	ditto	5,776	C.K. Chang
Takweishan, Sin	ditto	3,121	C.K. Chang
Taypingjuang, Tenghsien	ditto	2,783	C.C. Yang
Tangshan, Fanshishan, Hwaichi	ditto	240	C.C. Yang
	Total	7,964	

Data Source: Chen, Y.H., 1941.

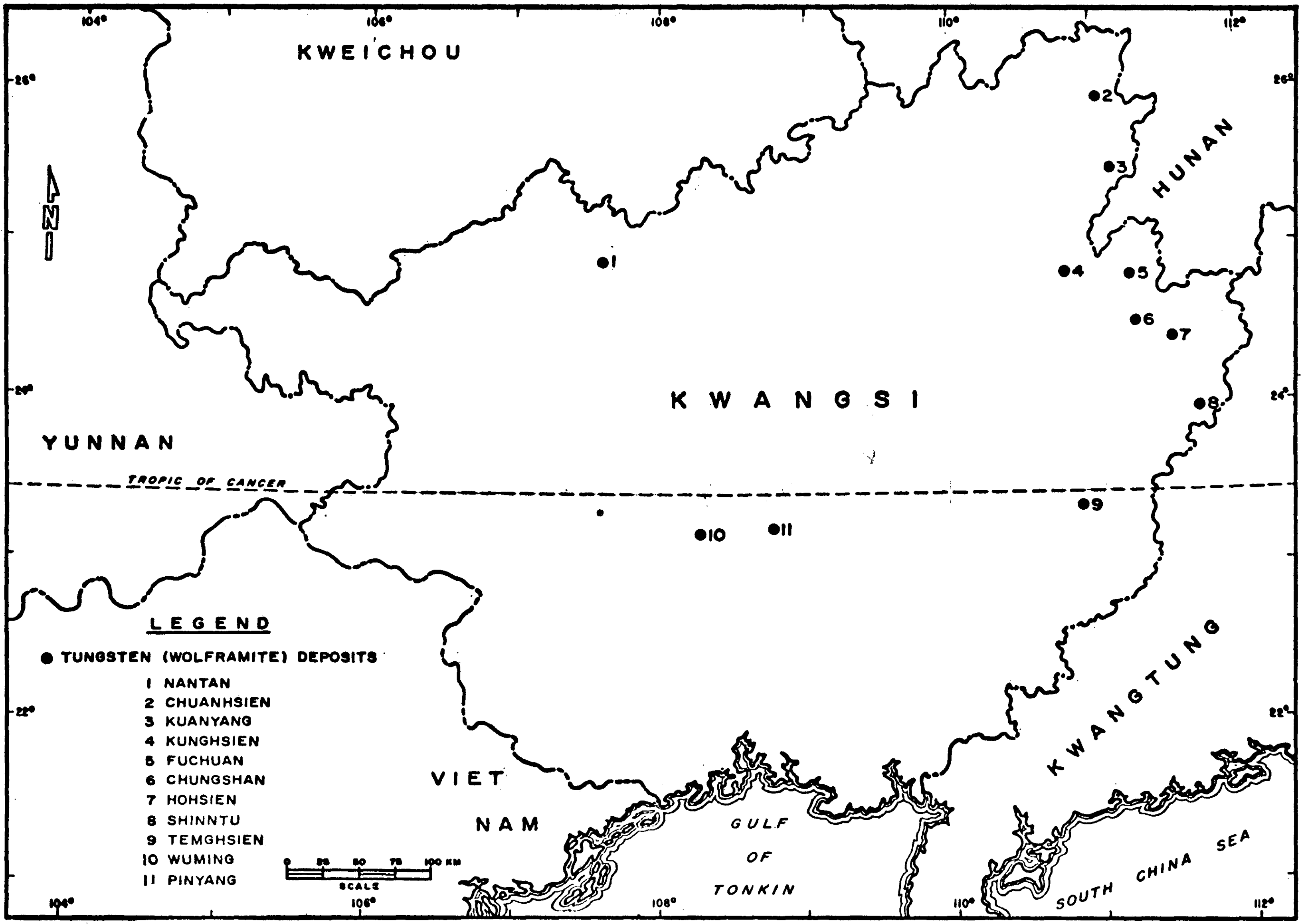

FIG. 5 - DISTRIBUTION OF TUNGSTEN DEPOSITS IN KWANGSI PROVINCE, CHINA

Fukien, Yunnan, and Sinkiang Provinces: Tungsten reserves in Fukien are estimated to be 476 short tons, most of them at Nuhuchan, Putien (Table 8) Reserves in Yunnan are unknown at present. The ore is a mixture of scheelite, wolframite, and some ferberite. The most important deposits are located at Chinghau and Shekping.

Sinkiang province is estimated to have 9,480 short tons of tungsten reserves (Table 9) Most of the reserves are located at Chiketai, Wenchuan.

TABLE 8

Tungsten Reserves in Fukien, China

Location	Minerals	Ore Reserves (short ton)	Data Source
Nuhushan, Putien	Wolframite manganese, iron.	476	K.C. Lee
	Total	476	

Data Source: Chen, Y.H., 1941.

TABLE 9

Tungsten Reserves in Sinkiang, China

Location	Minerals	Ore Reserves (short ton)	Data Source
Chiketai, Wenchuan		1,102	S.H. Sung
Kuczutai, Wenchuan		2,205	S.T. Kuan
Chulikun, Wenchuan		6,173	S.T. Kuan
	Total	9,480	

Data Source: Chen, Y.H., 1941.

IV. TUNSTEN PRODUCTION

World

According to the U.S. Bureau of Mines, China and the U.S.S.R. were in 1972 the largest world tungsten producers. (Table 10) The United States, the world largest consumer of tungsten, only produced 6.9 million pounds of contained tungsten, which is only about 60 percent of its tungsten requirements. Production of tungsten in the United States probably will remain about 8 million pounds per year. It is estimated in the report of the National Material Advisory Board (NMAB, 1973), that by 1987 the United States will be producing 25 percent of its requirement.

The U.S.S.R. probably will be a large producer for the next five years, during the 9th Five-Year-Plan to increase by 60 percent the tungsten production, with the discovery of new tungsten deposits.

China will have total output of 15 to 17 million pounds of tungsten annually. Future production of tungsten will be mainly of lower-grade tungsten deposits from underground mining activities.

TABLE 10

World Production of Tungsten
(thousand pounds of contained tungsten)

Country	1965	1966	1967	1968	1969	1970	1971	1972
China[e]	17,600	17,600	17,600	17,600	17,600	13,200	15,400	16,500
U.S.S.R.[e]	12,600	13,00	13,600	13,700	14,300	14,800	15,400	15,900
United States	7,566	8,482	8,644	7,496	6,904	9,625	6,900	8,150
Thailand	582	591	965	1,096	1,442	1,565	5,527	7,370
Bolivia	1,912	2,760	3,494	3,904	4,059	4,068	4,608	4,923
Korea, North[e]	4,200	4,720	4,720	4,720	4,720	4,740	4,740	4,740
Korea, South	4,698	4,533	4,464	4,614	4,345	4,564	4,539	4,374
Canada	2,964	3,296	220	2,855	3,223	2,956	3,667	3,527
Australia	2,090	2,322	2,123	2,549	2,756	2,789	3,411	3,373
Portugal	1,724	2,096	2,416	3,049	2,934	2,390	2,176	3,093
Brazil	402	494	638	957	2,222	2,549	2,989	2,515
Japan	758	724	862	1,177	1,343	1,882	1,609	1,978
Peru	836	762	871	1,221	1,519	1,773	1,673	1,887
France	N.A.	N.A.	N.A.	N.A.	N.A.	174	163	1,237
Burma	350	240	338	430	353	478	842	992
Mexico	192	150	328	586	635	635	899	798
Zaire	N.A.	N.A.	N.A.	N.A.	N.A.	416	708	635
Spain	49	106	166	273	443	899	897	798
Other	1,109	1,209	1,551	2,153	1,951	1,848	1,995	2,083
Total	59,632	63,085	63,000	64,410	76,889	71,351	78,055	85,320

Data Source: Stevens, 1967-1973.

N.A. (not available)
e Estimate

Thailand, Bolivia, Brazil, France, Mexico, and Spain were countries with a relatively high production level during 1972.

Production of tungsten in Thailand increased from 0.5 million pounds in 1965 to 7.4 million pounds in 1972. Thailand advanced to fourth place. The increase was primarily due to a new scheelite deposit mine at Wiang Pa Pao in the north and a wolframite mine at Khao Soon in the south. Bolivia's tungsten production rages from 4.0 to 4.5 million pounds per year. This nation's tungsten output has been reasonably stable for the past several years. Brazilian tungsten production increased sharply since 1969, with an output of 2.5 million pounds in 1972. France is another country reporting higher production levels, with 0.1 million pounds in 1970 and 1.2 million pounds in 1972. Mexico and Spain both had an output of 0.7 million pounds of tungsten in 1971.

Out of the world's output of tungsten in 1972, 44 percent were produced in Communist countries and about 56 percent in Western countries. Since 1965 the total world production of tungsten increased from 59.6 million pounds to 85.3 million pounds in 1972.

China

China leads the world as a tungsten producer. It started during the First World War with a production of almost zero, and climbed to the rank of first in total world production shortly after the war. At present no official tungsten production statistics are available from China. The U.S. Bureau of Mines and the United Nations Conferences on Trade and Development (UNCTAD, 1973) estimates of an annual production of 17.6 million pounds of contained tungsten seem to be reasonable. The estimation is based mainly upon historical perspective, scattered reports, official trade statistics, and import data published by other nations.

The production of high-grade wolframite from southern Kiangsi Province is the most important. Scheelite deposits became important after the great discovery in southern Hunan Province. Official information shows shipment of wolframite concentrates of a special grade, carrying 71.39 percent of WO_3, 0.08 percent CaO, 0.12 percent Sn, 0.02 percent As, 0.42 percent S, and 0.02 percent Mo.

Based on historical data Kiangsi seemed to have an average output of about 8,390 short tons per year (average of nine years official production data), which is about 70 percent of the total output of China. Important districts for tungsten production are Pankushan, Anyuan, Kueimeishan Lungnan, Tachichan Chienna, and Shangping Yutu (Fig. 2)

Important tungsten mining districts in Kwangtung Province are Shihhsing, Wuyuan, and Lochang (Fig. 3) Smaller mines are widely distributed throughout the province. Wolframite is the chief ore mineral with an annual production of 1,273 short tons.

Hunnan province is important not only for its wolframite production but also for the discovery of scheelite in the southern part of the province. As reported, the scheelite deposits are found near a wolframite producing district at greater depths. The most important districts in this province are located mostly at Yaokangsien Tzuhsing, Yueyjaoau Wuhsing, Paiyunsien Jucheng, Chingtung Kueitung, Tengfusien Chaling, and Laitzuling Linwu (see Fig. 4) Production of scheelite is aimed mostly for domestic industrial uses.

Kwangsi province has an annual average output of tungsten of about 860 short tons. The ore mined in this province mostly contain tin and wolframite. Mining activities concentrate at the eastern part of the province. Mines with a relatively high output level are located at Sintu, Kunghsien Nantan, Tenghsien, and Hwaichi (Fig. 5) Sintu deposits are the richest in this province.

Yunnan province has an annual output of 423 short tons. The most important deposits are located at Chinghsu and Shekping. The ore is a mixture of scheelite, wolframite, and some ferberite, with scheelite predominating.

Production of tungsten in Fukien and Sinkiang provinces is less important in China. In Sinkiang province tungsten deposits had been mined by the Russians. When the Russians were forced to move out of the province, they moved all the equipment back to Russia.

The People's Republic of China was established in 1949. The tungsten industry has been nationalized and under government control during the period of economic recovery from civil war disruptions (1949-1952) As shown in Table 11 and because of the civil war, production of tungsten in 1949 was only 8.0 million pounds, which was 30 percent of world production. Since the tungsten industry became under government control, tungsten production increased to 20.0 million pounds in 1952. Production increased because of the Korean War (1952-1953) (Fig. 6) and the high prices ($50 to $82 a short-ton unit)* of tungsten in the London market in 1951. China decreased tungsten production to 17 million pounds at the end of the Korean War in July 27, 1953 because of low tungsten prices. High levels of tungsten production during the First Five-Year Plan (1953-1957) was achieved because of Soviet aid and mechanization of some of the larger mines. At the same time, most of the tungsten concentrates were exported to Russia in exchange for aircraft, motor vehicles, modern machine tools, power generating equipment, and metallurgical and mining equipment. The highest tungsten production level in China was during

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* A short ton = 2,000 lbs; a short-ton unit = 20 lbs.

TABLE 11

China's Production of Tungsten
(thousand pounds of contained tungsten)

Year	China	Total World Production	China % of World Production
1949	8,000	27,100	30
1950	12,000	38,400	31
1951	15,000	52,100	29
1952	20,000	68,800	29
1953	17,000	71,300	24
1954	19,800	79,300	25
1955	19,800	82,800	24
1956	19,800	82,900	24
1957	16,500	68,500	24
1958	16,500	56,700	29
1959	22,500	61,200	37
1960	24,900	72,200	34
1961	24,900	77,300	32
1962	24,900	72,400	34
1963	23,600	60,000	39
1964	21,400	62,000	35
1965	17,600	59,632	30
1966	17,600	63,085	28
1967	17,600	63,000	28
1968	17,600	64,410	27
1969	17,600	76,889	23
1970	13,200	71,351	19
1971	15,400	78,055	20
1972	16,500	84,470	20
1973	17,600	85,320	21

Data Source: Stevens, 1967-1973.

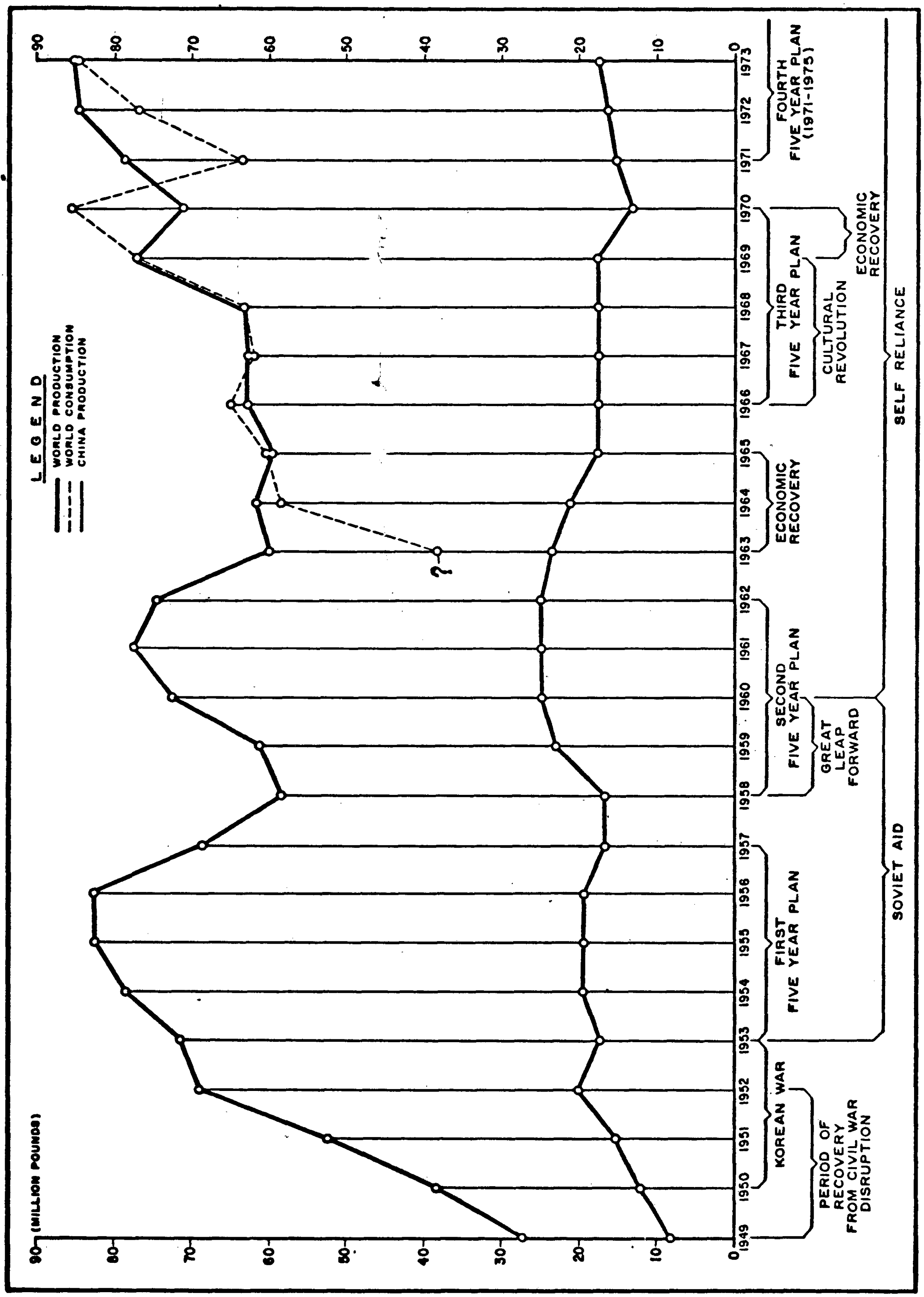


FIG. 6 - WORLD TUNGSTEN PRODUCTION IN RELATIONSHIP TO THE ECONOMIC AND SOCIAL MOVEMENTS OF CHINA (1949-1973)

the Second Five-Year Plan (1958-1962) when world prices were at about $12.7 per short-ton unit. Output decreased during the Third Five-Year Plan (1966-1970) Tungsten production and other industries were affected by the Cultural Revolution (1966-1969); as a result, output reached a low of 13.2 million pounds in 1970, in spite of favorable world prices. The end of the Cultural Revolution and the beginning of the Fourth Five-Year plan in China in 1971 only increased production to 15.4 million pounds, 20 percent of the world production.

The weakness of the Chinese tungsten industry is due to extensive use of hand laborers. For the past twenty-five years mechanization of mining methods and mill plant have been neglected due to high-grade ore and a stable low labor cost. It is believed that because of deeper mining for ore, lower ore grade, and the inadequate mining equipment, China has been unable to increase production. Although China could use more laborers to increase production, these low productivity methods are less and less profitable when used on the lower grade materials. At the recent Canton Trade Fair, China quoted higher prices than the international market quotation for tungsten. One reason for these high prices in the international market can be explained by the recent devaluations of the U.S. dollar relative to the Chinese dollar (RMB).

V. SUPPLY

As described in previous chapters, China has the world largest reserves and is the world's largest tungsten producer. According to UNCTAD, 1972. As indicated in figure 7, Chinese tungsten supply to both Western countries and Communist countries has declined since 1964 (Table 12) The Free World tungsten market has been strongly influenced by China. Figure 6 shows that world tungsten consumption showed a sharp increase after 1968. During the same period China's mine production declined. The critical questions raised are:(1) has China been stockpiling for higher prices?;(2) are declining Chinese exports due to increased domestic consumption rather than declining production?;and (3) are the figures showing declining production accurate?

Since tungsten supply in China is under government control, government policy and planning are the key factors. Production of tungsten has been decreased since 1963. It is the author's opinion that the major reasons for the decline are lower grade of ores, deeper underground mining, and government stockpiling in preparation for war. The Chinese

TABLE 12

China's Tungsten Ore and Concentrate Supply/Demand
(in million pounds contained tungsten)

	1964	1965	1966	1967	1968	1969	1970
Production	21.4	17.6	17.6	17.6	17.6	17.6	13.2
Western Countries	2.13	6.80	9,62	7.70	4.81	5.97	4.29
Communist Countries	7.87	7.23	3.90	0.75	0.88	0.88	0.99
Total	10.00	14.03	13.52	8,45	5.69	6.85	5.28
Possible Stockpile (unexplained balance)	10.35	2.52	3.03	7.90	10.53	9,35	4.42
Consumption	1.05	1.05	1.05	1.25	1.38	1.40	3.50

Data Source: Stevens, 1967-1973.

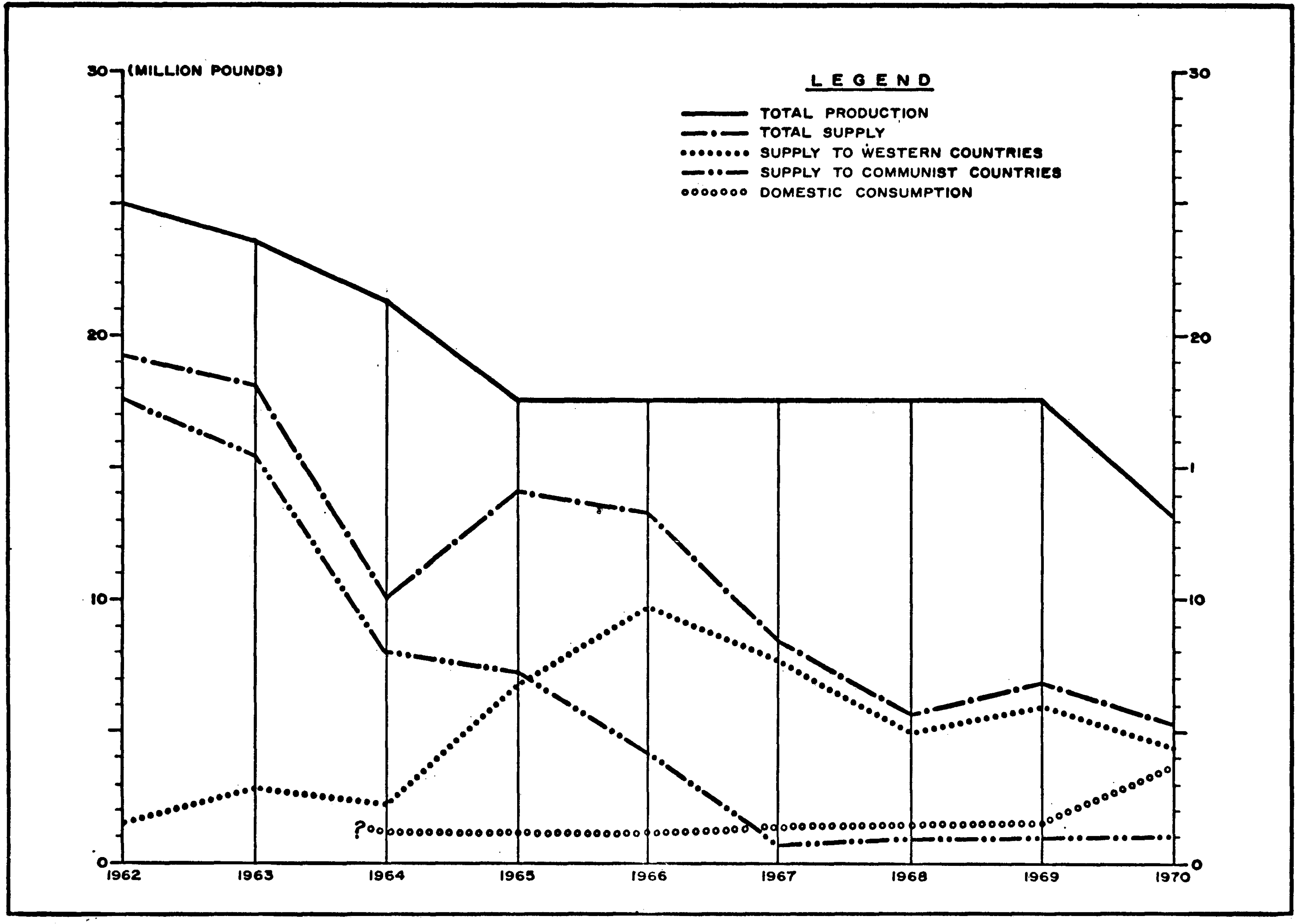
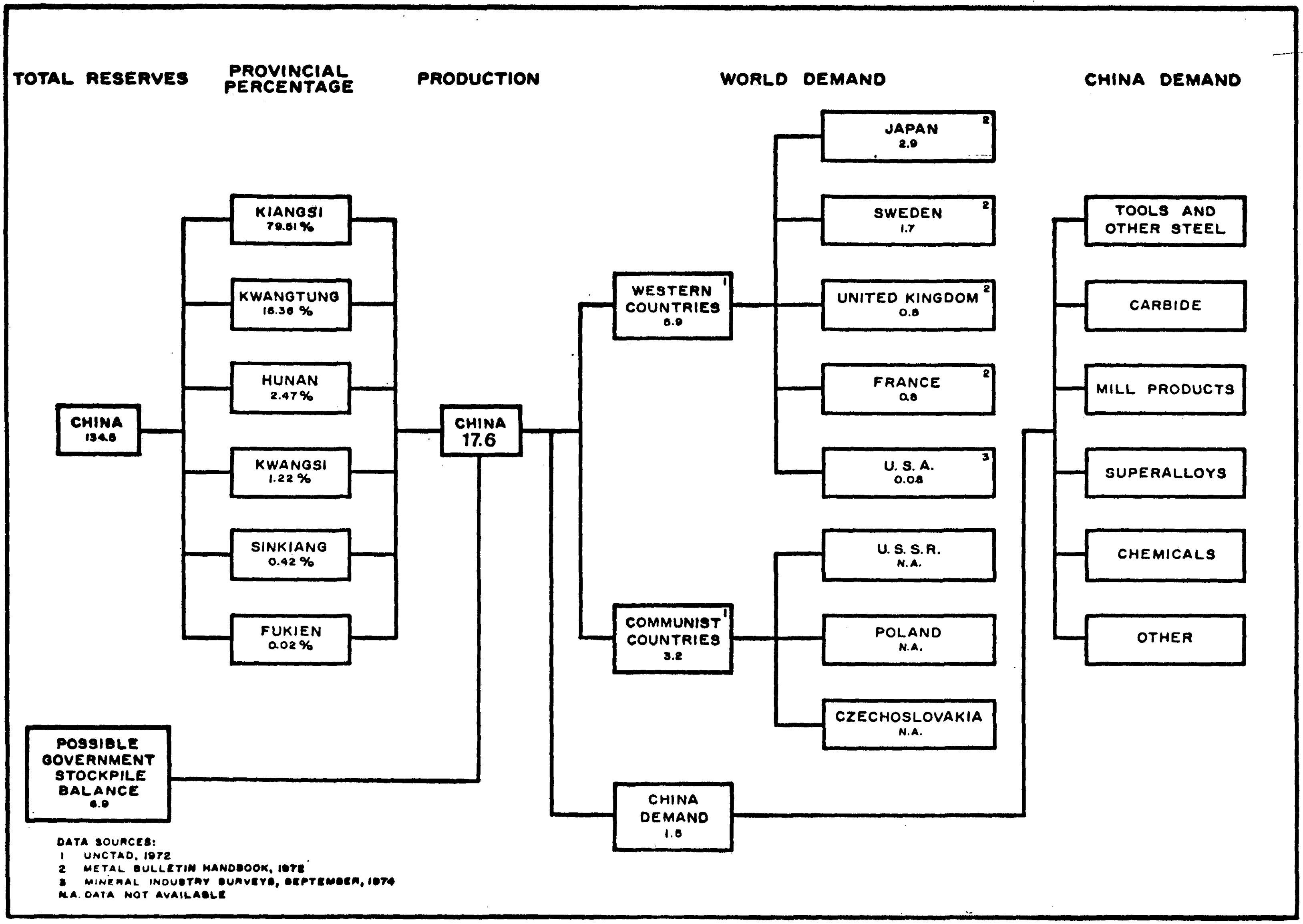


FIG. 7 - CHINA TUNGSTEN PRODUCTION SUPPLY/DEMAND

tungsten industry has faced difficulties for the past twenty-five years, because of unfriendly relations with the Soviet Union after 1960 and because of the Western prohibition on transfer or technology to China since 1949. It was only after President Nixon visited China in 1972 that the U.S. opened the door of western technology to China. It is the policy of the U.S. government to promote trade in non-strategic goods with the People's Republic of China. The import of western technology is viewed as an important factor in transforming China into a modern industrial state, as well as an instrument to foster the overall political and economic goals of making China a strong unified nation. China now has trading relations with over 100 countries. The continuing interest of the People's Republic of China in importing technology and equipment may indicate that China will very likely import complete plants for her tungsten industry in order to meet the growth in domestic comsumption, as well as increasing export shipment in the near future.

The main importers of Chinese tungsten in recent years have been Austria, West Germany, Sweden, France, The United Kingdom, Japan, Czechoslovakia, Poland, and U.S.S.R. The United States joined these nations as an importer in 1973 (Fig. 8).



DATA SOURCES:
1 UNCTAD, 1972
2 METAL BULLETIN HANDBOOK, 1972
3 MINERAL INDUSTRY SURVEYS, SEPTEMBER, 1974
N.A. DATA NOT AVAILABLE

FIG. 8 – AVERAGE CHINA SUPPLY/DEMAND RELATIONSHIP 1964-1970 (IN MILLION POUNDS OF CONTAINED TUNGSTEN)

Chinese Government Supply Policy

The People's Republic of China was established in 1949. During the years 1950-1952 (period of rehabilitation of the national economy) and the Korean War (1950-1953), production of tungsten ranged from 8 million pounds in 1949 to 20 million pounds in 1952. Most of the tungsten was exported to U.S.S.R. China decreased its exports to the United States from 4.9 million pounds in 1949 to 0.39 million pounds in 1951. Although the London price during the same period ranged from $50 to $80 per short ton unit, the higher price did not divert its supply policy away from Communist countries to Western markets. Shipments were continued to the Soviets due to agreements made to support the North Korean war.

The First Five-Year Plan (1953-1957): Soviet aid played an important role in priority development of China's heavy industry. As a result, tungsten production reached a level of 19.8 million pounds per year. China exported its mineral resources and agricultural products to Russia in exchange for machines, metallurgical, and mining equipment.

Only a small portion of tungsten exports was directed toward the Western market. At the same time, more tungsten shipments were diverted to assist the national growth of heavy industry (aircraft, motor vehicles, machine tools, steel, chemicals, electrical, metallurgial, and mining equipment).

The Second Five-Year Plan (1958-1962): In 1960 when the Soviets withdrew all their experts from China, they abandoned hundreds of agreements and contracts, and terminated supply of important equipment. It is believed by the writer that modernization of the mineral industry faced difficulties for lack of mining equipment. The idealogical struggle between the Soviet Union and other Soviet alliances forced China to look to western markets for disposal of her products. As a result, the tungsten concentrate supply to the Soviets decreased substantially (from 21,000 tons gross wt. to zero in 1969). Most shipments to the Soviets were redirected to western markets at higher prices. As shown in Figure 7, tungsten supplied to Communist countries dropped sharply from 17.62 million pounds in 1962 to 15.40 million pounds in 1963 7.80 million pounds in 1964, and 7.23 million pounds in 1965. The decrease of supply to Communist countries was accompanied by an increase in tungsten exports to Western countries. The latter increased from 1.45 million pounds in

1962 to 2.74 million pounds in 1963. Although supply to the west decreased to 2.13 million pounds in 1964, it increased again during 1965 to 6.80 million pounds.

The Great Leap Forward (1958-1960) was designed to accelerate the rate and the economic modernization of the country, with an emphasis on industry. Production of tungsten during this period increased in order to supply domestic demand. The Great Leap Forward was a failure and as a result production decreased in 1963. In addition, the declining and low world tungsten price in 1963 was not conductive to expanded production. When the world tungsten price rose in 1964, tungsten exports increased to both East and West countries, but production failed to respond to higher prices.

<u>The Third Five-Year Plan</u> (1966-1970): The tungsten supply to Western countries was 9.62 million pounds. At the same time, the supply to Communist countries decreased to 3.90 million pounds.

The Cultural Revolution begun in 1966 and subsided in 1969. During the Cultural Revolution factories, mines, and state enterprises generally were invaded by the Red Guard units. Targets included all kinds of cadres in the industrial system. Since the Cultural Revolution there has been a general narrowing of the gap between the lowest and highest wages in industries. Reports indicate that local workers resisted attempts to lower wages and opposed with physical force many Red Guard intrusions into industrial plants. As a result, tungsten production dropped to 17.6 million pounds and supply of tungsten to the Western market decreased from 7.70 million pounds in 1967 to 4.81 million pounds in 1968 but increased to 5.97 million pounds during 1969 the last year of the Cultural Revolution. Although the world tungsten price was higher in 1967 than in 1966, China was not able to supply more tungsten to the Free World Market. Because of price fluctuations and political movements during the Cultural Revolution, Chinese supply decreased. Although China was able to increase some supply to the high price during 1969 and early 1970, Chinese supply to Communist countries decreased to 0.75 million pounds.

<u>The Fourth Five-Year Plan</u> (1971-1975): During this period, the Chinese government reflected stability; as a result, there was large-scale increases in industrial production. Domestic consumption during this period reached the highest point since 1949 and production remained at 17.6 million pounds. During 1970, China supplied only 4.29 million pounds to the West and 0.99 million pounds to the East. The increased supply to the Communist countries was a result of resuming supply to the Soviet Union, which amounted to 0.95 thousand pounds in 1970.

China needs to improve her mining and mill process industry for future tungsten competition. In mid-1972, China began to move into foreign markets to invest in factories, mining equipment, power plants, and long-range jet aircraft. With change of government policies in 1973, the shopping list included nearly 60 foreign built plants and technologies.

Chinese Domestic Consumption

One of the most difficult phases of this thesis is the analysis of China's domestic consumption of tungsten. Estimates by U.S. Bureau of Mines range from 4,000 to 4,500 tons of concentrates during 1971 and 1972. Tungsten usage involves steels, carbides, mill products, pressed and sintered products, cast alloys and superalloys, chemicals, and government uses. Domestic consumptive will be increased at annual rate of 12 percent. Great stress is being placed on making tools of production, mining, meta-lurgical, chemical, refining equipment, and factories.

The writer believes that because of the growth in domestic consumption and the unstable world price the exports of Chinese tungsten will be insufficient to meet increased world demands. According to UNCTAD, 1972, since 1962, the total supply to the West and East were decreased from 19.07

million pounds to 5.28 million pounds in 1970. Domestic consumption increased sharply from 1.4 million pounds in 1969 to 3.5 million pounds in 1970. Domestic consumption reached 4.5 million pounds in 1972. China was able to increase her supply from a total of 5.69 million pounds in 1968 to 6.85 million pounds in 1969 because of world high prices. With the sharp increase of domestic consumption in 1970, and with world high prices, China decreased her exports to the world market to a level of 5.28 million pounds. As reported by Japan at the 1973 Canton Trade Fairs, China quoted higher tungsten prices than international market. With increased domestic consumption, government stockpiling, and limited amount of supply, China was forced to quote higher prices.

Steels

The withdrawal of Soviet experts in 1960 forced China to change its economic construction policy to self-reliance. High priority was given to development of the steel, which is a major user of tungsten. During the Great Leap Forward (1958-1960) steel production increased from 8 million tons in 1958 to 13.35 million tons in 1959 and 18.45 million tons in 1960. The Chinese government announced that steel output had risen from 21 million tons in 1971 to 23 million tons in 1972. Despite the increase in output of steel, China was still dependent upon imports. Imports of steel and steel products in 1973 were over 3 million tons, of which about 2.3 million tons were from Japan. To prepare the foundation for industrial expansion, great stress was placed on making tungsten tool steels. China has been negotiating with both West Germany and Japan to build large steelmaking and processing facilities. Domestic consumption of tungsten will increase as the government makes greater efforts to improve steel production.

Carbides

The largest use of tungsten carbide in China is for metal-cutting machines. In 1949, China produced only 1,582 units of metal-cutting machines. This increased to 28,000 units in 1957. Production of metal-cutting machines increased to 36,500 units in 1969, decreased to 35,000 units in 1970, and increased to 38,500 units in 1971 (Chen, 1967) Another large use is of cemented tungsten carbide and tools for oilwell drilling, coal mining, rock drilling, and tunnel boring. With more demand for oil, drilling equipment construction will be increased; oil production has increased at an annual rate of 25 percent during the past three years. In 1973 crude oil production in China was 50 million metric tons. Crude oil production in 1972 showed an increase of 60 percent. China is looking for higher prices, not only for oil, but also for other surface products after domestic requirements are met.

Increased carbide use is directly related to an increase of mining activity. Also tunneling applications in railway and road construction demands more carbide equipment.

Military Usage

Information relating to military applications, such as annual consumption of tungsten in aircraft, missile, electronic, and miscellaneous items is uncertain. Since China has to self-rely in producing all military weapons, it is believed that the military is one of the major users of tungsten.

VII. STOCKPILING

The writer believes government stockpiling is underway in China. However, to determine the degree of the Chinese stockpiling is difficult. Analysis of stockpiling is based on reports from the U.S. Bureau of Mines (Stevens, 1962-1973), estimating tungsten production and domestic consumption in China. Also, United Nations (UNCTAD, 1972) data on tungsten exports have been used to analyze possible stockpiling. The analysis requires one to look back on the political and economic goals of China. As indicated in Table 12, considerable quantities of tungsten were stockpiled since 1964. The unaccounted for tungsten amounted then to 10.3 million pounds, about 10.5 million pounds in 1968, and about 9.5 million pounds in 1969. The question is, for what reason was the tungsten stockpiled? There is no evidence of stockpiling for higher prices. During periods of high tungsten prices in world market China did not release from stockpiles. This is why most western importers did not believe China was stockpiling tungsten. The writer believes that the high world market price was responsible for reduced stockpiling by the Chinese government during periods of high prices, but they did not release stockpiled material to the world market. The unaccounted for tungsten in 1964 was about 10 million pounds. This was reduced to 2.5 million pounds in 1965, because the price of tungsten in 1965 was higher than in 1964. Although the price of tungsten in 1966 was higher than in 1965, unaccounted for tungsten increased to 3.0 million pounds. This was due to the development of the Proletarian Cultural Revolution and to government policy.

The amount of unaccounted for tungsten between 1964 to 1970 must represent the amount of stockpiled material. This inference is based on the assumption that estimates made by U.S. Bureau of Mines (Stevens, 1962-1973) on Chinese production and domestic consumption and United Nations' (UNCTAD, 1970) data on Chinese exports of tungsten are accurate. It is the writer's opinion, based on analysis of data between the years 1964 to 1970, that an average of 6.9 million pounds per year were stockpiled (Fig. 6)

After the report given by Chinese Premier Chou En-lai (Chou, 1975), during the First Session of the Fourth National People's Congress of the People's Republic of China (held in Peking from January 13 to January 17, 1975), it is clear that China is preparing for a future war. China requires large quantities of high-speed cutting steels and alloys, and needs munitions. All of these increase demand for tungsten. Stockpiling policy will be continued unless tension between China and the Soviet Union is reduced.

VIII. COST ANALYSIS OF A PROJECTED MINE-MILL COMPLEX

This chapter is a cost analysis of an underground tungsten mining operation with mill tonnage rated at 300 tons per day in southern Hunan province. This model assumes complete mining and mill plant technology acquired from the United States. Cost analyses have never been published by Western Chinese mineral industry experts. The purpose of this study is to better define the capability of the Chinese to supply tungsten to the world market after modernization. By using the latest technology and Chinese labor, it is possible to define the lowest possible economic cost for Chinese tungsten. What will be the effect on the world tungsten industry if China lowers her tungsten price to below the world market price?

This model is based on Western technology. Total plant cost is based on a recent study by the U.S. Bureau of Mines (Larson, 1971), using updated cost indices. The mineral ore is scheelite, 1.0 percent WO_3. Mill recovery is 90 percent. The mine is to operate on a two-shifts, six-day per week basis with an average output at 360 tons per day. The mill will be operating three shifts per day for 360 days per year. The annual mill output average 108,000 tons of ore. There will be 97,200 short ton units of contained WO_3 ore produced. Total capital requirements will be as follows:

TABLE 13

Total Capital Requirements of 300-tpd Mine and Mill Complex
1974 (U.S. $)

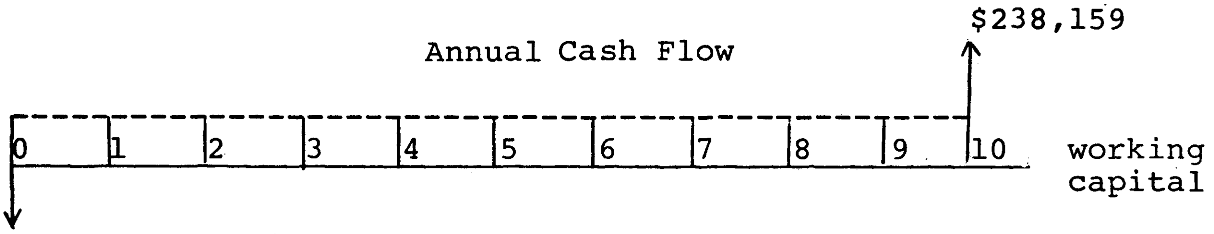
	150% Cost	U.S. fob Costs Percent
Mine cost:		
Surface mine plant	347,454	7.8
Underground equipment	176,651	4.0
Mill cost:		
Crushing section	276,799	6.2
Grinding section	214,152	4.8
Flotation section	223,293	5.0
Leaching section	87,883	2.0
Transportation cost:	1,989,348	44.6
Plant facilities and utilities:	663,116	14.9
Interest during construction:	238,722	5.3
Working capital	238,149	5.4
Total Cost in China	4,455,567	100.0

Cash Flow

A discounted-cash-flow-rate-of-return (DCFROR) of 20 percent (Perkins, 1968) is required by Chinese planners in China. The total investment in this plant is U.S. \$4.45 million. Operations can be profitable because of high rate of return and low labor costs. The Chinese tax rate is 40 percent on industry. Future cost variations are not considered for this operation because of stable labor costs. Depletion is assumed to be 50 percent of net income after depreciation.

The life period for operation is 10 years and the time value of money factors used are:

F_{RP}, 20% 10 yr = 4.1925 and F_{SP}, 20%, 10 yr = 0.1615



Investment = \$4,455,567

\$4,455,567 = 4.1925 CF + 238,149 x 0.1615

CF = \$1,053,573

Net income before depletion, after depreciation = NI

NI = CF - Depletion - Depreciation + Tax + Deplection

Tax = .4 (.5 NI)

Annual depreciation = 4,217,418/10 = \$421,742 (Appendix Table A-10)

$$NI = 1{,}053{,}573 - 421{,}742 + .4\ (.5\ NI)$$

$$NI = 789{,}789$$

Income before depletion, after depreciation	$ 789,789
Depreciation	421,742
Direct costs, labor, and supplies	863,518
Revenue from sales	$2,075,049

Revenue for sale must be $2 million annually in order to provide capital recovery in 10 years and to provide 20 percent DCFROR. Revenue from sales per crude ton of ore milled:

$2,075,049 ÷ 108,000 = $19.21

(Annual revenue from sales divided by annual tonnage)

The average grade of ore is 1.0 percent WO_3, and mill recovery is estimated to be 90 percent. The selling price is as follows:

$19.21 ÷ 1.0 x 0.90 = $21.34/s.t.u. WO_3

Since China is a Communist country, depletion may not be in account; if this is the case the calculation will be as follows:

Net Cash Flow	$1,053,573
Depreciation	(421,742)
Net profit after tax	631,831
Income tax @ 40%	421,220
Taxable income	1,053,051
Depreciation	421,742
Gross earnings	1,474,793
Direct costs, labor and supplies	863,518
Revenue from sales	$2,338,311

Revenue from sales per crude ton of ore milled:

2,338,311 ÷ 108,000 = $21.7

Selling price:

$21.7 ÷ 1.0 x 0.90 = $24.1/s.t.u. WO_3

There is an argument whether China is going to use more laborers for the plant; if there are 10 percent more laborers, the price variation will be 8 cents increase for selling price, which is $24.9 per short ton unit, when depletion is not considered.

IX. THE CAPABILITY OF CHINESE TUNGSTEN INDUSTRY

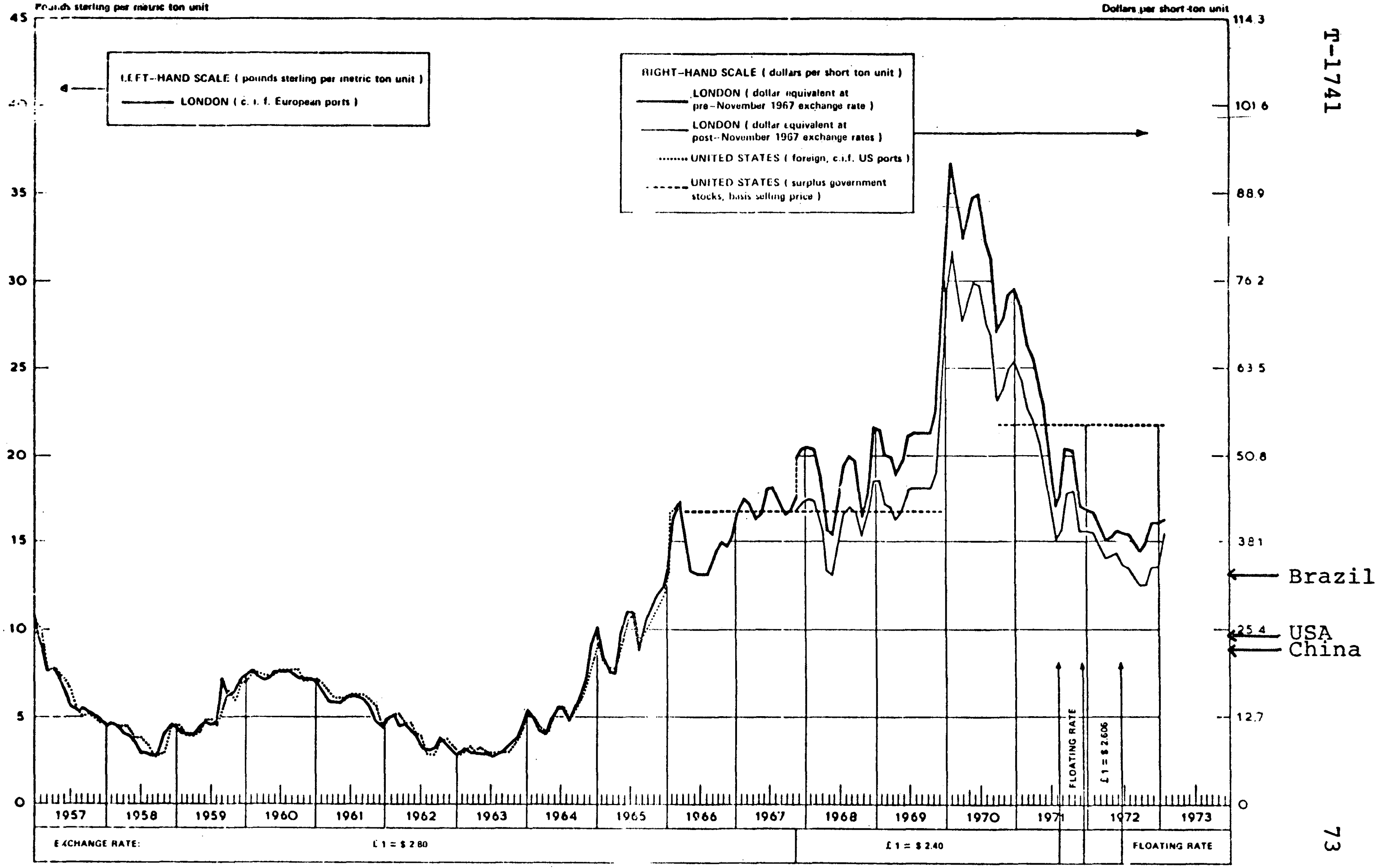
The total investment of 300-ton-per-day mine-mill complex would cost China about $4 million in 1974. Due to the stable and low labor salary system, no mine property expense and high rate of return, the seeling price of WO_3 per short-ton unit can be as low as $21.2. The comparable price in the United States would be $24.42 per short-ton unit (Larson, 1971) At a similar type of plant in Brazil, the selling price would be about $33.80 per short-ton unit (Barbosa, 1972)(Fig. 9)

The United States is the world's largest consumer of tungsten. U.S. consumption production and imports of (contained) tungsten during the period 1970-1974 were as follows (in million pounds)

	Consumption	Domestic Production	Imports PR China	Imports Total
1970	16.7	9.6	--	2.6
1971	11.6	6.9	--	1.0
1972	14.1	7.1	--	11.6
1973	15.4	7.1	.08	21.3
1974	(15.4)	(8.0)	(.27)	(21.3)

Data Source: (Stevens, 1973)

By 1987 the National Materials Advisory Board (NMAB, 1973) expects 75 percent of U.S. demand will be imported.



Source: UNCTAD, October 1972.

Figure 9. Prices: Tungsten Concentrates, United Kingdom and United States (Adapted from NMAB, 1973, pg. 39, with modifications)

It is predicted that the United States will increase her supply from China in the future.

With current unfavorable import duty on tungsten concentrate from China, it is a question whether China can supply tungsten concentrate to the United States. Import duty on tungsten ore in the United States and in some other non-Communist countries is 25 cents per pound; in Communist countries it is 50 cents per pound. In 1973, the average duty in the U.S. for Chinese tungsten was $7.93 per short-ton unit or 40 cents per pound. In this case, the best estimate for the lowest Chinese selling price in the U.S. can be $29.27 per short-ton unit, which is $4.85 higher than the U.S. domestic production cost per short-ton unit. It is interesting to note that importing tungsten concentrates from China would not pose a risk for U.S. domestic tungsten industry; but the Chinese price could be stable for the next ten years, however, while cost for U.S. domestic production could increase and eventually become higher than the Chinese tungsten prices. It is possible that the Chinese tungsten price will go below the world price.

Future Chinese tungsten supplies to the United States would not interfere with the Canadian supply to the United States since production costs of tungsten in Canada are comparable to those of the United States and they are imported under a decreased rate of duty. The cost is estimated at about $29.42, not much higher than the Chinese price. Tungsten supplies from Bolivia, Peru, and Brazil to the United States could be affected by the Chinese supply. These countries have an advantage on import duty but their production costs are much higher than those of China. Production costs in Bolivia and Peru are believed to be close to that of Brazil or about $33.80 per short-ton unit.

X. CONCLUSION

The total tungsten reserves in China are adequate, at about 134.5 million short tons, 79.5 percent of which are located in Kiangsi province, 16.4 percent in Kwantung province, 2.5 percent in Hunan province, 1.2 percent in Kwangsi, 0.4 percent in Sinkiang province, and 0.02 percent in Fukien province. Wolframite can be found in all the provinces; only Hunan province is important for scheelite deposits.

Between 1964 and 1970 average government stockpiles were about 6.9 million annually in China. It appears that government stockpiling is in preparation for war. There is no evidence in the past of release of stockpile to the world market as a result of higher prices.

Due to increase in domestic consumption at 12 percent annually, tungsten supply to the world market will probably remain at 5 to 6 million pounds annually. Production of tungsten will remain stable at about 17 million pounds.

After modernization of her tungsten industry, China could sell at an f.o.b. price of U.S. $21.34 per short-ton unit and still realize a 20 percent return on investment.

This minimum economic price will probably be the same for the next 10 years because of government control and stable labor costs in China. One of the obstacles for Chinese tungsten supply to the Western countries is the unfavorable import duty levied on tungsten concentrates from China. The Chinese tungsten price is lower than the price of domestic tungsten in the United States (about $24.42 per short-ton unit) and is even lower than Brazilian price ($33.80 per short-ton unit) There is a cost variation at about 8 cents more in China if 10 percent more labor is used in the plant. But it will still be the lowest price compared to other nations.

APPENDIX

GENERAL

Figure A-1 is the flowsheet for the 300-tpd mill. Table A-1 to Table A-13 include the detail material used for the cost analysis. The estimation is done by using index numbers to update information from L.P. Larson (1971) and Chinese costs on labor. Table A-8 and Table A-9 show that production costs per crude ton before depletion, income taxes, and rate of return are $16.35 in China.

Labor Wage System

Central planning with governmental controls is being followed in China. The wage and salary system is based on fixed grades into which each employee is categorized. The difference between the various grades is usually about 20 percent. In the mining and metallurgical industry, the monthly salary of an engineer involves eight grades. The lowest salary is 92 RMB (1 RMB or Yuan = U.S. $0.50) and the highest salary is 210 RMB (Table A-13) The monthly salary for technicians contains 5 grades ranging from 52 RMB to 83 RMB. Assistant technicians contain 4 grades; the lowest is 30 RMB and highest is 46 RMB. The mining laborer system contains eight grades--the lowest is 32 RMB and highest up to 106 RMB monthly. The monthly salary of salesmen and clerks usually range from 25 to 45 RMB. The purpose of wage differential is to provide an incentive for workers to acquire additional skills and to improve output. Prices of daily necessities are low and stable; rent, water, and electricity charges account for only 4 to 5 percent of a worker's wage. There is no personal income tax. All workers enjoy free medical treatment, labor insurance, and other welfare services. Workers' dependents pay only half the cost of medical treatment. Under government regulations workers may retire at 60 for male; female workers at 50; and female office workers at 55. Life pensions range between 50 and 70 percent, depending on the length of service.

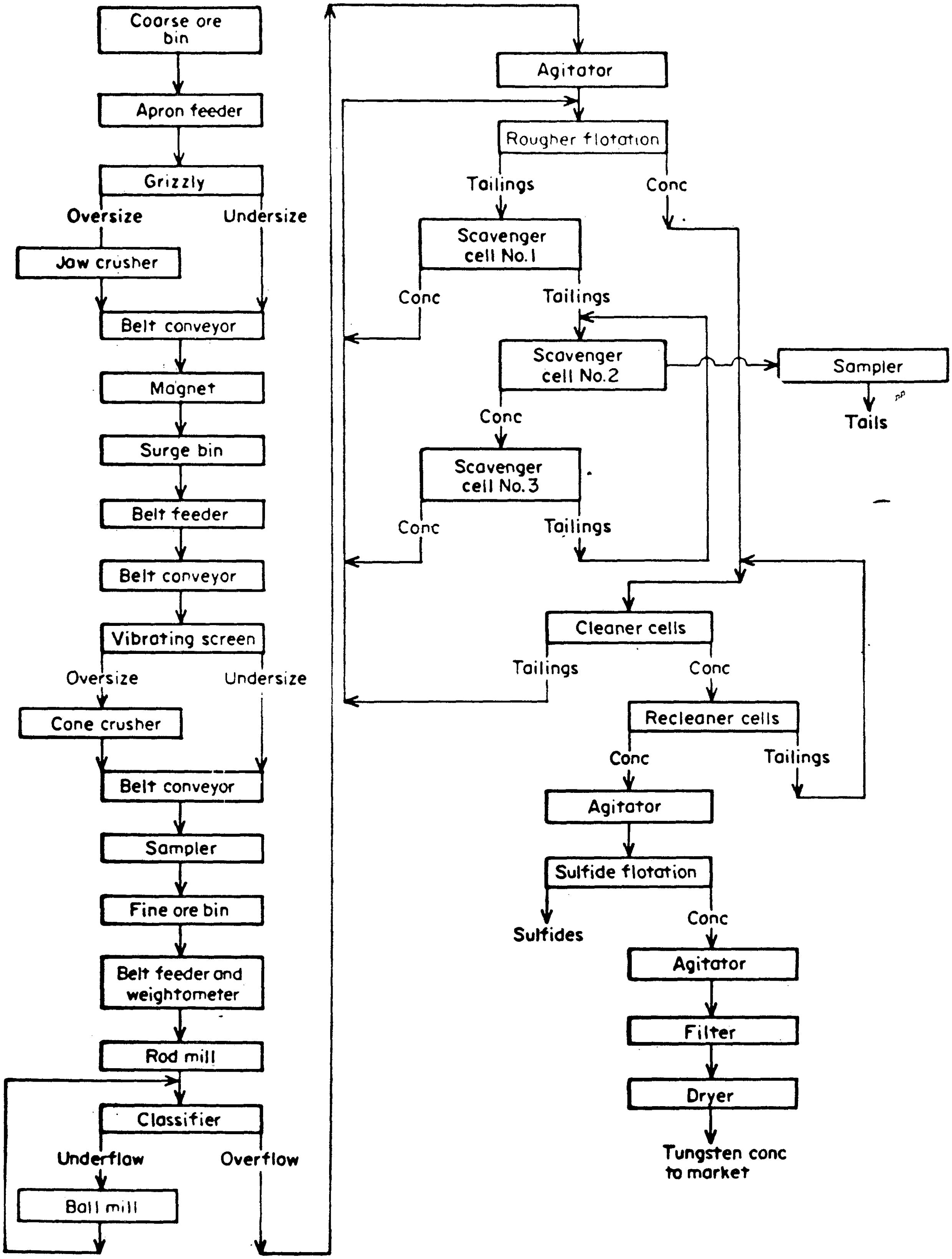


FIGURE A-1 - Flowsheet of 300-tpd Mill.

Adapted from Larson, 1971.

TABLE A-1

Total Capital Requirements of 300-tpd Mine and Mill, 1974 (U.S. $) (Lawson, 1971)

	150% Cost	U.S. fob Costs Percent
Mine cost:		
Surface mine plant	$347,454	7.8
Underground equipment	176,651	4.0
Mill cost:		
Crushing section	276,799	6.2
Grinding section	214,152	4.8
Flotation section	223,293	5.0
Leaching section	87,883	2.0
Total	1,326,232	29.8
Transportation cost	1,989,348	44.6
Total	3,315,580	74.4
Plant facilities and utilities	663,116	14.9
Total plant cost	3,978,696	89.3
Interest during construction	238,722	5.3
Subtotal for depreciation	4,217,418	94.6
Working capital	238,149	5.4
Total cost in China	4,455,567	100.0

TABLE A-2

Mine Cost Summary, Surface Section
1974 Data (U.S. $)(Larson, 1971)

150% U.S. fob Costs

Direct:	Quantity	Cost Material	Cost Labor	Total
Hoist	1	40,248	5,265	45,513
Wire Rope	1	1,800	270	2,070
Skip-cages	2	7,696	945	8,641
Storage tanks	2	3,952	540	4,492
Headframe	1	6,760	945	7,705
Ore bin	1	5,200	675	5,875
Sheaves	2	1,456	135	1,591
Compressor	1	19,656	2,565	22,221
Air receiver	1	1,248	135	1,383
Fan	1	9,776	1,215	10,991
Motor	1	2,600	405	3,005
Subtotal		100,392	13,095	113,487
Foundation		14,288	16,605	30,893
Structure		11,096	4,995	16,091
Buildings		13,912	6,615	20,527
Instrumentation		2,546	1,890	4,436
Electrical		12,596	8,910	21,506
Piping		6,432	3,240	9,672
Painting		670	2,025	2,695
Miscellaneous		8,978	7,290	16,268
Subtotal		70,518	51,570	122,088
Total direct costs		170,910	64,665	235,575
Field Indirect:				37,392
Total construction				272,967
Engineering				14,850
Administration and overhead				14,850
Subtotal				302,667
Contingency				30,267
Subtotal				332,934
Fee				14,520
Total				347,454

TABLE A-3

Mine Cost Summary, Underground Section, 1974 Data (U.S. $)(Larson, 1971)

150% U.S. fob Costs

Direct:	Quantity	Cost Material	Cost Labor	Total
Locomotives	2	37,030	1,350	38,380
Mine Cars	20	14,375	405	14,780
Mucking Machines	3	12,765	135	12,900
Drilling Machines				
Stopes	8	11,040		11,040
Jacklegs		9,200		9,200
Drilling Steel	600 ft	1,380		1,380
Drilling Bits	50	920		920
Hose	2000	3,450	270	3,720
Pumps	3	9,660	2,835	12,495
Blower	1	1,035		1,035
Piping	2000 ft	1,035	675	1,710
Subtotal		101,890	5,670	107,560
Foundations		1,216	1,485	2,701
Electrical		2,680	2,025	4,705
Miscellaneous		8,040	6,480	14,520
Subtotal		11,936	9,990	21,926
Total direct cost		113,826	15,660	129,486
Field indirect:				8,816
Total construction				138,302
Engineering				7,695
Administration and overhead				7,695
Subtotal				153,692
Contingency				15,369
Subtotal				169,061
Fee				7,590
Total				176,651

TABLE A-4

Mill Cost Summary, Crushing Section, 1974 Data (US $)
(Larson, 1971)

150% U.S. fob Costs

Direct:	Quantity	Cost Material	Cost Labor	Total
Coarse ore bin	1	3,350	270	3,620
Surge bin	1	4,824	540	5,364
Fine ore bin	1	4,824	540	5,364
April feeder	1	6,834	675	7,509
Grizzly	1	804	135	939
Primary crusher	1	15,946	1,620	17,566
Belt Conveyor	1	5,092	540	5,632
Belt Conveyors	2	3,618	405	4,023
Magnet	1	536	135	671
Vibrating screen	1	3,618	405	4,023
Belt feeders	2	6,432	675	7,107
Cone crusher	1	27,738	2,835	30,573
Sampler	1	1,206	135	1,341
Weightometer	1	3,082	270	3,352
Bridge crane	1	2,814	270	3,084
Subtotal		90,718	9,450	100,168
Foundations		10,336	12,150	22,486
Structures		7,752	3,510	11,262
Buildings		10,064	12,150	22,214
Instrumentation		1,876	810	2,686
Electrical		9,122	6,885	15,997
Piping		1,876	945	2,821
Painting		536	1,350	1,886
Miscellaneous		6,298	5,130	11,428
Subtotal		47,850	42,930	90,780
Total direct cost		138,568	52,380	190,849
Field indirect				29,488
Total construction				220,436
Engineering				10,800
Administration and overhead				10,800
Subtotal				242,039
Contingency				24,203
Subtotal				266,239
Fee				10,560
Total				276,799

TABLE A-5

Mill Cost Summary, Grinding Section, 1974 Data (U.S. $)
(Lawson, 1971)

Direct:	Quantity	Cost Material	Cost Labor	Total
Rod mill	1	26,398	4,050	30,448
Rod charge	1	2,841	405	3,218
Spiral classifier	1	9,380	1,350	10,730
Ball mill		24,254	3,780	28,034
Ball charge	1	1,876	270	2,146
Bridge crane	1	4,422	675	5,097
Subtotal		70,350	10,665	81,015
Foundations		8,056	9,450	17,506
Structures		5,928	2,700	8,628
Buildings		7,844	9,450	17,294
Instrumentation		1,474	540	2,014
Electrical		7,100	5,400	12,500
Piping		1,474	675	2,149
Painting		402	1,080	1,482
Miscellaneous		4,958	4,050	9,008
Subtotal		37,236	33,345	70,581
Total direct cost		107,586	44,010	151,596
Field indirect				18,848
Total construction				170,444
Engineering				8,370
Administration and overhead				8,370
Subtotal				187,184
Contingency				18,718
Subtotal				205,902
Fee				8,250
Total				214,152

TABLE A-6

Mill Cost Summary, Flotation Section, 1974 Data (U.S. $) (Larson, 1971)

Direct:	Quantity	Cost Material	Cost Labor	Total
Agritator	1	4,556	810	5,366
Rougher and scabenger	2	13,668	2,295	15,963
Scavenger flotation	2	10,854	1,890	12,744
Cleaner and recleaner	2	6,566	1,080	7,646
Sand pumps	2	3,484	540	4,024
Sand pump	1	2,010	405	2,415
Reagent feeders	5	3,484	540	4,024
Boiler	1	3752	540	4,292
Water storage tank	1	2,144	270	2,414
Sampler	1	1,206	135	1,341
Mixer and tanks	1	536	135	671
Launderers	1	4,020	540	4,560
Air Compressor	1	1,474	270	1,744
Subtotal		57,754	9,450	67,204
Foundations		7,144	8,505	15,649
Structures		5,320	2,430	7,750
Buildings		7,548	6,885	14,433
Instrumentation		1,206	540	1,746
Electrical		6,298	4,725	11,023
Piping		15,812	7,965	23,777
Painting		670	1,890	2,560
Miscellaneous		4,422	3,510	7,932
Subtotal		48,420	36,340	84,870
Total direct cost		106,174	45,900	152,074
Field indirect				25,840
Total construction				177,914
Engineering				8,640
Administration and overhead				8,640
Subtotal				195,194
Contingency				19,519
Subtotal				214,713
Fee				8,580
Total				223,293

TABLE A-7

Mill Cost Summary, Leaching Section, 1974 Data (U.S. $)
(Larson, 1971)

150% U.S. fob Costs

Direct:	Quantity	Cost Material	Cost Labor	Total
Agitators	2	2,680	135	2,815
Flotation cell	1	2,546	270	2,816
Filter press	1	6,164	675	6,839
Dryer	1	9,648	1,080	10,728
Subtotal		21,038	2,160	23,198
Foundations		2,432	2,835	5,267
Structures		1,824	810	2,634
Buildings		10,064	9,180	19,244
Instrumentation		402	270	672
Electrical		2,144	1,620	3,764
Piping		402	270	672
Painting		268	675	943
Miscellaneous		1,604	1,350	2,958
Subtotal		19,144	17,010	36,154
Total direct cost		40,182	19,170	59,352
Field indirect				10,792
Total construction				70,144
Engineering				3,375
Administration and overhead				3,375
Subtotal				76,894
Contingency				7,689
Subtotal				84,583
Fee				3,300
Total				87,883

TABLE A-8

Annual Mining Cost Per Ton of Ore Milled in People's Republic of China

Direct Cost:	Cost per Ton	Cost	Percent
Mining production labor	0.08	8,856	0.8
Maintenance labor	0.03	2,646	0.3
Services	0.01	889	0.1
Supervision	0.03	3,426	0.3
Materials:			
Explosive	0.81	87,450	8.0
Timber	0.45	48,600	4.4
Power	0.28	30,750	2.8
Other (spare parts etc.)	2.07	223,500	20.3
Fringe benefits: 20% of payroll	0.29	31,634	2.9
Development	1.56	168,300	15.3
Total direct cost	5.61	606,051	55.2
Indirect cost:			
Administration and general overhead, 15% of labor, supervision and supplies	0.56	60,917	5.5
Depreciation	1.09	117,922	10.7
Government tax: 40% per ton of ore	2.90	117,922	10.7
Total operating cost	10.16	1,098,846	100.0

TABLE A-9

Annual Milling Cost Per Ton of Ore Milled in People's Republic of China

Direct Cost:	Cost per Ton	Cost	Percent
Direct labor mill	0.05	4,890	0.7
Maintenance labor	0.02	1,576	0.2
Services	0.01	889	0.1
Supervision	0.03	3,426	0.5
Material			
Power	0.27	29,250	4.4
Rods and balls for mills	0.47	50,250	7.5
Natural gas	0.08	8,100	1.2
Chemicals and reagents	0.87	93,900	14.1
Other (spare parts)	0.58	2,136	0.3
Total direct cost	2.40	257,467	38.5
Indirect Cost:			
Administration and general overhead, 15% labor, supervision and supplies	0.35	38,300	5.7
Depreciation	1.67	180,479	27.1
Government tax 40% per ton of ore milled	1.77	190,498	28.7
Total annual operating cost	6.19	666,744	100.0

TABLE A-10

Depreciation

	Year Life	Capital Cost	Annual Depreciation
Mine:			
Surface plant	10	347,454	34,745
Underground equipment	10	176,651	17,665
Plant facilities and utilities 1/2 of total	10	262,053	26,205
Subtotal		786,158	78,615
Mill:			
Crushing section	10	276,799	27,680
Grinding section	10	214,152	21,415
Flotation section	10	223,293	22,329
Leaching section	10	87,883	8,788
Plant facilities and utilities 1/2 of total		1,203,191	120,319
Subtotal		1,989,348	198,934
Transportation cost	10	1,989,348	198,934
Total		3,978,696	397,870
Interest during construction	10	238,722	23,872
Grand Total		4,217,418	421,742

TABLE A-11

General Personnel Table, People's Republic of China (RMB)

Unit and Personnel	Shifts per Day	Annual Cost (RMB)*
Supervision:		
Superintendent	1	2520
General mine foreman	1	2016
Mine foreman	2	3216
Mill foreman	1	1824
Shop foreman	1	1824
Mining Engineer	1	2304
Total Supervision	7	13704
Services:		
Accountant	1	540
Clerk	3	1440
Assayer	1	523
Engineer's helper	2	1056
Total Services	7	3559
Mine production:		
Miners	6	5760
Hoistmen	2	1632
Skip-loaders	2	1344
Motorman	1	816
Trainman	1	816
Trainman	1	816
Trammers	4	2688
Timberman	4	3840
Utility man	1	816
Total Mine Production	21	17712
Mine maintenance:		
Electrician-mechanic	1	996
Electrician-mechanic helper	2	1800
Track and pipe man	2	1392
General labor	2	1104
Total Maintenance	7	5292

Table A-11 continued

Unit and Personnel	Shifts per Day	Annual Cost (RMB)
Mill:		
Crusher operator	1	996
Flotation operator	3	2988
Flotation helpers	3	2880
Leach operator	1	996
Leach helper	1	960
Utility	1	960
Total Mill	10	9780
Mill Maintenance:		
Mechanic	1	996
Electrician	1	996
Labor	1	960
Total Maintenance	3	2952

* U.S. $1 = 2 RMB (Chinese dollar)

TABLE A-12

Working Capital

	U.S. $ Cost
Direct labor and supervision, mine and mill-3 months	$ 6,625
25 percent overhead	1,656
Operating supplies and spare parts	158,700
Indirect cost	45,888
Miscellaneous expense	25,280
Total	$238,149

TABLE A-13

Mining and Metallurgical Wage System in People's Republic of China

a) Mining and Metallurgical Engineer:

Monthly Salary (RMB)

Grade:	1	2	3	4	5	6	7	8
	210	192	168	152	134	120	104	92

b) Mining and Metallurgical Technicians

Monthly Salary (RMB)

Grade:	1	2	3	4	5
	83	74	65	58	52

c) Assistant Technicians

Monthly Salary (RMB)

Grade:	1	2	3	4
	46	46	35	30

d) Workers

Monthly Salary (RMB)

Grade:	1	2	3	4	5	6	7	8
	106	92	80	68	56	46	38	32

e) Commercial personnel: Salesmen and clerks and state-operated commercial stores, personnel of supply-marketing cooperatives, warehouse keepers. 25-45 per month.

Note: U.S. $1 = 2 RMB

Source: Charts concerning Chinese Communists on the Mainland, 1972.

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