MINERAL ISSUES

An Analytical Series

NOVEMBER 1988

THE TUNGSTEN INDUSTRY OF THE U.S.S.R.

Cover Photo.—This is a color-infrared Multispectral Scanner (MSS) image of the Uzbek S.S.R., taken by the Landsat-1 satellite from an altitude of 914 kilometers (568 statute miles) on October 1, 1972. The frame covers about 10,000 square miles of ground. The Uzbek capital, Tashkent, lies to the northeast off the frame, and the largest city, Samarkand, lies in the fertile valley just south of the Zeravshan River in the southwest of the Turkestansky Range, which is made up primarily of Silurian sedimentary rocks. The large, blackish Aydarkul Lake in the northwest lies within the Kyzyl Kum Desert. The Naratau Ranges to the south of the lake are composed of Silurian and Devonian rocks intruded at several places by mid-Paleozoic granitic rocks. All of these mountains lie along an active earthquake zone. The Kattarkutanskoe Reservoir lies in the southwest corner of the frame.

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THE TUNGSTEN INDUSTRY OF THE U.S.S.R.

by George A. Rabchevsky[1]

ABSTRACT

The present study indicates that the Soviet Union is the world's second largest mine source of tungsten and the world's largest consumer of this strategic commodity. Nonetheless, because of security considerations, the Soviets have published but little in the way of official statistical data on tungsten mining, processing, trade and consumption. This study, one of a series of detailed reports on selected commodities in the Soviet Union, summaries the contents of a wide variety of Russian language technical literature and other materials. These served as the basis for the compilation of statistical tables presenting estimates of salient statistics on reserves, production, trade and apparent consumption of tungsten in the U.S.S.R. from the inception of tungsten mining in the early 1900's through 1986. By far the greatest emphasis is placed on reserves, mining, beneficiation and consumption of Soviet tungsten deposits and ores therefrom, and on trade in ores and concentrates. Some material also has been included on the downstream tungsten industry, that is, the production and trade in ferrotungsten and other materials. This emphasis is directly related to the volume of material available in Soviet sources on these topics. In addition to the Russian language sources used, other source materials have been utilized where they have proven useful or essential to developing a comprehensive picture. The study substantially revises previously published Bureau of Mines estimates of Soviet tungsten production for a number of years, utilizing source materials that were not previously available or evaluated.

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Prior to the formal review of the report, a draft of it was made available for inspection to several Soviet Offices; none, however, agreed to receive or review it. In the United States, the late Mr. Eric Ho, then with the AMAX Metals Group in Greenwich, Connecticut, read and commented briefly on the report; Drs. James E. Elliott and S. Warren Hobbs, of U.S. Geological Survey in Denver, Colorado, informally read through the report and made useful critical comments. A number of other individuals provided occasional references and suggestions. The preparation of this report would be more difficult and time-consuming without the contributions by the individuals mentioned; their participation is greatly appreciated.

Introduction

The Bureau of Mines, Division of International Minerals, is preparing a number of reports on the mining industry of the Soviet Union for its Mineral Issues-Analytical Series. This report on the Soviet tungsten industry is one such report.

This study was based on review of the readily available published literature in the United States, published in Russian and other languages. Included were the "Minerals Yearbook" series published by the U.S. Bureau of Mines, the trade statistics for the USSR and various trading partner countries, and the quarterly statistical publication of the Tungsten Committee of the United Nations Conference on Trade and Development (UNCTAD) (1).

Data on Soviet tungsten production in this report has been revised downward from previous Bureau estimates. The revision was based on information on imports of tungsten from China, which became available in recent times, coupled with a production series proposed by Dr. V. Strishkov (2).

The methodology used to arrive at the revised production series, outside of the review of additional published information, was basically straightforward, even though very tedious. The domestic production was procured from Soviet literature describing various aspects of the tungsten industry and from the published five-year plans and accomplishments. Although tonnage numbers rarely appeared in literature, the peformance of the plans of some tungsten facilities was given in percentages. In some instances, information appeared on the production of tungsten by specific plants and/or regions and the consumption by the various industry users, in percentages, and was used to estimate production of the major tungsten production complexes. Assuming that Soviet exports of tungsten concentrate were always relatively negligible, and assuming that the U.S.S.R. consumed almost all of the available supply except for periodic stockpiling, the domestic production series was then adjusted based on this information.

The report addresses primarily the production of tungsten concentrates, with descriptions of the major producing complexes. No attempt was made to analyze the Soviet ferrotungsten industry, primarily because of lack of substantative official data. The production of the various tungsten products is, however, touched on briefly, and the author is aware that the absence of data in this report on Soviet ferrotungsten production makes this report incomplete. For example, it was suggested that knowing the production of ferrotungsten, the production of concentrate may be derived (2). The proposed scenario assumed that over 50% of tungsten concentrate consumed in U.S.S.R. is used in the production of ferrotungsten. It was, therefore, further assumed that the growth of Soviet production and net imports of tungsten concentrate was more or less parallel to growth of ferrotungsten production. However, the distributive pattern of tungsten consumption by end use in the United States, and elsewhere in the world, was not static and did change and fluctuate from 1940, during World War II and later, as steel processes changed and the expansion of uses for new alloys, and air travel and space exploration applications, continued.

Definition of Terms

The term "tungsten" is presently used in the United States, Canada, Great Britain, and France and several other countries; the term "wolfram" is used in Germany, the Soviet Union, and most other European countries. The term "wolframite" is used in this report only when it pertains directly to the mineral wolframite.

The Soviet Russian-language literature contains many terms which are at times not translated consistently into English. Furthermore, more than one Russian word may be used for the same English meaning and vice versa. Thus, the English word "mineralization" in this report was translated for the Russian words "obrazovaniya", "orudenenie", and when applicable, for "rudoproyavlenie". (The latter literally translates as "a show of ore"). Russian terms such as "rudnye uzly" (ore knots), "rudonosnyy rayon" (ore-bearing region), "rudnoe pole" (ore-field), "mestorozhdenie", and others are translated in this report to mean an ore-field, a mining district, a deposit, or an ore occurrence, depending on the context of the Russian text (3, p. 51; 4, p. 8).

CHAPTER 1.—HISTORY OF SOVIET TUNGSTEN CONCENTRATE PRODUCTION

The term "wolfram" first appeared in Russian literature in 1824, in reference to deposits discovered in the Ural Mountains of Russian S.F.S.R. (R.S.F.S.R.) (5). Here wolfram was known as "volchets" (from German "wolf"), and wolfram acid as "volchetskaya kislota" (wolf's acid).

Production of tungsten in Imperial Russia was low and the process inefficient. In the Transbaikal region, the Belukha and Bukuka mines were operating, the Kolyvan mine in the Altay region, and Boevsk in the Ural (6, p. 6). Following the Revolution, in 1918 all industrial operations were nationalized, including the production of tungsten. From then on, the production of tungsten virtually stopped until 1925. In 1921 the Government's control of private enterprises was somewhat lessened, however, and by 1928, it was reported that 34 tons of tungsten concentrate were produced. Unable to restore the "nonferrous industry" (which in the U.S.S.R. included tungsten) on its own, the Soviet Government began also employing foreign technicians, and in 1928 started the first five-year plan. Just from the United States, 65 engineers and 151 technicians worked in the soviet nonferrous industry (2).

Geologic exploration for tungsten began in the 1930's, primarily in regions already known in Imperial Russia, such as Transbaikal, the Urals, Kazakh S.S.R. (Kazakhstan) and in the Maritime Province (Primor'ye) of the Soviet Far East Territory. During that time, smaller deposits such as Kuranzhinsk and Barun-Undursk in Transbaikal, Ubinsk and Kaindinsk at Kalba were developed. The Gumbeika Mining Complex in the Urals became operational at the end of 1929, and produced 148 tons of concentrate in 1930, revitalizing the region's declining production (7). In 1927, mines in the Far East were producing at least 15 tons of concentrate, with mines also operating in Transbaikal (8, p. 69). Based on regional information, the 1920 national production of tungsten concentrate is estimated to have been 170 metric tons. By 1932, however, tungsten production fell by 19% from that of 1930, primarily because of poor output by the Gumbeika complex and the mines in Transbaikal. The production of tungsten concentrate in the U.S.S.R. in 1932 was reported to have been almost 5 times that of 1929, ranking first in Europe and sixth in the world. The planned production for 1932 was 150 tons, and 300 tons for 1933 (9). Based in part on the above information, the 1932 production is estimated to have been 140 metric tons, and the 1933 production is estimated to have been 175 tons. The Gumbeika complex increased its production by 13% over that of the previous year, but mines in Transbaikal produced only 38% of their planned quota (10). At the end of 1933, the Kolbin tungsten complex in the Altay region (Gorny Altay) of Kazakhstan became operational on a small scale (11, p. 51). The 1934 production was 105.7% that of the first eight months of 1933, but the planned quota for the same period was met by only 45.2% (12). In 1935 the production was 242% that of the first half of 1934.

In late 1930's and early 1940's, a significant number of new deposits, such as Tyrny-Auz in western Caucasus Mountains: Dzhida, Shaktomin and Davenda in Transbaikal; Iul'tin in the Chukotka region; Akchatau, Kok-kul and Chindagot in Central Kazakhstan; Chorukh-Dayron, Koytash and Lyangar in Central Asia were discovered. From the descriptions of individuals mine and plants, the tungsten production seems to have been increasing gradually, by perhaps 5.5% per year during this period, and then by larger amounts after 1942. With the outbreak of World War II, Germany occupied Tyrny-Auz in November 1942, a major tungsten producer by that time, and held it until January 1943. The plant was blown up by the Soviets, and it was more than two years before Tyrny-Auz was put back on line (2). In 1943, the production reportedly increased by 84% over that in 1940 (13). During the World War II period, increases in production came mostly from Dzhida and other deposits in Central Asia, including the Tuim Complex in Siberia, and Balkhash Complex in Kazakhstan (14).

During World War II, because of the strategic importance of tungsten in the war effort, consumption of tungsten in the Soviet Union rose significantly, and exploration and development were renewed. The Karaoba deposit in Central Kazakhstan and Ingichke in Central Asia were discovered. The large Verkhne-Kayrakty stockwork deposit was discovered in Central Kazakhstan after the war. This also included the Vostok-2, Lermontov and Boguty deposits (6, pp. 6–7).

By 1945, tungsten concentrate production reportedly more than doubled in the U.S.S.R. from that of 1940. Production in 1946 was 11.6% over that of 1945, and it increased by 20.7% in the first nine months of 1947 compared with the same period of 1946 (15). The Soviet Union in 1947 reportedly ranked second among world producers in reserves of tungsten (16). By 1948, production of tungsten expanded in the Primor'ye Territory of the Soviet Far East (17, p. 33). Industrial recession started in the Soviet Union in 1949, and during the fifth five-year plan (1951–55), tungsten production is estimated to have risen by about 10% annually. In 1950, the Soviet Union increased imports of tungsten concentrates to over three times those of the previous year. Appreciable imports continued until 1963.

In 1951 and 1952, the large tungsten conentrators at Ingichke and Lyangar, both in Uzbek S.S.R. (Uzbekistan), were put into operation, as was the Skopin beneficiation mill southwest of Moscow. By 1954, there were at least 12 major tungsten concentrate beneficiation plants in full operation in the Soviet Union: Akchatau, Belukha, Bukuka, Chelyabinsk, Chorukh-Dayron, Dzhida, Gumbeika, Kolyvan, Koytash, Lyangar, Skopin, and Tyrny-Auz (18). In 1955, the Tyrny-Auz complex alone was reportedly producing an estimated 10–12 tons of tungsten concentrate from 5,000–5,500 tons of ore per day (2). Assuming that Tyrny-Auz accounted for 30–40% of Soviet tungsten output and produced about 2,500 tons of concentrate per year, the 1955 production is estimated to have been 6,250 metric tons. At the same time, production in Kazakhstan increased by 32% in 1954, 37% in 1955, and 45% in 1956, compared with that of 1953 (19). By the end of the fifth five-year plan (1951–55), the Soviet Union was importing large quantities of tungsten concentrate, primarily from China. In 1957, imports were estimated to have reached a historical high.

Under the sixth five-year plan (1956–60), which was then revised to a 1956–58 three-year plan, tungsten concentrate production in 1960 was to have increased by 57% over the 1955 level, or 11.4% per year (20). According to production data of various mines and plants, however, this quota was never achieved, and output growth is estimated to have been not more than 6–8% per year from 1956 to 1960. In 1956, production increased in plants in Tadzhik S.S.R. (Tadzhikistan) and Southwest Siberia; and in 1957, the Tyrny-Auz complex increased production by 3.4% to over that of the previous year (21). By that time, 45% of total explored reserves of tungsten ore were located in Kazakhstan.

Under the revised 1959–65 seven-year plan, production in Tadzhikistan in 1965 was to have been increased by 20% over that of 1958. Renovation of existing plants was also planned at the Chorukh-Dayron and Maykhura mines (22). The output of the Ingichke, Koytash, and Lyangar mines in 1965 was reported to have been increased by 187% over the 1958 level (23). However, the ore grade was declining in Kazakhstan. There were also problems with insufficient water supply, so that the Verkhne-Kayrakty deposit was not mined for more than ten years (24). There was also a shortage of ore at the Tyrny-Auz concentrator, and the WO_3 content of the ore was only 0.18–0.23% (25). During the 1962–67 period, it increased production of ore by only 13.6% over that of 1961 (26). Production of tungsten concentrate in the U.S.S.R. from 1961 to 1965 is estimated to have increased by 3% per year. During this plan period, the Soviet Union began to decrease its imports of tungsten concentrates, and by 1966 those imports reached a low level similar to the import level of 1949, but started to climb again gradually the next year. Soviet reported exports of tungsten concentrate reached the highest level in 1961.

During the eighth five-year plan (1966–70), Northeast Siberia was becoming an important producer of tungsten, and production in Magadan Oblast' increased by 11% during this period (27). The following deposits were explored: the Vostok-2 in Primor'ye, Inkura in the Buryat A.S.S.R., Bom-Gorkhon in the Chita Oblast', and Boguty in South Kazakhstan (28). By 1970, production is estimated to have increased by 28% over that of 1960 (29).

In 1971, at the start of the ninth five-year plan (1971–75), production increased by 5% over that of 1970 (30). It was planned that 1975 output would be 60% above that of 1970 (31). It is estimated, however, that production was increasing by 3–4% annually. In 1973, a new concentrator at Ingichke in Uzbekistan was built, making it one of the largest in the Soviet Union, with capacity doubled from the old one built in 1951. During the ninth five-year plan, the Boguty and Karaoba deposits in Kazakhstan were being explored (32).

At the start of the tenth five-year plan (1976–80), Tyrny-Auz was still the largest producer of tungsten in the Soviet Union; but because of poor ore grade, its production of tungsten was less than planned (33; 34). It is estimated that the Tyrny-Auz complex supplied 40% of the total Soviet output of tungsten concentrate by 1980. In Primor'ye Territory, the first stage of the Primorskiy complex was commissioned in 1976, and treated ore from the Vostok-2 deposit. In Tadzhikistan, the Chorukh-Dayron deposit was almost depleted by 1977, and the Maykhura and Yubileynoe deposits became major producers in this region (35). Because of poor ore grade, labor shortages, and lack of adequate equipment, it is estimated that Soviet tungsten production did not exceed 3% annual increases from 1976 to 1980. At the start of the plan period, imports began to increase, and have remained high, with yearly fluctuations, to the present.

The eleventh five-year plan (1981–85), called for increases in tungsten production, because of shortages of this commodity. Imports and consumption were also high. The planned production quotas, however, were not met, especially by the Tyrny-Auz and Akchatau complexes (36–37). During this time, the average tungsten content of mined ore had decreased by 50%, and there were shortages of flotation reagents. In 1984, the recovery of tungsten concentrate from ore was only 60–70% (38). Continued labor shortages added to poor production performance. During the eleventh plan period, the labor growth rate was about 2%, compared to 9% during the previous plan period. Nevertheless, in 1982, the Dzhambul mine and concentrator in Kazakhstan were put into operation, and work started on the new Kayrakty beneficiation plant in 1984 (39). The Novosibirsk tin plant and the Solnechnyy beneficiation plant continued to recover small quantities of tungsten concentrate as a byproduct (40). During this plan period, it is estimated that production of tungsten concentrate in the Soviet Union increased by only 2% per year.

CHAPTER 2.—GEOGRAPHIC DISTRIBUTION OF DEPOSITS, MINES, AND BENEFICIATION PLANTS

Tungsten ore deposits are widely distributed around the world and tungsten is produced on all continents except Antarctica. Except for a few deposits, most of the Soviet Union's tungsten deposits are relatively small and/or are of poor ore grade, as is the case for most other countries.

The major Soviet tungsten deposits stretch, in general (except in the Ural Mountains), along the southern border of the Soviet Union, from the Caucasus in the west to the Primor'ye Territory in the east, and to the Magadan Oblast' in Northeast Siberia. Recently, scheelite mineralization has also been investigated in southern Karellian A.S.S.R., on the eastern rim of the Baltic Shield (41). The deposits, then, except those in the Urals, thus girdle, in essence, almost the entire southern and eastern frontiers of the Soviet Union with mines and beneficiation plants that are located far from the major R.S.F.S.R. cities and industrial centers, and close to foreign borders. Mining in the Ural Mountains was proportionately more important in the past when consumption was low, because of their proximity to population centers. Mining at present is uneconomical in the Urals because the deposits are small or depleted, ore grades are low, and tungsten can be transported cheaper from remote regions in the East. At present, mining is most active in the Caucasus, Central Asia, Kazakhstan, the Primor'ye, and Transbaikal. As a rule, the tungsten beneficiation plants in the U.S.S.R. are located close to or at the mines. In a few cases, however, the ore is transported from the mines over a considerable distance to the processing plants.

The geographic locations of selected Soviet tungsten deposits, beneficiation plants and metallurgical plants are shown on the map at the back of the report. There is some confusion in Soviet and Western literature in regard to the exact location of some deposits, mines and beneficiation plants. In many instances, Soviet published sketches of deposits do not include even the basic cartographic information in their legends, such as latitude and longitude, scale, or even azimuthal direction. Furthermore, many geological sketches bear no place names or identifiable physiographic features.

CHAPTER 3.—RESERVES AND EXPLORATION

RESERVES

The definitions of reserves and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals", which is reprinted in the introduction of Minerals Facts and Problems, 1985 edition. The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources) (42).

Reserves of tungsten in the Soviet Union are estimated to be substantial, but definitive information on the reserves and about the production and prospects for future development is lacking. By the end of the 1920's, about 30 deposits of tungsten were known, and in 1933, the explored reserves of tungsten were estimated to be 12,000 metric tons of WO_3 concentrate (43). Soviet tungsten reserves in 1945 were estimated to be at least 30,000 metric tons of 60% WO_3 concentrate, with predictions that in the foreseeable future the Soviet Union would need to import three-fourths or more of its needs, presumably from China and North Korea (44). Soviet explored reserves of tungsten reportedly increased 15 times by 1959 over those of 1945 (45). In 1957, 45% of total explored Soviet reserves were located in Kazakhstan (19).

The U.S. Bureau of Mines estimated the geological reserves of tungsten ores in the Soviet Union to be 500,000 metric tons of 60% WO_3 in 1972 (46). At that time, there was a shortage of high quality explored reserves; 50% of the total was concentrated in large deposits of poor ore grade (47). According to estimates in 1975, the identified tungsten reserves of the Soviet Union were over 158,500 metric tons of contained tungsten, and over 317,500 metric tons of other tungsten resources, for a total of over 476,000 metric tons, representing 9.2% of the world reserves, making it the third largest in the world after China and Canada (48). Stafford slightly revised those estimates in 1981 to 213,000 metric tons of reserves and 317,500 tons of other resources (49). The U.S.S.R. in 1984 was still in third place in tungsten reserves, behind China and Canada. In 1985, the Soviet tungsten in situ resources were estimated to be over 635,000 metric tons WO_3, based primarily on the Bureau's 1983 contract study of the major Soviet tungsten deposits (50–51). Table 1 is a summary of the in situ ore resources of the major Soviet tungsten deposits based on those studies. It should be mentioned here, however, that the Bukuka mine, mentioned in the previous studies, was closed in 1959 and the Kti-Teberda mine may be inoperative today, both because of poor ore grades or ore depletion; the Lyangar deposit was depleted in 1974. In a recent article by the Minister of Geology of the German Democratic Republic, explored reserves of Soviet tungsten were stated to be 215,000 metric tons, or 8% of the world total (52). No attempt has been made in this study to recalculate the reserves of Soviet tungsten.

The grade of Soviet tungsten ore is usually less than 1% WO_3, and reportedly the average tungsten content of ore has been decreasing (53). According to one Soviet source, 58% of total explored reserves in 1975 were in large deposits of very poor grade of 0.14% to 0.21% WO_3 (54). Thus, the average ore grade shown in table 1 as 0.57% WO_3 may be high, and perhaps could be as low as 0.35%.

The calculation of reserves is especially difficult for a vast country such as the U.S.S.R. The geographical designations of the regions alone add to this confusion and difficulty exists in keeping track of the reserve estimates, as is illustrated in table 2. In 1933, the Chita Oblast' of East Transbaikal was to have contained 60.3% of Soviet tungsten reserves, followed by Kazakhstan at 23.4%, the Chelyabinsk region of southern Urals at 11.1%, the rest being at 5.2%. By the end of the second five-year plan, the

Table 1.—In Situ Resources of Major Soviet Tungsten Deposits (metric tons)

Deposit Name	Resource	Grade (% WO_3)	Contained WO_3[1]	Metal Content (W)[1]
Tryny-Auz, Caucasus	50,800,000	.60	304,800	241,740
Vostok-2, Primor'ye	22,025,000	.58	127,745	101,310
Dzhida, West Transbaikal	10,910,000	.43	46,910	37,200
Maykhura, Central Asia	5,000,000	.40	20,000	15,860
Boguty, Kazakhstan	4,320,000	.60	25,920	20,560
Ingichke, Central Asia	2,866,000	.43	12,320	9,770
Akchatau, Kazakhstan	2,741,000	.50	13,705	10,870
Iul'tin, NE Siberia	1,505,000	.80	12,040	9,550
Yubileynoe, Central Asia	1,432,000	.60	8,590	6,810
Verkhne Kayrakty, Kazakhstan	1,400,000	.45	6,300	5,000
Belukha, East Transbaikal	1,181,000	.60	7,090	5,620
Antonovogorsk, East Transbaikal	1,179,000	.80	9,430	7,480
Spokoyny East Transbaikal	1,000,000	.50	5,000	3,970
Bukuka, East Transbaikal	958,000	.60	5,750	4,560
Lyanagar, Central Asia	540,000	.50	2,700	2,140
Kti-Teberda, Caucasus	475,000	.60	2,850	2,260
Bom-Gorkhon, West Transbaikal	400,000	1.00	4,000	3,170
Balcan, Urals	386,000	.60	2,320	1,840
Karaoba, Kazakhstan	204,000	.80	1,630	1,290
Total or Average	109,322,000	.57	619,100	491,000

[1] Rounded figures.

Table 2.—Geographic Distribution of Soviet Tungsten Reserves, as Estimated by Various Sources (In percent)

Geographical Region	Year of Estimate 1933	1937	1960's	1977	1986
Kazakhstan	23.4	9.3	52.3	30.0	8.0
Urals	11.1	2.6	*	=> 8.0	*
Gorny Altay	*	*	*		*
Caucasus	*	16.2	24.7		45.0
Central Asia	*	12.2	4.4	=> 14.0	9.0
Far East	*	*	9.2	=> 20.0	*
Transbaikal, East	60.3	20.5	*		=> 15.0
Transbaikal, West	*	=> 37.1	*		
Mongolia	*		*	*	*
Siberia, Northeast	*	*	9.4	*	21.0[2]
Other	52.0	2.1	*	28.0	2.0
Total, percentage	100.0	100.0	100.0	100.0	100.0

(*) Not estimated.
[2] Includes Far East.

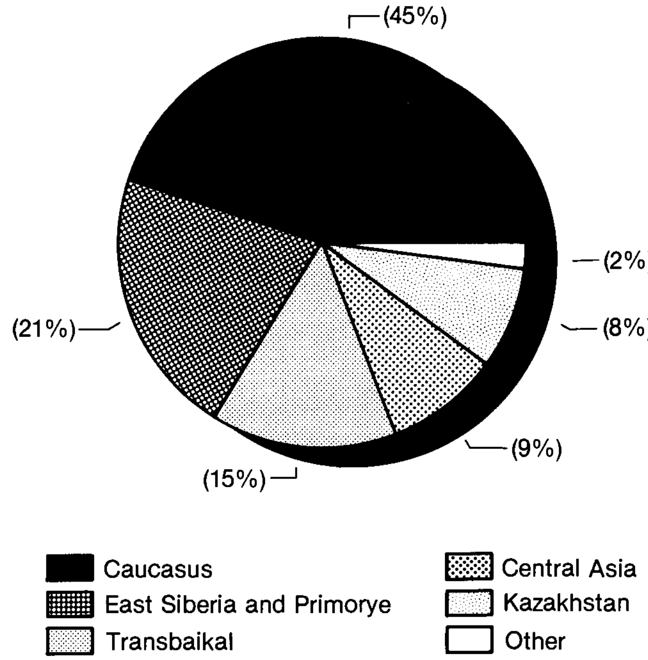

Figure 1. Regional Distribution of Soviet Tungsten Reserves in 1986.

Buryat A.S.S.R. of West Transbaikal, together with the U.S.S.R. Mongolia, accounted for 37.1% of tungsten reserves, followed by Chita at 20.5%, the Caucasus at 16.2%, Kazakhstan at 9.3%, Kirghiz S.S.R. at 4.7%, Tadzhikistan at 4.5%, Uzbekistan at 3.0%, and Chelyabinsk at 2.6% (55). The Transbaikal at that time, therefore, apparently contained the largest reserve in the Soviet Union.

By the 1960's, the geographic distribution of Soviet tungsten reserves changed, with Kazakhstan designated as the largest area: Kazakhstan, 52.3%; North Caucasus, 24.7%; East Siberia, 9.4%; Far East, 9.2%; and Central Asia, 4.4% (56, p. 5). According to a non-Soviet 1977 estimate, over 70% of the reserves were contained in six deposits. The largest deposit and the most developed was the Tyrny-Auz deposit in North Caucasus; this deposit was also rich in molybdenum which was also extracted. The others were Boguty, Ingichke, Iul'tin, Kholtoson, and Vostok, the regional distribution being as follows: Kazakhstan, 30%; Transbaikal, 20%; Caucasus, Central Asia, and Far East, 14%; and Urals and Gorny Altay, 8% (57, p. 116). Based on these late 1970's estimates, most of the Soviet tungsten reserves were located in Kazakhstan.

The regional distribution of Soviet tungsten ore reserves, based on this study, is estimated to be as follows: Caucasus, 45%; East Siberia and Primor'ye, 21%; Transbaikal, 15%; Central Asia, 9%; Kazakhstan, 8%; others, 2% (Figure 1). The Urals has insignificant tungsten resources. However, it should be kept in mind that this distribution may illustrate more closely the calculated tungsten reserves of the major mining areas, rather than the actual reserves throughout the country. Apparent disparities among the various reserve and resources figures provided may well be due as much to differences between authors in definitions of regions, and the quantitative difference between the definitions for reserve base, economic reserves and resources used by each of the authors, as to the differences in the date when the estimation was made. Nonetheless, the present study seems to indicate that Kazakhstan reserves are relatively small, while the Caucasus is in first place, followed by Primor'ye region and West Transbaikal. It should be noted, however, that the Tyrny-Auz deposit alone in Caucasus accounted for over 95% of that regions reserves. It may be that Tyrny-Auz became the largest Soviet tungsten producer simply because of its geographic location. It is a major tungsten bearing area located closest to the most populated and industrialized centers of the U.S.S.R., with a well developed transportation system and a user network. Other important, but remote, tungsten areas, such as Ingichke, Atchatau, Dzhida, Vostok, and Iul'tin may eventually surpass Tyrny-Auz once these regions become industrialized, or the ore at Tyrny-Auz is depleted.

EXPLORATION

Exploration was proceeding in the 1980's in the Verkhoyansky Khrebet of Yakut A.S.S.R. (Yakutiya), the Kolyma Nagorye of the Magadan Oblasts' in Siberia, in Kazakhstan, and in the Chakylkalyan Mountains of Tadzhikistan in Central Asia. At the end of the 1960's, exploration was also concentrated in known tungsten-bearing regions, such as North Caucasus, Central Caucasus, Uzbekistan, Tadzhikistan, Primor'ye, and in Magadan (56, p.6). Little information exists on the progress or success of exploration, but by all indirect indications, it is slow, and no sizeable new deposits have been found. This, in part at least, may be because of the inaccessibility and vastness of the territory, severe climatic conditions, and unavailability of equipment and personnel. Furthermore, some Soviet geologists complained of the inadequacy of research and sluggish exploration efforts for tungsten (56, p. 7). The inadequacy of exploration models specifically for tungsten, requiring numerous sampling and close drill hole grids, may also account for poor exploration results. In Northeast Siberia, for example, of the numerous tin and tungsten occurrences, only 19% were examined to some extent, and only 1.5% have been evaluated in detail.

Elsewhere, discoveries included a small scheelite deposit in the Ladoga Lake area, containing 1.0–2.0% WO_3; a scheelite prospect at Kanyaz in central Tadzhikistan; wolframite zones in the Badzhial'sk Ridge and along the Amigun' River in the Khabarovsk area; and exploration in granites for mineralized quartz veins along the Omut River and Sergeevsk in the Amur region was in progress in the early 1970's. In Magadan, west of Chaunsk, a small tungsten vein deposit was located at El'veney. Although not all of the discoveries were of economic significance, the new finds indicate that new tungsten deposits will still be discovered in the Soviet Union.

No specific exploration methods were described in the reviewed Soviet literature, except that it is known that geophysics and geochemistry are used routinely, as appropriate. Prospecting is almost never conducted for tungsten alone, but is part of an overall regional, multi-mineral exploration program, and is done by conventional field methods, utilizing the ultra-violet lamp for scheelite, geochemical sampling of river valleys, core drilling, and chemical analyses of the collected rock and sediment samples. Aerial photographic and remote sensing prospecting methods are also used but are rarely mentioned in Soviet literature. Most aeromagnetic surveys are done at a 1:25,000 scale, but are inadequate for the detection of tungsten deposits (58). In Transbaikal, 15 intrusive bodies have been explored for tungsten by what has been termed the "thermobarogeochemical" method; this method, however, is not described in the literature (59). Standard field mapping and sampling techniques are most common in preliminary phases, using sampling grids superposed on maps at 1:50,000 scale. The data is later collated and interpolated back to 1:200,000-scale maps. The grid method is used both for rock sampling and structural mapping (4, p. 123).

CHAPTER 4.—MINERALOGY AND CLASSIFICATION OF SOVIET TUNGSTEN DEPOSITS

Mineralogically and economically, significant deposits of tungsten and other metallic ores, in the U.S.S.R. are associated with the mid-Paleozoic Hercynian (Silurian/Devonian), mid-Mesozoic (Triassic/Jurassic) geological systems (60). More than 80% of tungsten mineralization in the Soviet Union occurred during the Late Traiassic and Jurassic Periods (61; 62, p. 180; 63).

Of the twelve known tungsten minerals, only scheelite, $CaWO_4$, and wolframite, (Fe, Mn) WO_4, are of economic significance.Wolframite is a mineral comprised of iron and manganese with WO_3. The iron and manganese may also occur separately with WO_3 as ferberite, $FeWO_4$, and huebnerite, $MnWO_4$, but neither occur in significant commercial quantities in the U.S.S.R. While both wolframite and scheelite comprise commercial ores of tungsten, scheelite has certain metallurgical advantages and is more flexible, in that it can be used as a direct furnace charge in the production of tool steels and some super alloys, as well as a starting material for metal powder production through chemical processing (64, p. 185).

Mineralogically, tungsten deposits of the Soviet Union fall into 3 categories: those rich in scheelite, common in quartz veins and greisens; those rich in scheelite but occurring in skarns; and those rich in wolframite. Scheelite and wolframite can occur in the same deposit, but wolframite occurs mostly in quartz and hydrothermal quartz veins, and is frequently associated with granites or other acidic rocks. Cassiterite, arsenopyrite and pyrite also can be present. The crystallographic lattice of wolframite is such that a number of elements occur with it as isomorphs, such as molybdenum, columbium, tantalum, scandium, yttrium, and indium. Scheelite, on the other hand, is usually associated with quartz diorites and granodiorites; native gold, cassiterite and powellite are at times associated minerals (65, p. 9).

Tungsten deposits are classified on the basis of their genesis and mineralogy. The tungsten minerals are formed by hydrothermal activity, and are directly related to the composition of the intrusives. In the final stage of mineralization from magma, the resulting tungsten ore bodies may assume either vein-like or tabular form; or the tungsten minerals may be disseminated or concentrated in pockets in the host rock, depending on magmatic emplacement. Based on their form and mineralogy, the deposits may be grouped into various types of mineralogical suites or assemblages, that in Soviet literature are referred to as "formations." There are many classification schemes for these tungsten "formations" in the Soviet literature, and new ones are proposed often (4, p. 9; 66–72).

Bates grouped commercial tungsten deposits into five types: pegmatites, contact-metasomatic deposits, replacement deposits, fissure veins, and placers (73). Smirnov classified Soviet tungsten deposits of economic significance into three types: skarn, greisen, and hydrothermal. He also described pegmatite deposits and placer deposits. Various "varieties" or "formations" are also described by Smirnov, such as quartz-cassiterite-wolframite, quartz-scheelite, quartz-wolframite, quartz-sulfide-tungsten, and cinnabar-antimonite-ferberite formations for the hydrothermal deposits (62, pp. 180, 199). Based on Soviet literature, Byrosh and Wagner classified Soviet tungsten deposits into four groups: skarn deposits of Early Paleozoic age, greisen and vein deposits of Late Paleozoic, sulfide-wolframite deposits of Mesozoic age, and epithermal Cenozoic deposits, basically following Smirnov's classification (57, p. 7).

Most Soviet tungsten comes from hydrothermal veins, greisen, contact metasomatic deposits (skarn/tactites), and stockworks, although tungsten has also been mined from placers and pegmatites. Commercial pegmatite tungsten deposits are rare in the Soviet Union (74). Placer deposits were important in the Soviet Union during the first decades of this century, but have not contributed much to recent production. Economically, the most important tungsten deposits in the U.S.S.R. are of the greisen/stockwork and skarn types; greisen/stockworks represent about 60% of these deposits; stratified skarns, 35%; and quartz vein deposits, 5% (4, p. 5). Skarn deposits are relatively massive stratified bodies and are mined more easily than the tabular or vein-type greisen bodies. Many are mined by open pit method. It is estimated that scheelite-bearing ore makes up 70% to 75%, and wolframite 30% to 25% of the tungsten ore mined in the Soviet Union, a distribution quite different from that in most market economy countries. In 1957, explored Soviet tungsten reserves were in: 1) the greisen-stockwork scheelite and wolframite deposits, or 39% of the total; 2) skarn scheelite deposits, 35% of the total, producing 61% of Soviet tungsten; 3) quartz veins rich in wolframite, 16% of the total; 4) others, 10% of total, producing only 2% of total Soviet tungsten (75).

Appendix A summarizes Soviet tungsten deposits by geographical regions and deposit types.

CHAPTER 5.—STRUCTURE OF THE SOVIET TUNGSTEN INDUSTRY

INFRASTRUCTURE

Although beneficiation plants have been cited near to most major tungsten mines, a number of the smaller operations must truck ore considerable distances to beneficiation plants over rough terrain on poor roads. Although rail transport is quite important in general terms in the U.S.S.R., the tungsten mining areas and beneficiation plants are not well served by railroads. Even the existing network of overland truck roads becomes unusable at times, due to the severe climatic conditions in Siberia and in the deserts of Central Asia. The Baikal-Amur (BAM) railway is the most recent route made available to the tungsten industry in the Transbaikal and Primor'ye Territory. For all practical purposes, there are no efficient inland waterway transportation systems in tungsten mining areas. The mining complexes at Primor'ye and Chukotka, however, are located close to good seaport facilities.

Moreover, once the tungsten concentrate is produced, it has to be shipped overland to the ferroalloy and steel plants, all of which are far away from the mining and beneficiation centers. Concentrates are usually shipped by rail, with short hauls by truck and barges. Concentrate shipments, however, pose far less of a problem than does ore movement.

MINING

All Soviet tungsten mining and beneficiation complexes are state-owned and -controlled. The production goals and plans are set by the U.S.S.R. Ministry of Nonferrous Metallurgy, as five- and one-year plans.

The Tyrny-Auz mining complex in the Caucasus is the largest producer of tungsten, accounting for about 40% of the country's total output. The Vostok-2 mining complex in Primor'ye is the next largest producer, and the Dzhida complex in west Transbaikal is the third largest producer; the latter complex accounts for almost 70% of Transbaikal's output. The Ingichke mining complex in Central Asia, Vostok in Primor'ye, Iul'tin in Chukotka, and Kounrad, Akchatau, Karaoba, and Uspensky in Kazakhstan are other major producers of Soviet tungsten concentrate. Figure 12 shows the location of the major mining complexes.

Although the particular method may vary considerably from mine to mine, in general, mining methods such as cut-and-fill, shrinkage stoping, room-and-pillar, and sublevel and block caving, are probably most often used in the U.S.S.R. Conventional shrinkage stoping methods are most generally used to mine steeply dipping tungsten veins, and in smaller mines. The wider mineralized zones are mined by sublevel caving or by sublevel stoping, as in other countries. The room-and-pillar method is used usually in gently dipping or flat-lying strata.

In the late 1910's to late 1930's, tungsten in the Soviet Union was mined from open pits along the vein outcrops and from placers and talus materials and separated by gravity in sluice boxes. Such inexpensive and readily available sources of tungsten were limited, and mining at many deposits moved underground. At present, most Soviet tungsten mining is underground. In the 1950's, mechanization in all Soviet underground mines was at a low level, and even at that time 37.4% of all rock during the development stages of mines was loaded by hand (76). Lack of labor and unwillingness of available personnel to work underground, hampered production. Thus, surface mining was continued wherever possible. During the 1950–70 period, the production of tungsten and molybdenum ores from surface mines increased from 12.78% in 1950 to 62.5% in 1970 (77). Harsh climatic working conditions, however, especially in cold and heavy snow areas, hampered production from the surface mines.

The dilution of mined tungsten ore fluctuated from 11% to 22% in 1975: in underground mines 23% to 32%, and in surface mines 6% to 17%. The losses of ore during mining operations ranged from 6% to 12%: in underground mines 11% to 19%, and in surface mines 3% to 6% (78).

BENEFICIATION

Although the Soviet Government has not published an official listing of operating tungsten beneficiation plants, information on a number of such facilities has been published over the years in the technical press. The following section summarizes in a general way Soviet tungsten ore beneficiation operations, based on information gleaned from reports on individual plants and on tungsten extractive metallurgy in general.

The standard grade of Soviet tungsten concentrate is 60% WO_3. In western markets, the standard grade of tungsten concentrate is generally defined as containing a minimum 65% WO_3 with relatively low impurity levels, although this is a very inexact definition and varies considerably. The current marketplace is complex in terms of concentrate and product types (79). High-grade concentrate is most likely used in the Soviet Union directly for alloy steel production, while low grade concentrate may be used for ammonium paratungstate (APT) production and for conversion to synthetic scheelite.

Scheelite and wolframite are the chief minerals in concentrates produced by the tungsten beneficiation plants in the Soviet Union. Figure 2 is a simplified flowchart of the Soviet tungsten industry, showing generalized and most likely treatment of tungsten ores, concentrates, and other intermediate products in the U.S.S.R. Most deposits in the U.S.S.R., as in other parts of the world, are polymetallic, so that during beneficiation, in addition to tungsten, minerals of molybdenum, tin, beryllium and bismuth are all usually extracted. The efficiency of the Soviet extraction of tungsten concentrate from the ore is about 50% to 75%, depending on the complexity of the ore and plant productivity. In the 1960's, for example, recovery of metal in concentrate in Transbaikal plants was 65.70% for tungsten, 56% for molybdenum, and 52% for bismuth (80). Table 3 illustrates the beneficiation efficiency of Soviet tungsten concentrate in 1936 (81).

Table 3.—The Efficiency of Beneficiation of Soviet Tungsten Concentrate in 1936

Concentrator	In percentage			Processing of ore tons per hour	
	WO_3 Content in ore	WO_3 content in concentrate	Recovery of WO_3 in concentrate	Planned	Actual
Balkan (Urals)	1.0	50.0	50.0	2.5	0.9
Belukha (Transbaikal)	0.41	66.9	58.8	2.5	0.9
Bukuka (Transbaikal)	0.38	69.2	48.5	2.1	0.9

Tungsten ores in the Soviet Union are beneficiated by flotation and gravity separation. In some smaller mines, the ore is upgraded by hand sorting prior to milling. The tungsten concentrate is further upgraded during the production of intermediate products by electromagnetic separation for the removal of impurities, mostly iron. Almost 80% of tungsten contained in dust and slurries may also be recovered (82, p. 15).

The most effective beneficiation method of scheelite ore is flotation. N.S. Petrov, in the late 1930's, is credited for the improvement of the selective flotation method for tungsten scheelite ore (83). In the 1970's, Soviet scientists began research to improve their flotation recovery processes for scheelite and other minerals. The new flotation processes reportedly have improved the recovery of scheelite in the rough concentrate by 30% to 35% (65, p. 3).

Sodium silicate, fatty acids and froth-forming solutions are the basic flotation reagents. In many cases, the tungsten minerals occur with sulfides such as molybdenite. In these cases, the sulfide minerals are removed from the slurry prior to the flotation of the scheelite. The tailings from the sulfide flotation could later be conditioned further. Wolframite is more difficult to separate by flotation than scheelite, and the process produces products which require further upgrading. According to Soviet scientists, it is possible to upgrade the concentrate by 10% to 15% through the use of improved flotation methods, so that the final concentration of wolframite will be 71% to 78% (84, p. 14).

Gravity separation methods rely on the high density of the tungsten minerals and their separability from the gangue minerals for their recovery. Most gravity separation plants use both jigs and shaking tables to produce a scheelite concentrate. In slurries from gravity separation, about 23% is composed of the −0.074 mm size-fraction, of which about 25% is tungsten minerals. Tungsten minerals in the slurries are further separated by wet magnetic separation for ores high in iron content, followed by repeated flotation.

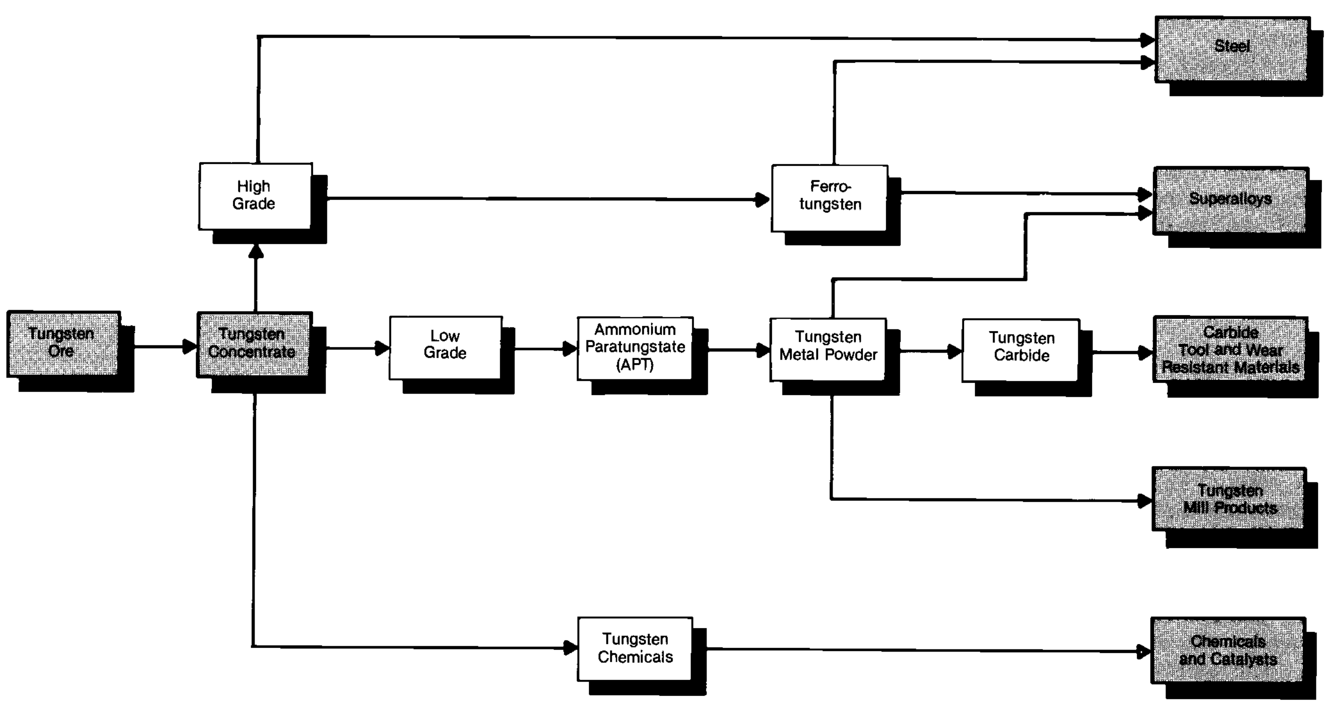

Figure 2. Generalized Flowchart of the Soviet Tungsten Industry.

TUNGSTEN PRODUCTS

The production of tungsten products is a complex metallurgical process involving a number of steps. It starts with the mining of ore and the concentration of tungsten materials from the ore, which averages only about 1% or less of tungsten. The concentrate is then processed generally into the more advanced forms of tungsten–ammonium paratungstate,tungstic oxide, tungstic acid, tungsten carbide, tungsten-bearing ferroalloys, and tungsten metal and other alloys, unwrought and wrought (figure 2).

Soviet scheelite concentrates may still contain from 1% to 6% molybdenum, and when these are processed to ferrotungsten, the resulting product contains on the average 1.2% to 2% molybdenum. Most of the tungsten-containing steel alloys, however, contain less than 1% molybdenum.

The exact number of plants in the Soviet Union producing tungsten products is not certain, but at least eight are known to be operating. Figure 12 shows the location of the metallurgical plants mentioned in this report.

The Chelyabinsk steel combine in the Urals and the Zaporozhie steel combine in Ukrainian S.S.R. (Ukraine) are the two major producers of ferrotungsten in the Soviet Union (85). The Chelyabinsk is the largest and oldest operating plant. Ferroalloys began to be produced in Chelyabinsk in 1931, and ferromolybdenum in 1955. The Zaporozhie steel plant began production of ferroalloys in 1933 (86, p. 381). Tungsten metal is produced at Chirchik in Uzbekistan and at Nal'chik in Caucasus. There are no official Soviet quantitative statistics on the production of ferrotungsten or tungsten metal. According to one Soviet source, however, ferrotungsten output increased by 225% in 1946, 473% in 1950, and 1,130% in 1955, over that of 1940 (87).

The tungsten contents of the molybdenum-containing Soviet steel is estimated to be as follows: 1) construction steel, 0.60% to 2.20%; 2) machine and tool steel, 2.00 to 18.5%; and 3) alloys, 1.50% to 11.00% (57 p. 124). In 1967, 60% of the high-speed cutting steel contained up to 16% tungsten, but then its use began to decline. In 1971, most high-speed steels contained only 6% tungsten, and 5% molybdenum.

Soviet ferrotungsten was first produced in blocks. In 1917, three steel plants in the Soviet Union produced 600 metric tons of ferrotungsten: the "Electrosplav" in Bogorodsk near Moscow, and near Petersburg, the "Izhor" and "Electrosplav" plants (17). Since 1938, however, ferrotungsten was produced by the continuous method, and the metal was extracted from the furnace by ladles, while the slag was periodically released (86, p. 395).

The first Soviet hard alloy "pobedi" ("triumph/win"), was produced in 1929 on the tungsten carbide and cobalt base. In 1937, the production of hard alloys was transferred from the various rare metals plants and was reorganized into the Moscow combine of hard alloys (88). Tungsten carbide, the so-called "hard metal" of Soviet literature, is produced at the Chirchik smelter in Uzbekistan, Kirovgrad in Ukraine, and in Moscow, RSFSR. Sandvik AB, a Swedish multinational company, under a contract worth $34 million in 1975, was to build a cemented carbide cutting tool plant near Moscow. Reportedly, it was put into production in 1980, but no information is available on its production rate (89–90).

Tungsten powders and salts have been produced primarily at the Novomoskovsk (Stalinogorsk) plant southeast of Moscow since 1933. Reportedly, the first stage of a tungsten powder plant was brought to design capacity in 1983 at the Ordzhonikidze plant inthe Caucausus, which was planned to become a major supplier of improved quality tungsten (91). There is essentially no information, however, on the status of Soviet tungsten powder industry. Very little has been published about the Soviet tungsten alloying facilities, chemical conversion, or hydrogen-reduction facilities.

CHAPTER 6.—SUPPLY POSITION

It is not easy to arrive at the Soviet supply position for tungsten in a simple way because of lack of officially published data for the various components that comprise the supply position. Information on tungsten is much more sparse than for the large volume metallic commodities, such as chromium, copper, iron ore, lead, manganese or zinc. It is well known, however, that the Soviet Union is not able to meet its tungsten requirements from domestic production. The U.S.S.R., therefore, imported tungsten at every opportunity and most likely stockpiled significant amounts, especially at times of favorable market prices. Nevertheless, the Soviet Union, because of inadequate domestic production and fluctuating imports, probably always had a problem in the long-term supply of tungsten. The deposits in the Urals and Caucasus were of low grade, and later-discovered higher grade deposits were in Transbaikal and even further East. Complex and inadequate transportation of tungsten from those regions may have significantly curtailed their availability, especially during the times of military conflicts. Poor production performance may have also made imports and stockpiling necessary to ensure a steady availability of tungsten concentrates.

PRODUCTION

The Soviet Union, and Imperial Russia, rarely produced sufficient quantities of tungsten to satisfy the required domestic consumption. The necessity of imports has continued, especially since the start of World War II, when tungsten began to be in great demand by the steel industry and in the late 1950's during the extensive space exploration program. Contrary to the fall of many metallic commodities during the middle 1940's, the production of tungsten remained stable, and actually increased.

The U.S.S.R. is at present the second largest producer of tungsten in concentrate in the world after China. During the peak years of world production in 1980, the leading producers were China, 29%; the U.S.S.R., 17%; Australia, 7%; Canada, 6%; and the United States, 5%. During the worldwide economic recession of 1983, when production was at its lowest level since 1969, the leading world producers were China, 32%; the U.S.S.R., 23%; the Republic of Korea, 6%; Bolivia, 6%; and Australia, 5% (92). The situation changed again in 1984, with China, the U.S.S.R. and Canada being the largest producers, as shown in figure 3 (93). Tungsten in concentrate was produced from at least 31 countries in 1984. Estimated Soviet production in 1984 was 9,100 metric ton of tungsten concentrate, which represented 21% of the world output. Taking into account the adjusted Soviet tungsten-in-concentrate production figures of this report, and the most recently available Bureau of Mines' statistics for other countries, in 1986 China remained in first place at 37%, the U.S.S.R. in second at 18%, and the Republic of Korea in third place at 6% (Figure 4).

Because tungsten production is under state control, and because of the numerous strategic military applications of tungsten, the Soviet Union is not motivated by considerations of profit maximization and efficiency in its domestic production and trade transactions. Instead, domestic and international political situations probably play an important role in supply decisions. Others have suggested that the amount of tungsten bought from other countries in certain years may be a function of the U.S.S.R.'s need to conserve foreign exchange or to use it for other purposes (94). Exports may also be governed by foreign exchange considerations.

It may be that domestic production has been restricted by the easy availability of tungsten from China at favorable prices and conditions, just as the United States has easy access to Canada's and the Republic of Korea's

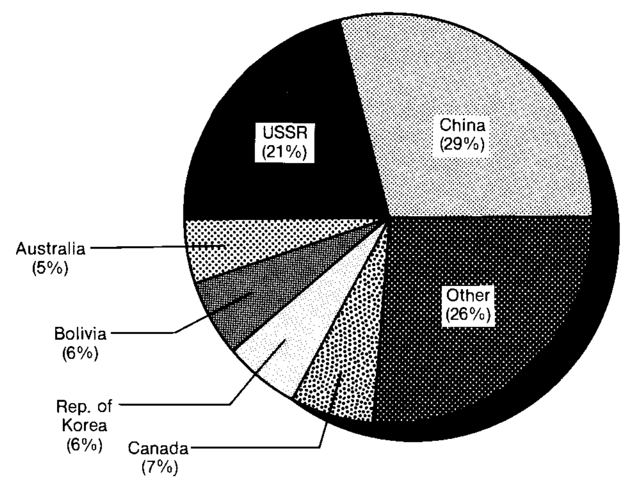

Figure 3. Relative World Production of Tungsten in Concentrate in 1984.

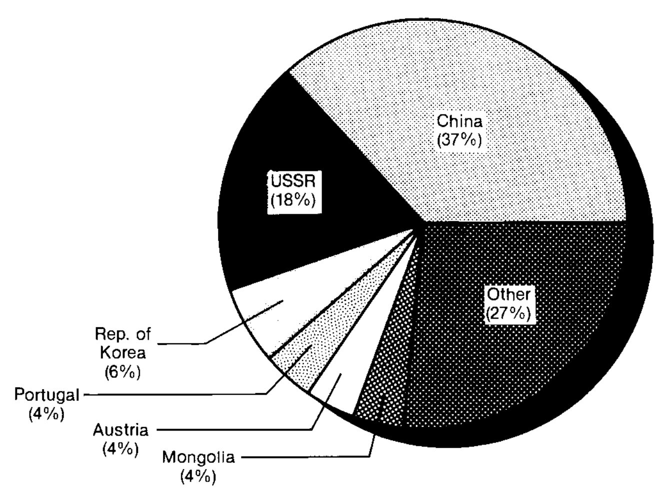

Figure 4. Relative World Production of Tungsten in Concentrate in 1986.

tungsten. Domestic production of tungsten in the U.S.S.R. could be much larger, but it lags also because of the following reasons: 1) the infrastructure is not well developed or doesn't exist at all; 2) the use of unskilled labor and lack of an efficient management system; 3) the lack of incentives among some managers to achieve high and efficient productive rates in the mining complexes; and 4) the lack of investment and renovation capital. In addition, the depletion of some deposits, the low ore grade, and severe working conditions also add to the sluggish performance of the Soviet tungsten mining industry (95). Insufficient production of chemical reagents for beneficiation is also cited as a cause in production difficulties.

Lacking direct Soviet statistics on production and consumption of tungsten, it is difficult to make firm economic projections. Data presented here are based on fragmentary information on individual plant activities coupled with reported five-year plan accomplishments, and limited official trade data and trade statistics of trading partner countries. Because of the lack of any official import statistics since 1975, these estimates have resulted in much confusion, as Soviet production, consumption, stocks, and imports change. The tungsten concentrate production series presented here was constructed from the assembly of scattered information on production of various plants and the five-year plans reported in Soviet literature. Much of the information is based on secondary sources, especially the historical development of the Soviet tungsten industry. The only reported numbers for concentrate production are for the years 1925, 1926, and 1927; the estimates for the years prior to that are reliable; the estimates from 1928 to 1941, the start of World War II and even to 1946, are more or less reliable; but the years after that to present are questionable. As stated in the introduction of this report, the tungsten import statistics also greatly influenced the scaling down of the previous Bureau production series.

It is estimated that more than three quarters of the Soviet Union's tungsten ore production is scheelite, and that in the future, the share of the total accounted for by such output may increase because many newer deposits are mostly scheelite. It is noteworthy that much of the Soviet tungsten production is a byproduct of tin, molybdenum or other metals, and output levels may thus be affected by plan requirements for these other commodities.

Table 4 summarizes the trend of the Soviet tungsten-in-concentrate production and relates it to historical events.

Table 4.—U.S.S.R.: Estimated Production of Tungsten Concentrate, 1915–1986 (Metric Tons)

Year	Gross Weight (60% WO_3)	Metal Content (W) [1]	Comments and Historical Events
1915	—	—	World War I started in 1914.
1916	34[2]	16	Trial runs for production of ferrotungsten steel began in Urals.
1917	126[2]	60	4 tungsten mines operated.
1918	25[2]	12	China became major producer of tungsten concentrate. WWI ended. Nationalization of all production.
1919	5[2]	2	
1920	—	—	Virtually no production of tungsten.
1921	—	—	New economic policy.
1922	—	—	
1923	—	—	
1924	—	—	
1925	2[3]	1	
1926	44[3]	21	
1927	43[3]	20	First production of ductile tungsten.
1928	58[2]	28	First five-year plan starts. Foreign technical workers invited. Industrialization & collectivization started.
1929	28	13	First production of hard-metal alloys for tools. About 30 tungsten deposits known.
1930	170	80	Gumbeika tungsten mine became operational, producing 148 tons.
1931	150	70	First production of ferrotungsten in steel industry.
1932	140	70	Production falls 19% from 1930; Prod. 5 times that of 1929. Planned production was 150 m.t.
1933	175	80	Kolbin Complex starts production. Second five-year plan starts; Planned production was 300 m.t.
1934	185	90	Production 105.7% as for first 8 months of 1933. Kolbin Complex increased output.
1935	450	215	Production 242% that of first half of 1934. Placer production at Dzhida.
1936	475	225	Buranov tungsten mine started operation.
1937	500	240	Tyrny-Auz under development.
1938	530	250	Kholtoson starts. First stage of Tyrny-Auz put into operation. Third five-year plan starts.
1939	560	265	U.S.A. starts production of tungsten concentrates.
1940	590	280	Buranov tungsten deposit depleted.
1941	650	310	Alyaskitov starts. Dzhida completed. World War II (WWII) starts.
1942	750	355	Tyrny-Auz occupied in November until Jan. 1943; Complex blown up.
1943	1,080	515	Production increased by 84% over 1940. Highest world production to date.
1944	1,150	545	Dzhida, Tuim, Balkhash tungsten mining complexes became important producers.
1945	1,300	620	WWII ends, Tyrny-Auz resumes production.
1946	1,450	690	Akchatau 1st stage starts. Fourth five-year plan starts. Production 11.6% over that of 1945.
1947	1,750	830	Reconstruction of steel industry and build-up of stockpiles. Production increased by 20.7% in 9 month over same period in 1946.
1948	2,400	1,140	Production in Far East expanded. U.S.S.R. becomes important tungsten producer.
1949	2,650	1,260	Industrial recession. No exports of tungsten to 1957.

Table 4.—U.S.S.R.: Estimated Production of Tungsten Concentrate, 1915–1986 (continued) (Metric Tons)

Year	Gross Weight (60% WO_3)	Metal Content (W) [1]	Comments and Historical Events
1950	2,900	1,380	Korean conflict starts, to 1953. Imports increased.
1951	3,400	1,620	Ingichke and Skopin plants start. Fifth five-year plan starts. Production increased by about 10% annually to 1955.
1952	3,800	1,810	Lyangar plant starts.
1953	4,300	2,045	
1954	5,000	2,380	Over 12 tungsten beneficiation plants operational. Production in Kazakhstan on increase. Iul'tin tungsten mine starts.
1955	6,250	2,975	Tyrny-Auz production at 2,500 m.t. per year, or 30–40% of total.
1956	6,630	3,155	Tuim complex starts. Sixth five-year plan starts (terminated in 1958). Production increased at estimated 6% annually to 1959.
1957	7,030	3,345	Imports of tungsten and apparent consumption the highest. Sputnik satellite launched.
1958	7,450	3,545	U.S.S.R. starts reporting exports, to 1966. U.S. tungsten production falls.
1959	7,900	3,760	Seventh five-year plan starts. Bukuka deposit depleted. Iul'tin beneficiation plant starts.
1960	8,370	3,980	Low WO_3 content in Kazakhstan and problems with water supply (to 1966). Production planned to increase by 57% over 1955.
1961	8,620	4,100	Production increased at estimated 3% annually to 1965. Peak exports of concentrate.
1962	8,880	4,225	
1963	9,140	4,350	Exports of ferrotungsten reported to 1966.
1964	9,400	4,480	Imports dropped by 51%.
1965	9,600	4,610	China started selling concentrate directly to western consumers. Vietnam conflict starts, to 1973.
1966	9,850	4,685	Eighth five-year plan starts. Imports of tungsten lowest since 1949. Northeast Siberia become important tungsten producer. Lowest apparent consumption since 1949. Decline of tungsten exports. Record rise in tungsten prices. Start of Sino-Soviet border clashes.
1967	10,100	4,805	Primor'ye Territory begins to be developed.
1968	10,300	4,900	No tungsten exports reported to 1978. U.S. flight to the moon.
1969	10,500	4,995	
1970	10,710	5,100	New deposits explored. Production increased by 28% over that of 1960.
1971	11,250	5,350	Ninth five-year plan starts. Production increased by 5% over that of 1970.
1972	11,450	5,450	Vostok-2 mine starts. Lermontov deposit explored. Production increased 3%–4% annually to 1975.
1973	11,800	5,615	Ingichke concentrator modernized; capacity doubled.
1974	11,900	5,660	Boguty and Karaoba deposits under exploration.
1975	12,200	5,810	Chinese exports to U.S.S.R. reporting stops. Iul'tin started in October. Lyangar deposit depleted. Production planned to increase 60% over that of 1970.
1976	12,300	5,850	Tenth five-year plan starts; production increased 3% annually to 1980. Koytash deposit depleted. Vostok-2 beneficiation plant starts. Record rise in tungsten prices to 1977.
1977	12,700	6,045	1st stage of Primorskiy complex starts production. Yakhon mine starts. Tyrny-Auz largest concentrator.
1978	13,100	6,235	Chorukh-Dayron depleted. Yubileynoe and Maykhura mines start.
1979	13,500	6,420	
1980	13,900	6,610	
1981	14,180	6,750	Eleventh five-year plan starts. Production increased 2% annually to 1986.
1982	14,460	6,880	Dzhambul mine and concentrator start.
1983	14,800	7,040	No exports to 1986 reported. Recession in market economy countries.
1984	15,100	7,185	Work starts on New Kayrakty beneficiation plant. Second stage of Orlovsk beneficiation plant completed.
1985	15,400	7,330	
1986	15,700	7,470	

1—Rounded after 1929.
2—(191, p. 420; 192, p. VII–2).
3—Reported Number (7, p. 176)

TRADE

During the period of time covered in this report, the U.S.S.R. has had a substantial role in world tungsten trade, both importing and to lesser degrees exporting the commodity in a variety of forms ranging from tungsten concentrates and middlings to the metal itself. However, the strategic nature of the commodity and the Soviet government's traditional withholding of detailed statistics that might reflect economic and/or strategic weaknesses has made the reconstruction of comprehensive trade statistics quite difficult. The following text outlines what has been reported and what has been done to augment the reported statistics with estimates for those tungsten-bearing materials for which there appears to be sufficient information to formulate estimates. The discussion is divided into two major sections: imports and exports, treating them in this order because imports, in the form of ore and concentrates at least, have exceeded exports, and can be regarded as providing the basis for exports. Within each of these two sections, trade in concentrates is treated first and in the greatest detail, followed by summary discussions of information available on trade in materials of more advanced forms. A brief section on U.S. land-lease exports to the U.S.S.R. during World War II is appended at the end of the import section.

Imports

The Soviet Union has relied heavily on imports of tungsten to meet a significant share of its consumption requirements since its first usage of the metal. In Imperial Russia, tungsten concentrate was imported primarily from Korea. All tungsten was imported by Russia prior to World War I. Although the U.S.S.R. became a major world tungsten producer, it is evident that for at least the past 35 years, domestic output has still been inadequate to support Soviet indigenous needs and a more limited level of demand for exports. Thus, the country has obtained substantial amounts of tungsten from other major producing countries. The most notable of these countries over the post World War II period has been China. Between 1949 and 1962, it was reported that China exported 270,000 metric tons of tungsten concentrates to the U.S.S.R. and Soviet sources verified the receipt of at least 137,800 metric tons in the years 1950, 1955, and 1958–62 inclusive. Moreover, Soviet sources report the import of nearly 47,700 metric tons of tungsten concentrates from China between 1963 and 1975, the last year for which such imports were officially reported. There is strong evidence to suggest, however, that such shipments continued after 1975.

In order to attempt an assessment of the Soviet supply situation for tungsten, it has been necessary to engage in an exhaustive study of worldwide tungsten trade, concentrating on shipments from countries such as China, North Korea and Mongolia—those for which official export statistics have not been published at all, or for which such published data does not reveal the destinations of exports. Additionally, because limited officially published Soviet import data was terminated with 1975's report, the export trade of all major market economy countries tungsten concentrate producers was examined to ascertain the levels of shipments, if any, from these countries to the U.S.S.R. Each of the three major potential communist concentrate suppliers, China, North Korea and Mongolia, has been examined separately in the following discussion, with a final section reviewing shipments from other countries.

Estimates of Soviet imports of tungsten concentrates from China have been divided into two groups, based on the nature of available information. The first group, those for 1949, 1951–54 inclusive, and 1956–57, are crucial to fixing the level of supply from the end of World War II through 1975, but despite the generally secretive nature of the governments of both the U.S.S.R. and China during those years, and the strategic nature of the commodity, there is sufficient information available to formulate fairly precise estimates. The Chinese have published their total tungsten concentrate exports for each year from 1950 through 1986, although they have provided no detail on the geographic distribution of these shipments. Soviet trade publications record their receipt of tungsten concentrates from China for 1950, 1955 and 1958–75, but not for other years. However, a Chinese radio broadcast in early 1964 provided a key fact: that during 1949–62 inclusive, the Chinese sent a total of 270,000 metric tons of concentrates to the U.S.S.R. Subtracting the total of the reported Soviet imports for 1950, 1955 and 1958–62 (table 5) from the 270,000-metric-ton Chinese export total for 1949–62 leaves 130,200 metric tons to be distributed between 1949, 1951–1954, and 1956–57. This has been done on the basis of the total reported Chinese exports for each of these years and on data on the quantity and value of Soviet total imports of nonferrous metals from China for the same years, to produce the estimates for these years shown in table 5.

For these years, examination of possible receipts of Chinese tungsten by other countries is unnecessary because the claimed deliveries to the U.S.S.R. were equal to more than 85% of total Chinese exports.

For the years 1958–75, imports from China are officially reported in Soviet trade returns, but problems arise for the years 1976–86 inclusive (96). For these years, the Chinese have published total annual export statistics, but provide no distribution by trading partner. To make estimates of Chinese deliveries to the U.S.S.R. in this period, it has been necessary to reconstruct, as completely as possible, Chinese deliveries to other countries. This has been possible for all market economy countries that could be significant recipients of such shipments, and for Poland alone among the CMEA countries. This leaves a reporting gap for Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, and Romania, each of which must be regarded as at least a potential destination for some Chinese tungsten concentrates. Examination of import data for the years 1958–75, for which Soviet imports from China are recorded, together with comparable data for market economy countries, and comparison of the total of such imports with Chinese-reported total exports, provides an undistributed remainder which apparently represents the receipts of these non-reporting countries (together, perhaps, with minor amounts to lesser destinations).

In estimating Soviet receipts from China for 1976–86, it has been considered that a portion of China's total reported export has continued to be directed to these statistically unreported destinations. Thus actual Soviet receipts could be higher than those estimated, but this appears unlikely.

In the process of ascertaining the level of Chinese exports to the U.S.S.R. and to the aforementioned East European countries, import statistics for the following countries were examined: Austria, Belgium-Luxembourg, Canada, France, Federal Republic of Germany, Hong Kong, Italy, Japan, the Netherlands, Norway, Poland, Portugal, Singapore, Spain, Sweden, the United Kingdom, and the United States, in addition to the limited figures available for the U.S.S.R. and data for a few years for Hungary. It was not necessary to closely examine import data for Australia, Brazil, and the Republic of Korea, because these countries, although consumers of tungsten concentrates, are also major producers. Some small amounts of concentrates of Chinese origin may have occasionally been delivered to minor consumers such as Argentina, Denmark, Finland, India, Israel, the Republic of South Africa, Switzerland, and Yugoslavia, but is unlikely that any appreciable amounts, even in aggregate, would be so directed. (It should here be noted that for one year, Yugoslavia reported a very large import, alleged to be tungsten concentrate, from China, but this, on the basis of unit value, could be an error in reporting).

Having subtracted imports by reporting trading-partner countries from China's reported exports for 1976–86, the unaccounted remainder was divided between the U.S.S.R. and an unspecified "residual", which would represent chiefly the receipts by Czechoslovakia, the German Democratic Republic, Hungary and Romania, with a minor component destined for other minor recipients.

The relationship between North Korea and the U.S.S.R. with regard to tungsten trade is not so clearly defined as that between China and the U.S.S.R. North Korea has long been regarded as a substantial producer of tungsten concentrates, although statistical substantiation of this output has been almost nonexistent. Thorough review of trade statistics of potential importers among market economy countries reveals only occasional receipts of tungsten concentrates to North Korea during the years 1960–86, and the quantity of such receipts has never totalled more than 140 metric tons in any one year, an amount that can be contrasted with an annual production, estimated to range between a low of 1,000 metric tons and a high of 4,600 metric tons of concentrates (gross weight) within the years 1947–86. Thus, even at the lowest level of production, a very substantial quantity of tungsten concentrates has been produced in each year for which there is no evident market. It must be presumed that if production estimates are correct, a fairly large proportion of this output must have been directed to the U.S.S.R., for there certainly is no large internal demand for tungsten in North Korea, and it would seem unlikely that any major amount would be shipped to China for use there, because of that country's pre-eminence among world tungsten producers. Of course, shipments may have been made to China in repayment for goods obtained from the Chinese, but such material would be in addition to that country's own production, creating an even larger exportable supply.

It is also possible that a part of North Korea's production has moved to the CMEA countries that do not report tungsten concentrate imports specifically but available information on their receipts of materials in the broad categories of metallic ores are insufficient to judge whether tungsten is included or not.

It is known, however, from Soviet import returns on the broad category of metallic ores and on detail on shipments of lead and zinc bearing materials into the U.S.S.R. from the North Korea, that Soviet imports of tungsten concentrates from North Korea had to be nil in the six years 1961–66 inclusive. Aside from this period, however, it is apparent that the U.S.S.R. imported some metallic ore and/or concentrate from North Korea during 1950–60—something other than lead- and zinc-bearing material, and the obvious possibilities are tungsten concentrate, a limited amount of copper-bearing material, and possible titanium-bearing materials. For this report, it has been assumed that a significant share of North Korea's estimated tungsten concentrate output has been directed to the U.S.S.R., as indicated in table 5.

The Soviet Union also has imported tungsten in the forms of tungsten concentrates and tungsten middlings from Mongolia. There are official Soviet data on such imports only for the years 1972–75 inclusive, but general, non-statistical reporting suggests that shipments began as early as 1961 or before, and that they have continued to the present. Indeed, there is no evidence to suggest that any of Mongolia's production has been destined for any market other than that of the U.S.S.R., although it could be debated that portions of this production could have been sent to other CMEA countries that do not report imports of tungsten concentrates as separate line items. For many years, up through those for which the U.S.S.R. reported imports, output, and therefore exports, were undoubtedly small, but by 1981, production was estimated to have reached about 2,000 metric tons of concentrates on a 60% WO_3 basis. There is no evidence of any processing of this material to any more advanced state within Mongolia, hence there is no domestic consumption in that country, and lacking any indication of deliveries elsewhere, it is assumed that the entire output has been exported to the U.S.S.R.

Examination of export statistics of all major market economy countries that produce tungsten concentrates in significant quantities, as well as export statistics of market economy countries that engage in entrepot trade in the commodity, produced data on shipments to the U.S.S.R. by only nine countries between 1949 and 1986—Australia, the Federal Republic of Germany, Hong Kong, the Netherlands, Peru, Singapore, Spain, the United Kingdom and the United States. The data collected for these countries is shown in table 6. It should be noted, however, that export statistics are not the best means of measuring actual receipts, for once a shipment has left the country of origin, there is no way to record its ultimate destination, and re-sale of such relatively low-volume, relatively high-value materials as tungsten concentrates cannot be regarded as unlikely. Hence, these shipments to the U.S.S.R. may not have ultimately reached that country, and conversely, shipments originally destined for other countries may have been subsequently diverted to the Soviet Union. The figures obtained by this "backwards" trade method thus may be regarded with some suspicion, but they are all that is available for all years save 1972–75, when the U.S.S.R. reported total imports of tungsten concentrates (not just imports from China).

Although it is considered that the foregoing represents a reasonably reliable measurement of deliveries of tungsten concentrates from China to the U.S.S.R., data are wholly inadequate to formulate estimates of similar trade in more advanced forms of tungsten—ammonium paratungstate, tungstic oxide, tungstic acid, tungsten carbide, tungsten-bearing ferroalloys, and tungsten metal and other alloys, whether unwrought or wrought. No official Soviet import statistics on these materials have been published, but it is known that China exports each of some in fairly substantial amounts, to the United States and to other market economy countries, but the total amount exported is reported only in the case of a category described as "tungsten metal" (which is not clearly specified as to whether it represents simply unwrought metal or includes semimanufactures). This reporting is also limited in time span, covering only 1981–86, as follows in metric tons: 1981—494, 1982—183, 1983—65, 1984—79, 1985—156, 1986—365. Relatively little of these tonnages can be accounted for in import statistics of market economy countries, hence it seems likely that significant shares of the foregoing totals are delivered to the countries of Eastern Europe, including the Soviet Union, but there is no way to reliably quantify such deliveries by destination. Likewise, it is suspected that quantities of the totally unreported products such as the others itemized previously may indeed be marketed by China in the U.S.S.R. and other CMEA countries, but available information is inadequate to formulate reliable estimates of the levels of such shipments.

Beyond the possibility of Chinese exports to the U.S.S.R. in these more advanced forms of tungsten, there may well be an appreciable delivery of such materials from other countries, but available information is too spotty to discern any patterns or trends. The lack of information on direct shipments is complicated further by the possibilities for re-direction of exports once they leave the country of origin, and further still be inadequate and/or nonexistent

Table 5.—U.S.S.R.: Imports of tungsten concentrates, 1949–1986[1]
(Metric tons, gross weight, 60% WO_3, except where noted).

	Origin													
Year	Australia	China	Germany Federal Republic of	Hong Kong	Korea North	Mongolia	Netherlands	Peru	Singapore	Spain	United Kingdom	United States	Total[2]	Total[6] (contained W)
1949	([3])	[e]2,000	—	([3])	[e]1,000	—	—	([3])	([3])	([3])	—	—	3,000	1,430
1950	([3])	8,000	—	([3])	[e]1,200	—	—	([3])	([3])	([3])	—	—	9,200	4,375
1951	([3])	[e]13,000	—	([3])	[e]1,200	—	—	([3])	([3])	([3])	—	—	14,200	6,755
1952	([3])	[e]20,000	—	([3])	[e]1,200	—	—	([3])	([3])	([3])	—	—	21,200	10,090
1953	([3])	[e]20,000	—	([3])	[e]1,500	—	—	([3])	([3])	([3])	—	—	21,500	10,630
1954	([3])	[e]22,000	—	([3])	[e]1,500	—	—	([3])	([3])	([3])	—	—	23,500	11,185
1955	([3])	28,000	—	([3])	[e]1,500	—	—	([3])	([3])	([3])	—	—	29,500	14,040
1956	([3])	[e]26,000	—	([3])	[e]2,000	—	—	([3])	([3])	([3])	—	—	28,000	13,325
1957	([3])	[e]29,000	—	([3])	[e]2,000	—	—	([3])	([3])	([3])	—	—	31,000	14,750
1958	([3])	26,000	([3])	([3])	[e]2,500	—	—	([3])	([3])	([3])	—	—	28,500	13,560
1959	([3])	25,600	([3])	([3])	[e]2,500	—	—	([3])	([3])	([3])	—	—	28,100	13,370
1960	([3])	18,900	([3])	([3])	[e]2,500	—	—	([3])	([3])	([3])	—	—	21,400	10,185
1961	—	18,300	—	([3])	—	[e]50	—	—	([3])	—	—	—	18,350	8,730
1962	—	13,000	—	([3])	—	[e]50	—	—	([3])	—	—	—	13,050	6,210
1963	—	12,000	—	([3])	—	[e]50	—	—	([3])	([3])	—	—	12,050	5,735
1964	—	6,000	—	([3])	—	[e]100	—	—	([3])	([3])	—	—	6,100	2,900
1965	—	6,000	—	([3])	—	[e]100	—	—	([3])	—	—	—	6,100	2,900
1966	—	3,000	—	([3])	—	[e]100	—	—	([3])	—	—	—	3,100	1,475
1967	—	600	—	([3])	[e]3,000	[e]100	—	—	([3])	—	—	—	3,700	1,760
1968	—	—	—	([3])	[e]4,000	[e]100	—	—	([3])	—	—	—	4,100	1,950
1969	—	—	—	([3])	[e]4,500	[e]100	—	—	([3])	—	—	103	4,703	2,235
1970	—	799	—	—	[e]4,500	[e]100	—	—	—	—	—	406	5,405	2,570
1971	—	4,792	—	—	[e]2,000	[e]100	—	—	—	—	—	—	6,892	3,280
1972	—	5,249	—	—	[e]1,100	[4]153	—	—	—	—	—	—	[5]6,568	3,125
1973	—	3,650	—	—	[e]1,100	[4]10	30	—	—	—	—	—	[5]4,823	2,295
1974	—	3,900	—	—	[e]2,900	[4]53	155	—	—	—	—	—	[5]7,044	3,350
1975	—	1,700	20	—	[e]5,900	[4]34	398	—	—	5	—	—	[5]8,120	3,865
1976	916	[e]7,400	—	—	[e]4,000	[e]500	215	216	—	—	—	36	13,283	6,320
1977	544	[e]4,000	24	—	[e]4,000	[e]500	40	67	—	—	—	48	9,223	4,390
1978	742	[e]6,500	46	—	[e]4,000	[e]600	258	223	—	—	—	—	12,369	5,885
1979	292	[e]7,000	—	—	[e]4,000	[e]1,100	757	—	—	—	—	—	13,149	6,255
1980	—	[e]7,000	—	—	[e]4,000	[e]1,700	933	—	30	—	—	—	13,663	6,500
1981	—	[e]6,000	15	—	[e]4,500	[e]2,100	80	—	—	—	566	—	13,251	6,305
1982	418	[e]1,500	—	—	[e]4,500	[e]3,200	618	—	63	—	524	—	10,823	5,150
1983	364	[e]10,000	—	—	[e]500	[e]3,200	421	([3])	—	—	54	—	14,539	6,920
1984	NA	[e]7,000	—	—	[e]1,500	[e]3,200	—	([3])	—	—	—	—	11,700	5,565
1985	NA	[e]6,500	—	606	[e]1,500	[e]3,200	266	([3])	149	NA	—	—	12,221	5,815
1986	NA	[e]9,000	—	1,415	[e]1,500	[e]3,200	NA	([3])	—	NA	NA	—	15,115	7,195

[e] Estimate NA Not available.

[1] Compiled from reported Soviet trade returns (China 1950, 1955, and 1958–75: Mongolia 1972–75, and totals 1972–75) and from export trade returns of trading partner countries (all other figures not noted are estimates). All estimates by U.S. Bureau of Mines, based on information presented in accompanying text. Table prepared by W. Steblez.

[2] Total of listed figures only, except where otherwise noted.

[3] Estimated as nil. (Other nil entries, denoted by leaders are reported).

[4] In addition to concentrate imports reported, there were additional imports of tungsten middlings, as follows, in metric tons: 1972—208, 1973—419, 1974—80, 1975—154. Although middlings may have been imported during 1961–71 and 1976–86, they have been included with estimates of concentrate.

[5] Reported totals.

[6] Rounded figures.

published reporting on these more advanced commodities by the Soviet Union's CMEA partners.

One aspect of Soviet import trade not shown in the import table seems to deserve special mention, this being the land-lease shipments from the United States to the U.S.S.R. during World War II. There were no shipments of tungsten concentrates to the U.S.S.R. during 1940–46, but shipments of ferrotungsten, not reported separately in 1940 and 1941 (but not significant) and totalling only 2 metric tons in 1942 and nil in 1943, totaled 1,041 metric tons in 1944 and 330 metric tons in 1945. Similarly, tungsten metal shipments (unwrought and semimanufactures) aggregated 4 metric tons each in 1941 and 1942, 13 metric tons in 1943, 71 metric tons in 1944, and 39 metric tons in 1945. In 1946, there were no shipments of metal and ferrotungsten.

Exports

As was the case with import information, the summary of export trade is presented in two parts: exports of tungsten concentrates and exports of other tungsten materials.

There is no evidence of any significant concentrate exports from the Soviet Union prior to 1958, although as a result of the lack of sufficiently detailed and complete statistical reporting, it may be that there were some shipments from the U.S.S.R. to one or more of CMEA countries prior to 1958. Beginning with that year, the U.S.S.R. began reporting exports on a country basis, although never publishing a total export for any year, thus the information provided was never alleged to be complete, and unreported deliveries to the CMEA countries indeed may have been made. It should be noted however, that careful examination of trade statistics of all significant potential importing market economy countries from 1949 through 1986 have revealed no quantitatively significant additions to the officially reported exports, as shown in table 6. The latter distinguishes Soviet-reported exports from those gleaned from trade returns of partner countries. It is noteworthy that no Soviet exports were found for any year 1950–57 inclusive, 1968–78 inclusive, nor for 1983–86 inclusive. Consequently, these years are omitted from the table.

Comparison of the calculated Soviet imports with indicated Soviet exports suggests that exports have only been feasible during those years when the receipt of imports exceeded annual industrial needs and/or planned additions to stockpiles.

There are virtually no official Soviet statistics on the export trade of more advanced tungsten materials. For the years 1963–66 inclusive, the U.S.S.R. reported total exports of ferrotungsten as shown in table 7. There are no official Soviet published figures on ferrotungsten exports for other years, and there are no such figures for any year for other forms, such as ammonium paratungstate, tungstic oxide and acid, tungsten carbide, or tungsten metal and alloys, either unwrought or wrought. The lack of data from the U.S.S.R.'s most likely significant trading partners in these materials—Czechoslovakia, the German Democratic Republic, Poland, and Romania—makes it virtually pointless to document the available scattered results on trade in such forms derived from the trade returns of market economy countries. From such returns however, it is evident that there is trade between the market economy countries and the four countries listed above, as well as with Bulgaria and Hungary (in lesser amounts). Hence, it is reasonable to assume that the U.S.S.R. may well export tungsten-bearing materials to these countries as well.

Table 7.—U.S.S.R.: Officially reported exports of ferrotungsten, 1963–66
(Metric tons, gross weight)

Destination	1963	1964	1965	1966
Korea, North	200	200	200	—
Romania	300	500	500	—
Sweden	200	200	500	300
Undistributed	800	900	700	100
Total	1,500	1,800	1,900	400

Table 6.—U.S.S.R.: Exports of tungsten concentrates, 1950–1986[1]
(Metric tons, gross weight 60% WO_3, except where stated)

Year	Austria	France	Germany, Federal Republic of	Japan	Netherlands	Poland	Sweden	United Kingdom	Total[2]	Total[4]
1958	200	—	1,000	NA	200	NA	90	100	1,590	755
1959	500	—	1,700	NA	100	NA	200	200	2,700	1,285
1960	1,200	140	2,200	NA	100	NA	380	700	4,720	2,245
1961	1,200	160	2,300	[3]166	100	NA	220	800	4,946	2,355
1962	1,100	170	2,000	[3]237	90	—	300	600	4,497	2,140
1963	800	440	1,800	[3]67	100	—	420	700	4,327	2,060
1964	1,000	240	1,240	[3]97	—	—	160	1,200	3,827	1,820
1965	1,100	—	700	11	—	[3]425	120	1,400	3,756	1,785
1966	100	—	600	—	—	—	80	900	1,680	800
1967	NA	—	[3]60	—	—	—	—	[3]44	104	50
1979	—	—	—	—	—	NA	—	[3]25	25	12
1980	—	—	—	—	—	NA	—	[3]20	20	10
1981	—	—	—	—	—	NA	—	—	—	—
1982	—	—	—	—	—	NA	—	[3]38	38	18
1983	—	—	—	—	—	—	—	—	—	—
1984	—	—	—	—	—	—	—	—	—	—
1985	—	—	—	—	—	—	—	—	—	—
1986	—	—	—	—	—	—	—	—	—	—

NA Not available.

[1] Years covered by the study that resulted in this table included 1950–1957, 1968–1978, and 1983–86, in addition those shown individually, but no export shipment were found for the years that are omitted. It should be further noted that trade returns of certain countries do not report tungsten concentrates separately (see text). Data are from official Soviet trade returns unless otherwise noted.

[2] Total of listed figures only; may be incomplete.

[3] Data from import statistics of country of destination.

[4] Rounded figures.

Consumption

Figures for world consumption of tungsten in concentrate are published regularly by UNCTAD and the U.S. Bureau of Mines. In 1986, only 11 countries reported actual consumption to UNCTAD, and apparent consumption was calculated for 17 more, including the U.S.S.R. Data on consumption of tungsten by the U.S.S.R. is not reported at all, and it is unavailable. A data series for the apparent consumption, although a fragmentary one, has been compiled in table 8.

World consumption of tungsten is very sensitive to changing economic conditions and especially to military and naval demands during war. For example, during World War II tungsten consumption reached a world-high in 1943, when 14,600 metric tons of contained tungsten in concentrates, as well as primary products, were consumed, based on pre-1986 Bureau of Mines statistics. The consumption of tungsten in concentrate after the war fell to below pre-war level; after a brief upswing in 1947–48, the industrial recession in 1949 reduced world consumption to 9,700 metric tons. The Korean War again stimulated world consumption of tungsten until in 1951 it reached an estimated 13,300 metric tons, not far below the 1943 record-high level. World consumption of tungsten in concentrate in 1952 reached a high of 17,600 metric tons tungsten content (97, pp. vii–5). By 1981, world consumption of tungsten in concentrate had reached almost 47,900 metric tons, but during the market economy country recession that followed, it fell to under 40,000 metric tons 1983; but it recovered to more than 50,000 tons in 1984, dropping then to about 48,000 metric tons in 1985 and to 45,000 metric tons in 1986.

Based on this study, apparent consumption of tungsten concentrates by the Soviet Union increased steadily from the late 1940's until a record high in 1957. The increase in consumption has paralleled the increase in imports. Demand by the armament, and some by the space industries, may account for much of the increase in the apparent consumption. Also much of the apparent consumption increase may be due to continued and increased stockpiling. Consumption of tungsten concentrate (at 60% WO_3) has been estimated at 30,815 metric tons in 1986 in this report, which is the largest of any country, accounting for about 51% of the world's total, based on the latest statistics (98). Table 8 presents the apparent consumption of tungsten concentrate by the Soviet Union for the past 38 years. Figure 5 graphically illustrates the relationship between consumption and supply position.

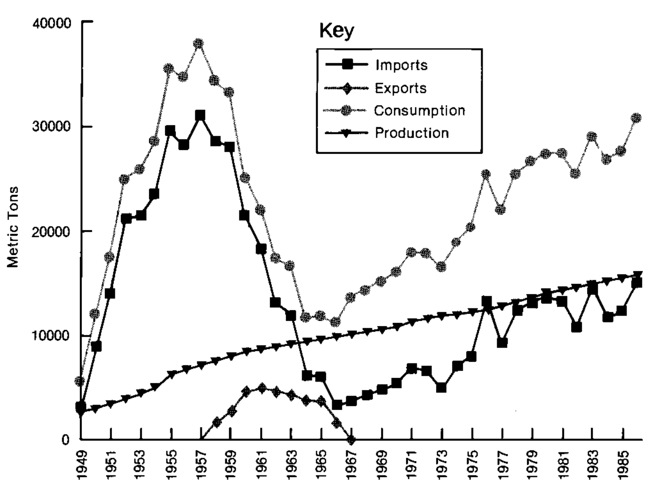

Figure 5. Trends in Production, Exports, Imports, and Apparent Consumption of Tungsten in Concentrate in the U.S.S.R.

Table 8.—U.S.S.R.: Estimated Production, Trade and Apparent Consumption of Tungsten Concentrates (Metric tons, gross weight, 60% WO_3, unless otherwise stated).

Year	Production	Import	Export	Consumption	Contained W[3]
1949	2,650	3,000	[1]	5,650	2,690
1950	2,900	9,200	[1]	12,100	5,755
1951	3,400	14,200	[1]	17,600	8,375
1952	3,800	21,200	[1]	25,000	11,895
1953	4,300	21,500	[1]	25,800	12,275
1954	5,000	23,500	[1]	28,500	13,560
1955	6,250	29,500	[1]	35,750	17,010
1956	6,630	28,000	[1]	34,630	16,480
1957	7,030	31,000	[1]	38,030	18,095
1958	7,450	28,500	1,590	34,360	16,350
1959	7,900	28,100	2,700	33,300	15,845
1960	8,370	21,400	4,720	25,050	11,920
1961	8,620	18,350	4,946	22,024	10,480
1962	8,880	13,050	4,497	17,433	8,295
1963	9,140	12,050	4,327	16,863	8,025
1964	9,400	6,100	3,827	11,673	5,555
1965	9,600	6,100	3,756	11,944	5,685
1966	9,850	3,100	1,680	11,270	5,360
1967	10,100	3,700	104	13,696	6,515
1968	10,300	4,100	[2]	14,400	6,850
1969	10,500	4,703	[2]	15,203	7,235
1970	10,710	5,405	[2]	16,115	7,665
1971	11,250	6,892	[2]	18,142	8,635
1972	11,450	6,568	[2]	18,018	8,575
1973	11,800	4,823	[2]	16,623	7,910
1974	11,900	7,044	[2]	18,944	9,015
1975	12,200	8,120	[2]	20,320	9,670
1976	12,300	13,283	[2]	25,583	12,175
1977	12,700	9,223	[2]	21,923	10,430
1978	13,100	12,369	[2]	25,469	12,120
1979	13,500	13,149	25	26,624	12,670
1980	13,900	13,663	20	27,543	13,105
1981	14,180	13,251	—	27,431	13,055
1982	14,460	10,823	38	25,245	12,015
1983	14,800	14,539	[2]	29,339	13,960
1984	15,100	11,700	[2]	26,800	12,755
1985	15,400	12,221	[2]	27,621	13,145
1986	15,700	15,115	[2]	30,815	14,665

[1] Insignificant quantities.
[2] No exports found.
[3] Rounded figures.

The chief tungsten-consuming countries are those industrial countries that have facilities for the conversion of concentrate to primary products such as ferrotungsten, metal powder, tungstic acid, carbide powder, and chemicals. The Soviet Union consumes considerable quantities of tungsten for its defense and expanding industry (97, pp. vii–5). Its domestic tungsten consumption, compared with production, is high because most of the applications for tungsten require an advanced state of industrialization, which the Soviets possess, especially in defense and steel production.

Because of its high melting point, the highest of all metals, hardness, and durability, tungsten has many industrial and military applications. Tungsten is a vital constituent in many superalloys, high-speed tool and die steels, and corrosion-resistant alloys. Its high density, 19.3 g/cm^3, makes it an ideal metal for such applications as armor-piercing projectiles and aircraft counterweights. It is universally used for lamp and vacuum tube filaments, but this use accounts for only small quantities. Its other application in metallurgy is its ability to form an extremely stable and wear-resistant carbide. Sintered and bonded, primarily with cobalt, this carbide has for years been the basis of a large and important segment of the cutting-tool industry. Cutting tools and wear-resistant applications together account for about 65% of tungsten consumption in the United States (99). The U.S.S.R. reportedly consumed only about one-third of tungsten production in the manufacture of metal cutting instruments. In 1983, the country declared the production of hard alloys for cutting instruments that did not contain tungsten a priority matter. Such hard alloys, however, comprised only 1.9% of total production in cutting instruments in the 1980's (91).

In 1971, more than 80% of the tungsten produced was allocated to the ferrous metals industry. Up to 18% was used in ferroalloys and 2%–5% in the electrical industry (46). The estimated primary current use of tungsten metal in the Soviet Union, exclusive of that in ordnance and other military and space applications, is in steelmaking and production of carbide alloys, 78%; drilling tools, 18%; electrical industry, 3%; and chemical industry, 1%. Consumption of tungsten by the Soviet alloy steel industry is higher than that of the carbide industry, despite the growing importance of molybdenum at present in the manufacture of high-strength steels to replace tungsten.

CHAPTER 7.—OUTLOOK

The production, trade, consumption and utilization pattern of tungsten are difficult to predict for the future, especially in the Soviet Union. The export policies of China (its main foreign supplier), highly variable world tungsten prices, substitution for tungsten, and recycling, are just a few factors that may affect the supply pattern for tungsten concentrate. Even without allowing for requirements for local conflicts, the arms race and space programs could affect the need for the production of tungsten substantially.

Despite the poor grade of Soviet tungsten ore and poor production efficiency, it is unlikely that the Soviet Union will run out of reserves. The country is vast, and with improved mining and processing technology, the Soviet Union could be in a position to improve its production significantly if the need arose.

Most of the known tungsten deposits of the Soviet Union are located on the outskirts of the R.S.F.S.R. or outside of it, although the R.S.F.S.R. occupies about three-quarters of the total land mass of the Soviet Union. This is because more than half of the R.S.F.S.R. is located in Siberia, and exploration there has proceeded at a much slower pace than in Middle or Central Asia. However, the completion of the Baikal-Amur Railroad (BAM) may provide access to the remote areas further to the East and North for development of deposits already discovered there. The leading contenders for targets for further exploration and possible development in the future are most likely to be the eastern region of Transbaikal, Central Yakutiya, and the Magadan Oblast', essentially all located in remote reaches of Siberia; but such development would require construction of considerable new infrastructure.

Despite new deposit discoveries, and new mines and plants, however, the Soviet Union by the end of this century will most likely still depend on imports for a significant share of its needs, although it will concurrently remain an important world producer of tungsten concentrate. Production of tungsten concentrate may eventually double or even triple by the start of the 21st century. Self-sufficiency may not be the priority of the Soviet planners, at present, especially if manpower is needed elsewhere and tungsten concentrate is readily available on the market at reasonable prices in the immediate future.

Historically, primary tungsten demand in the world has grown at about 3% per year but in the U.S.S.R. this has been more erratic: from over 240% in 1935, by 84% in 1943 over that of 1940, by 21% in 1947, to 6% from 1956 to 1959, 5% in 1971, and at about 2% per year in the last 6 years, based on this study. Most of the world supply was consumed by highly industrialized nations, including the Soviet Union. Many analysts feel that if the current usage slump levels off, it may be optimistically projected that annual world demand for primary tungsten through the end of the 1980's will increase 4% to 5% at best, with 3% being more likely. In the Soviet Union, taking into account its defense posture, space research, and high imports, consumption of tungsten concentrate may grow by 4% to 6% annually during the next decade.

Given the traditional and conservative nature of the Soviet mining and metallurgical industry, and because of scheelite's important properties, it is more than likely that its use as a direct additive in steelmaking will continue to grow more rapidly than will ferrotungsten due to the economics of its processing and more widespread experience in its use by steel producers. However, ferroalloys will continue to be critical for proper melt balance in electric steelmaking and for late furnace and ladle additions. The only factor that could change this would be an increase in the Soviet Union's use of substitutes such as molybdenum and titanium in some of tungsten's traditional roles in steelmaking and drilling tools. The U.S.S.R. uses tungsten for armor-piercing projectiles, having decided not to use depleted uranium (DU) because of the corrosive nature of DU and other problems. Most likely, a tungsten alloy containing 90% or more tungsten will continue to be used for other military purposes.

Advances in metallurgy, however, could eventually make the conventional usage of tungsten, even by the Soviet Union, obsolete. For example, the use of composites, such as those in organic, metal, carbon-carbon, and hybrid matrixes could possibly evolve, decreasing the need for conventional steels, titanium, and other metal. Although the "off-the-shelf" or "technology-at-hand" mentality will most likely persist in the Soviet metallurgical industry, it is also just as plausible that the Soviet Union will have the technology to produce composites by the 1990's. If that happens, it will then be immaterial that the Soviet Union's tungsten deposits are of low grade. Because large tonnages are not required to produce composites, large reserves and production will not be a critical factor in military or space consumption. If only 25% of the total current tungsten consumption will be needed for the manufacture of composites, it is conceivable that, even with limited mining, the Soviet Union will have sufficient tungsten available from current production and stockpiles.

It may be also argued that tungsten has no fully satisfactory substitutes where hardness has to be maintained at high temperatures. Wear resistance is another significant property of cast tungsten carbide, though this can sometimes be replaced by titanium, tantalum, and columbium carbides. On the other hand, tungsten can be recycled; for example, about 40% to 45% of the tungsten used outside of the United Kingdom's steel industry comes in the form of scrap (100). The Soviet Union may not be as efficient in recycling its scrap, and if substitution is impractical, then the Soviet tungsten industry will continue to grow and the U.S.S.R. will remain an important tungsten producer and consumer.

CHAPTER 8.—PRINCIPAL TUNGSTEN DEPOSITS, MINING AND BENEFICIATION COMPLEXES

The following material summarizes the geology, mining operations and beneficiation facilities of selected Soviet tungsten deposits. It is arranged strictly in geographic order, proceeding from the Ural Mountains in the West, eastward through the Caucasus, Central Asia, Kazakhstan, Southwest Siberia, Transbaikal, and Primor'ye, and then northward to Northeast Siberia. This geographic arrangement has been selected because the relative importance of deposits may vary over time, but the geography will not. In 1986, insofar as can be determined, the principal operating deposits were Tyrny-Auz in the Caucasus; Vostok-2 in Primor'ye; Dzhida in West Transbaikal; Maykhura in Tadzhikistan, and Ingichke in Uzbekistan (both in Central Asia); and Akchatau and Boguty, both in Kazakhstan.

Table 9 summarizes the production of tungsten concentrate by the major Soviet beneficiation complexes. Each complex is then described in the sections that follow.

Appendix A lists Soviet tungsten deposits and mineralization sites listed alphabetically and by geographic regions. The deposit type, the predominant tungsten ore, and associated minerals are given for each deposit. The list was compiled from available published literature, without verification of their economic importance or production status.

Table 9.—Estimated Production of Tungsten Concentrates by Major Soviet Beneficiation Plants — 1986. (Metric tons; average 60% WO_3).

Beneficiation Plant	% Total Production	Gross Weight	W Content
Tyrny-Auz, Caucasus	40.0	6,280	2,988
Vostok-2, Primor'ye	15.0	2,355	1,120
Dzhida, West Transbaikal	10.0	1,570	747
Ingichke, Central Asia	3.0	471	224
Maykhura, Central Asia	2.6	408	194
Akchatau, Kazakhstan	2.5	392	184
Iul'tin, NE Siberia	2.3	361	172
Verkhne Kayrakty, Kazakhstan	1.2	188	89
Bom-Gorkhon, West Transbaikal	1.1	173	82
Antonovogorsk, East Transbaikal	1.0	157	75
Balkhash, Kazakhstan	1.0	157	75
Yubileynoe, Central Asia	1.0	157	75
Belukha, East Transbaikal	0.8	125	59
Karaoba, Kazakhstan	0.7	110	52
Balkan, Urals	0.5	79	38
Sherlovogorsk, East Transbaikal	0.5	79	38
Solnechnoe, Primor'ye	0.5	79	38
Subtotal	83.7	13,141	6,250
Other	16.3	2,559	1,217
Grand Total	100.0	15,700	7,467

URAL MOUNTAINS

In the Ural Mountains, the tungsten and tungsten-molybdenum deposits are located predominantly in the eastern part, and are associated mostly with granite (4, p. 52). The deposits originated during Late Devonian to Late Permian time(Hercynian)and the area is geologically and structurally complex.

Based on the geographical distribution and mineralogical occurrences the Urals may be divided into northern and southern regions. In the northern Urals there are more than 20 tungsten mineralization localities, the Pripolyarny, Talbeisk and Torgovsk deposits being mentioned most often in the Soviet literature. The Pripolyarny greisen deposit is Precambrian in age and is mostly scheelite, while Talbeisk and Torgovsk are Late Paleozoic vein deposits. None of these deposits have been mined economically.

In the western part of the Torgovsk area wolframite-molybdenite-bismuthinite vein deposits are confined to quartz veins which cut through the Paleozoic quartz-sericite shale sequences. The metal content is 0.3–7.6% WO_3, 0.07–2.5% Mo, 1.2% Bi, and 0.07–0.24% Sn. The eastern part of the area is richer in molybdenite and bismuthinite concentrations than the west.

The existence of wolframite-cinnabar deposits in the Tal'beisk area was first mentioned in the Soviet literature in 1974. The mineralization occurs mostly in highly weathered diabase dikes, and the minerallized zone is 50–60 kilometers long. Other ore-forming minerals are cinnabar, scheelite, pyrite, and pyrrhotite. The tungsten content is 0.043% maximum and mercury content is 0.037–0.077%. The economic significance of this deposit is as yet unknown.

Gumbeika Mining Complex

In the southern Urals, the predominant tungsten ore-forming mineral is scheelite which is associated with skarns and different mineral assemblages. Most of the scheelite deposits occur between Magnitogorsk and Gumbeika, in association with Late Paleozoic (Hercynian) granites. In some areas, the skarns are cut by veins containing chalcopyrite, galena, magnetite, molybdenite, pyrite and scheelite. Other parts of the deposits are also rich in gold.

The Gumbeika mine and beneficiation plant were in full operation in 1930, but its production declined already in 1932 (43; 101). The scheelite mine is situated only 8 kilometers from the Magnitogorsk railroad spur (11, p. 4). The mine also produced small quantities of gold. The Aydyrlinsk and Kumarsk deposits nearby contain gold and huebnerite, but are presently not mined. Hand sorting (cobbing) was the initial method of ore concentration at the Gumbeika deposit, with 8.25% WO_3 content (102). In 1930, the Gumbeika concentrator produced about 148 metric tons of tungsten concentrate with about 63% WO_3 content. The production, however, decreased to 54 metric tons in 1931, and to 38.3 metric tons in the first 10 months of 1932 (8). The WO_3 content of the Gumbeika scheelite ore was 0.70% in 1933 (11, p. 3). The concentrate at Gumbeika was produced in two stages in 1933. The first stage produced a concentrate of 18–30% WO_3, while the second stage, at which the concentrate went through a special washing table, produced a concentrate of 40–50% WO_3. During the latter process, however, much of the finer particle scheelite was lost (103).

This complex also was used to process ore from the Balkan, Buranov and Trebin (Treba) deposits nearby. The WO_3 content of the Buranov deposit varied from 0.37%–0.7% (11, p. 51). The production capacity of the Buranov mill was 1.17 metric tons of ore per hour in 1937 (81). The deposit was depleted in 1940, but others put it beyond 1950's (18; 104–105).

Balkan Deposit

The Balkan deposit and mining complex are situated near the village of Treba, northeast of Magnitogorsk, on the right bank of the Gumbeika River, in the southern Urals. The deposit consists of scheelite-bearing pockets, which are mined underground, Mine 1, and in open pits, Mine 2 (106). Production may have started in 1928, and present assumed design capacity and average production are 20,000 metric tons per year. Some reports claim that the mine and plant were in planning at the end of the 1930's.

Beneficiation.—The Balkan plant previously was used to treat ore from the now depleted Buranov and Gumbeika deposits. Currently, the tailings at the Balkan plant are treated by flotation to eliminate most of the dolomite. The apatite and fine dolomite impurities are further treated by acid leaching to obtain a 60–65% WO_3 scheelite concentrate. Scheelite recovery is estimated at 65%. Annual production of the Balkan plant is estimated to be from 75 to 100 metric tons of concentrate, at 60% WO_3.

In the southern Urals scheelite also occurs in veins in granites, as at Velikopetrovsk and Novo-Berezovsk. Some veins are gold-bearing and most contain scheelite and wolframite. The sulfide content (arsenopyrite bismuthinite, chalcopyrite, molybdenite, and pyrite) is less than 2% in those deposits.

Huebnerite in scheelite skarns predominates in potassic granites at Boevsk, Igisansk, Karas'evsk, Porokhovsk, Pyankovsk, Saburovsk, Yugo-Konevsk, and others. The skarns also contain disseminated molybdenite.

The Porokhovsk deposit is part of a volcanic sequence and is in contact with the Yugo-Konevsk granite. Its geologic setting is similar to that of the Gumbeika area. The mineralization is in two intersecting, steeply dipping, southeasterly striking quartz veins, which cut across a small epidote-garnet skarn.

At Karas'evsk and Yugo-Konevsk, mineralization is in veins in strongly faulted and fissured rocks. Huebnerite increases with depth, while scheelite decreases. Huebnerite is concentrated at intersections of short quartz veins, which are not as thick as the scheelite-quartz veins. The deposits also contain some ferberite and sulfide minerals.

In addition to those deposits, Soviet literature also mentions the occurence in the southern Urals of ferberite at Krasny Ogorodnik and of huebnerite and molybdenite at Vostok, the latter not to be confused with the major Vostok II mine of Primor'ye in the Soviet Far East.

CAUCASUS MOUNTAINS

The geology and ore deposits of the Caucasus have been amply described in literature, beginning from early Imperial Russian explorations to the present. The geology only of Tyrny-Auz and several other selected tungsten deposits is described in more detail here.

Tyrny-auz Deposit

Tyrny-Auz is economically the most important and largest scheelite-molybenite deposit in the U.S.S.R. The deposit is located in the northern Caucasus, between the Elbrus Mountain and the city of Nal'chik, the seat of the Kabardino-Balkarian A.S.S.R., and 150 kilometers west of the city of Ordzhonikidze. The deposit was discovered in 1934 and has been intensely studied since then (62, pp. 130–137; 107, p. 587; 108, p. 202; 109–110).

It lies in a strongly faulted 2–3 kilometers-wide belt and is made up of highly metamorphosed rocks which are cut by acidic and basic intrusions. Tyrny-Auz is unusual in that it is made up of tungsten-molydenum greisens and skarns, and sulfide scheelite deposits, the latter being of no economic significance (4, p. 33; pp. 580, 589–590; 108; 111–112).

The richest portion of the deposit occurs in skarns and is reportedly 100–600 meters long, 20–50 meters wide, and 100–300 meters deep. The Tyrny-Auz deposit is mineralogically complex, but the predominant ore minerals are scheelite and molybdenite. The gangue minerals include epidote, fluorspar, garnet, pyroxene and quartz. The grade is 1–1.3% WO_3 and 0.2–0.3% Mo. The scheelite content and the grade of the deposit diminish with depth, while the content of molybdenite increases (57, p. 11). Others state that the WO_3 content of Tyrny-Auz ore was only 0.18–0.23% in 1969, and 0.21% in 1975 (113). The deposit has an asymmetrical zoning. In the central part of the field are the molybdenum-tungsten skarns; to the southeast and northwest the skarns contain appreciable amounts of sulfides, at such locations as Tyutyu, Maly (Lesser) Mukulan, and the Severny (Northern) tin-bearing skarns (107, p. 589).

There is no straightforward information on the tungsten ore reserve at Tyrny-Auz. The reserves of tungsten have been calculated in 1983 to be 50,800,000 metric tons at 0.60% WO_3 and 0.2% Mo (50, p. 23).

Mining.—Tyrny-Auz is the largest tungsten-molybdenum mining complex in the Soviet Union, in recent years accounting for 40% of the country's total output. Mining there started underground in the late 1930's. The first stage of the mining complex became operational in 1938 (114).

The highest mine level is, reportedly, located over 3,000 meters above sea level. Access to the mine is through adits on the upper four levels of the mine, which are also connected by shafts, ore chutes and rock passes. The lower levels are reached by shafts only. The fourth mining level was completed during 1958–62, and an adit was cut at an elevation of over 2,000 meters, intersected by a 600-meter shaft and two ore chutes. In 1966, ore was taken out from 6 adits between elevations of 3,047 and 2,133 meters. Mining is by an open stope blasthole method. Stope size is approximately 60 meters long by 75 meters high, the width varying from 50–90 meters. The ore is broken underground, coarsely crushed and transported by cable car to a preparation plant 2 kilometers away (51).

There may have been some surface mining at Tyrny-Auz in 1934. The operation reportedly ceased from 1941 to 1945 during the German occupation. The first major surface operation, Vostochny, started in 1971, and another one was under exploration. The open pit mining is typical bench type, worked by conventional drilling equipment, electric shovels, trucks and bulldozers. The pit is about 1,600 meters long, by 30–90 meters wide, and 75-meters deep. The designed production capacity of the Tyrny-Auz open pit mine was reportedly 2 million metric tons of ore, and 14.2 million metric tons of waste per year in 1971. In 1972, the redesigned ratio of waste to ore was increased from 7.1:1–10.5:1, thus requiring 21 million metric tons of waste for 2 million metric tons of ore. The planned costs for the enlargement of the pit were 10.74 million rubbles (115).

Beneficiation.—The Tyrny-Auz tungsten-molybdenum beneficiation facility at Kabardino is the largest such facility in the U.S.S.R. (Figure 6) (116). In 1969, reportedly, it produced 4,500 metric tons of concentrate 60% WO_3, or about 2,100 metric tons of contained tungsten, which amounted to about 32% of total Soviet production (57, p. 11). The beneficiation plant opened in 1940, was destroyed in World War II, and rebuilt in 1945, with several expansions through the 1950's and 1960's (117, p. 146). The concentrator was expanded again in 1962. In 1966, the recovery of tungsten from oxidized ores was 84%, and that of molybdenum 55%. The tungsten concentrate contained 41–50% WO_3, 3–6% Mo, 10–13% CaF_2, and 5–11% water (57, p. 11). An automatic sampler and a computer was installed in 1976, which continuously recorded the tungsten and impurity levels of the ore (89, p. 185). The annual production of tungsten concentrate at 60% WO_3 is estimated to be 6,280 metric tons. The concentrate is shipped for treatment to the Nal'chik hydrometallurgical plant.

Several beneficiation processes have been described for Tyrny-Auz in Soviet and foreign literature. The plant processes scheelite-molybdenite ore to produce two or more concentrates. The ore also contains some copper. The basic beneficiation method reportedly consists of primary crushing and grinding, with the coarse product passing to ball mills for final grinding. The ground product is then subjected to flotation primarily to yield a sulfide concentrate containing molybdenite and other sulfides which are later cleaned to yield a high grade molybdenum concentrate (53% Mo) (57, p. 3). Sulfide flotation tailings, in turn, are conditioned and floated for scheelite recovery into a low-grade concentrate (15% WO_3) for conversion to APT in the adjoining Nal'chik hydrometallurgical plant. The high grade (KMSHA), and low grade (KMSHE) was 45% WO_3, concentrates are also sent to the Nal'chik hydrometallurgical plant for reprocessing (82, p. 10).

Figure 6. The Tyrny-Auz Beneficiation Plant.

The Tyrny-Auz plant also conducts research on tungsten beneficiation and production of intermediate products in attempts to increase recovery by subjecting concentrates to a variety of leaching conditions (65, pp. 32–33; 118–120; 121, pp. 109–117).

Nal'chik Hydrometallurgical Plant

The scheelite and molybdenum concentrates from Tyrny-Auz are transported by truck to the Nal'chik hydrometallurigical plant (Nal'chinskiy gidrometallurgicheskiy zavod—NGMZ) at Kabardino for the production of intermediate products. At Nal'chik, molybdenum recovery is about 90%; elsewhere it is only 40% (82, p. 10). Bismuth and maybe copper, are byproducts of tungsten production at Nal'chik. The processed water contains between 0.16 and 0.70 gm of WO_3 per liter, but this is not reclaimed (57, p. 13).

The tungsten-molybdenum intermediate products are essentially a mixture of scheelite and powellite containing 40–60% WO_3 and 4–5% Mo. Part of the intermediate product is upgraded at NGMZ by sodium autoclave leaching flotation, yielding synthetic scheelite and molybdenum tri-sulphide (Figure 7). The hydrometallurgical plant produces tungsten anhydrite for the hard-metal industry and hydrometallurgical molybdenum concentrate for ferromolybdenum production. A considerable portion of the intermediate products are used for the production of ferrotungsten for use in steel (118, pp. 43–44).

Kti-Teberda Deposit

This scheelite-arsenopyrite deposit is part of the Kurgazhin-Chatsky ore zone in the northern Caucasus, about 60 kilometers to the west of Elbrus Mountain. The ore occurs in steeply inclined veins in a 80–100 meterwide zone that is 600–800 meters long on the surface. The deposit contains up to 20 such veins, which decrease in number with depth. Most of the scheelite quartz-feldspar veins are in the northern part of the deposit, while the southern part has only a few zones with wolframite.

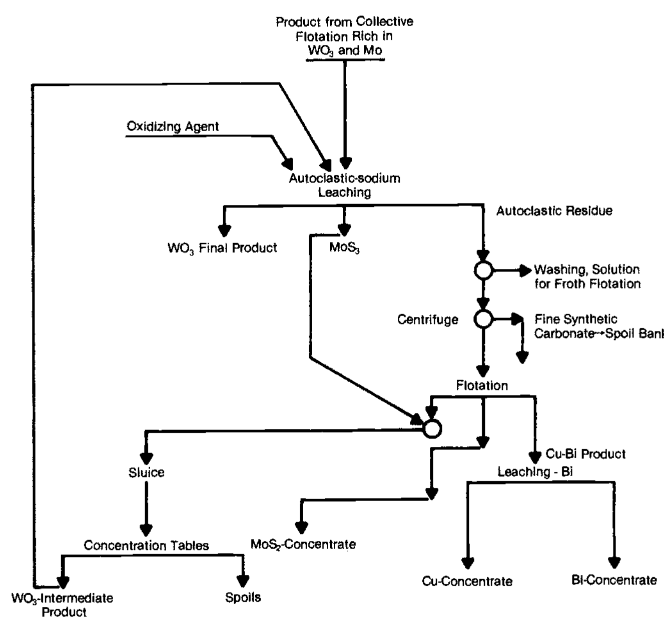

Figure 7. Basic Flowchart for the Production of WO_3 and Mo Intermediate Tungsten Products by Autoclave Sodium Leaching.

Biotite usually accompanies the lense-shaped scheelite veins. The richest mineralization is at the intersection of the veins. In addition to scheelite and arsenic, other minerals are chalcopyrite, lead, pyrite, pyrrhotite, wolframite, zinc, small quantities of beryl, bismuth, bismuthinite, and sulfosalts (57, p. 15; 122).

By some accounts, this deposit has been mined sporadically, the last time being during World War II. It is inactive, or a prospect, at present.

Chensky, Chorukhsky and Kvanarsky Deposits

Three small deposits make up this tungsten mineralization zone in the southern Caucasus,—Chensky, Chorukhsky, and Kvanarsky. Their economic significance is unknown, but most likely unimportant, and apparently none are in production today.

The Chensky deposit consists of wolframite-molybdenite veins in skarn, associated with a granitic porphyry stock intruded into Jurassic shales. Other minerals include arsenopyrite, cassiterite, chalcopyrite, pyrite, and scheelite. These veins are intersected by younger ones that contain some bismuthinite, scheelite, wolframite, and other minerals.

The Chorukhsky deposit contains more wolframite than Chensky. The quartz-wolframite veins are thin, and in addition to wolframite, also contain arsenopyrite, chalcopyrite, lead, pyrite, and scheelite. Wolframite content in the Kvanarsky deposit is small, occurring in quartz veins together with arsenopyrite, galena and pyrite.

CENTRAL ASIA

In this report, the Central Asian tungsten ore belt encompasses the Uzbek, the Tadzhik, and the Kirghiz Autonomous Republics. The most significant tungsten mines in Central Asia are in skarn deposits of Late Hercynian age. Pegmatites rich in wolframite and scheelite in quartz veins occur also, but are rare. Some scheelite is recovered as a byproduct at some gold mines in this area. Tungsten minerals occurs together with molybdenite, primarily emplaced along the 2500-kilometer-long Southern ore belt and the 400-km-long Northern ore belt of the Tien Shan Range in Uzbek S.S.R. By 1965, Uzbekistan was one of the Soviet Union's leading producers of tungsten and molybdenum. There are several large deposits located primarily in the Samarkand region (123). Mining of tungsten in Uzbekistan began in 1941. The reserves of the Republic are, reportedly, four times the annual production (124, p. 39). Of lesser significance is the Chorukh-Dayron tungsten mineralization zone in Central Tien Shan of Tadzhikistan. Tungsten mining in northern and central Tadzhikistan started in 1930's (125).

The Northern Ore Belt

The Northern ore belt of Central Asia contains the scheelite skarn deposits of Lyangar, Koytash, Ugat, and Melik-su. Almost all of the deposits of this or belt are located in northern Uzbekistan. All of the tungsten concentrate produced in Uzbekistan is sent to the Chirchik (Uzbek) metallurgical plant for the production of hard alloys, tungsten wire, and other metal products (124, p. 40).

Lyangar Deposit

The Lyangar deposit is located about 110 kilometers northwest of Samarkand, in the Ak-Tau Mountains, north of the Zeravshan Valley, Uzbekistan. The deposit is a scheelite-molybdenite skarn, made up of veins and ore pockets. A northwestly trending fault cuts through the deposit, enriching some of the ore pockets.

This medium-sized deposit was explored and developed between 1932 to 1936, and small-scale underground mining occurred in the 1950's, and again in the 1960's. The beneficiation plant was to have been constructed by 1950, and the concentrator was eventually built in 1952 (126–127). The deposit was depleted in 1974 (125, p. 39).

Chirchik Metals Plant

The Chirchik (or Uzbek) refractory and heat-resistant metals plant is located in Uzbekistan, a short distance northeast of the city of Tashkent. The plant began operations in 1956, and treated concentrates from the Lyangar mine, about 400 kilometers away. The smelter now produces tungsten metal, ferrotungsten, and other ferroalloys from other beneficiation plants. Reportedly, a plasma installation for the production of pure tungsten began operation on December 8, 1982. The incandescent jet of ionized hydrogen gas reduces the tungsten oxide at great speed. The installation has replaced the conventional furnaces.

Tungsten concentrates from the Ingichke and other regional mines are also refined and manufactured into high-temperature alloys, rods, sheets, wire, and other end products at the Chirchik plant (116, p. 327).

Koytash Deposit

The Koytash scheelite skarn deposit is in eastern Uzbekistan, about 80 kilometers northeast of Samarkand. Disseminated scheelite occurs along the North Tien Shan fault zone. Scheelite is found also in quartz veins that cut through the Koytash granite and the skarn. Molybdenite is an important ore-forming mineral of the deposit. The principal ore-forming minerals are chalcopyrite, molybdenite, pyrite, pyrrhotite, and scheelite. The gangue minerals include amphibole, chlorite, epidote, mica, pyroxene, quartz, vesuvianite and wollastonite.

Construction of the Koytash mine started in 1941 (113). The deposit was mined during World War II and expanded in the 1950's (116, p. 327). Molybdenum concentrate was produced as a byproduct (128). The flotation plant produced scheelite concentrate in 1972 at 58–65% WO_3, at 80% extraction efficiency (57, p. 55). The deposit was closed due to depletion in 1975.

Tungsten concentrate from the mine was refined and manufactured into alloys and other products at the Chirchik alloys plant.

Ugat Deposit

The Ugat scheelite mineralization zone is west of the Koytash deposit. Its geology and mineralization are similar to that of Koytash. The ore was processed by the Koytash concentrator in 1968. The grade of the tungsten ore was 0.45% WO_3 (129). No present mining activity is known at this deposit.

Melik-su Deposit

The deposit is in northeastern Tadzhikistan at the eastern end of the Alaysky Range, to the north of the Turkestansky fault. The deposit consists of the following smaller ore bodies: Besh-Arkha, Khal-Kuyryuk, Kumykh-Tash and Saya Lagernoe.

The deposit is of skarn type, but there are also small stockworks and veins containing tungsten. The ore minerals of the Melik-su deposit are scheelite and some galena. The gangue minerals are actinolite, albite, biotite, chlorite, garnet, plagioclase, pyroxene, quartz, and sericite. No present mining is known at this deposit.

The Southern Ore Belt

The Southern ore belt of Central Asia contains scheelite skarn deposits of Ingichke, Kanyaz, Karatyube, and Takfon. Other smaller deposits are Arkhamaydan-Sarymat, Kabuty, Maykhura (or Maykhurin; Maykhurinsk) Petinsk, Rars and Yubileynoe. The Kashkasu and Kumbel' (called Kara-Urkurt until 1945), were also mined for tungsten and molybdenum but may be inoperative at present (130). The Yakhton scheelite deposit in the Ingichke area was described in 1975 as a good prospect for future development. Production reportedly started in 1977 (131). Sargordon and Daykovoe deposits were also mentioned, the latter being more promising, and under investigation in 1974 (124, p. 39).

Ingichke Deposit

The Ingichke (Ingichka; Ingichinsk) tungsten ore zone is located about 100 kilometers west of Samarkand in eastern Uzbekistan.

The Ingichke deposit is the largest in the Southern Ore Belt of Central Asia. It was explored during the 1940–47 period (16, p. 12). There are three distinct ore bodies within this hedenbergite pyroxene skarn deposit that are more than 800 meters deep: 1) A marble-granodiorite contact ore body, which makes up almost 90% of the skarn, almost two-thirds of it is 0.5–27 meters wide, 0.4 meters thick, and the rest more than 1 meter thick, with a dip of 15–40°; 2) Discordant vein ore bodies along the periphery of the granite that make up 10% of the deposits, these in a zone from 0.6–0.8 meters thick; and 3) Layered, intrastratal ore far from the contact, which makes up only 1% of the deposit. Of the first category, 22 contact skarn bodies have been identified (62, p. 189).

In addition to the various shapes of the ore bodies, the tungsten mineralization also changes with depth and the jointing pattern. In plan, the largest amounts of scheelite occur where the joints and quartz veins are the densest (Figure 8) (72, p. 40).

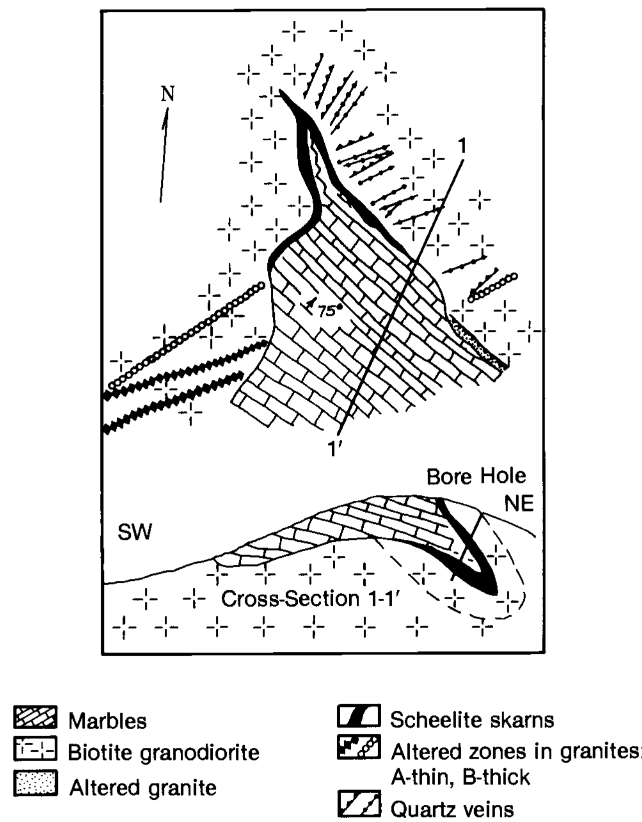

Figure 8. Contact Scheelite-Skarn Deposits of Ingichke.

The main ore-forming minerals of the deposit are chalcopyrite, galena, marcasite, pyrrhotite, pyrite, scheelite, and sphalerite. In contrast to other skarn tungsten deposits in the Soviet Union, molybdenite is absent, while yttrium and rare earths are present. Scheelite is distributed unevenly in the ore. The associated gangue minerals are amphibole, calcite, chlorite, dolomite, pyroxenes (diopside, hedenbergite), quartz, sericite, and vesuvianite (idocrase). Ushakov, Smirnov, and others, describe in detail the paragenesis of the Ingichke deposit (62, pp. 185–190; 132).

Mining.—All scheelite mining at Ingichke is underground, using the cut and fill method. Mining may have started in the early 1960's, and the mine was definitely producing in 1973. In 1963, the WO_3 content of the ore was 0.38–0.57%, on the average 0.43% (133). The average dilution in the underground mine was 58.5% in 1978 (26). The labor productivity was low, however, because up to 80% of the work was done manually (134).

Beneficiation.—The Ingichke concentrator may be the fourth largest in the Soviet Union. The plant may have been operational in 1951 and a new flotation plant was installed in 1972 and 1973, virtually doubling the capacity (124, p. 39; 135). The crushed and ground ore is processed by gravity flotation and electromagnetic separation. The scheelite concentrate is roasted prior to electromagnetic separation. The capacity of the concentrator was reportedly 25% greater than the capacity of the mine; the concentrator may have been idle for considerable periods and the recovery of concentrate was well below the planned level of 87.5% (89, p. 186). Reportedly, the plant processes pyroxene-scheelite bearing ore, with 0.30–0.44% WO_3 content (57, p. 52). The beneficiation products include scheelite and copper concentrates. Molybdenite is also concentrated, but not continually, at 82% with 0.06% Mo. Annual production of tungsten concentrate is estimated to be 471 metric tons. The high-grade scheelite concentrate is sent to the Chirchik alloys plant for the manufacture of various intermediate products.

When the Ingichke deposit is depleted, the beneficiation plant could continue to process ore from the Yakhtin and Karatyube deposits (124, p. 39).

Karatyube Deposit

The Karatyube deposit is located in northeastern Tadzhikistan, about 100 kilometers southeast of Samarkand. Karatyube is a scheelite skarn deposit, in an Upper Silurian metamorphosed limestone-shale sequence. The ore is concentrated in marble and is either layered, in lenses, or is massive. The deposit is made up of two ore zones 5 and 7 kilometers long, which are about 800 meters apart (57, p. 52). The deposit was explored in 1977 (131).

Mayhura Deposit

The Maykhura deposit is located 70 kilometers south of Dushambe, on the southern slope of the Gissar Range. The mineralization is within an anticline, whose carbonate core was intruded by a biotitie granite during Late Carboniferous (Pennsylvanian) to Early Permian time. It is part of a tin-tungsten ore field, with scheelite occurring in skarns (136). Mineralization is highest at the intersection of the northeasterly trending thrust fault zone with the northwesterly trending normal fault zone that is intruded by dikes and veins. The skarn is also cut by quartz and feldspar-quartz veins, containing high concentrations of scheelite and cassiterite, concentrated in lenses and elongated bodies.

Mining.—By some accounts, the Maykhura mine was under construction in 1972 and underground mining started in 1975 (89, p. 186). Others state that the tin-tungsten deposit was explored by 1977, the ore grade being 1% WO_3. Reportedly, the reserves were 5 million metric tons at 0.4% in 1983, making it the largest tungsten ore deposit in Soviet Central Asia. The Maykhura deposit was developed to replace the depleted reserves of the Chorukh-Dayron deposit (125). All mining at Maykhura is underground, by sublevel stoping. The mine is accessed through adits.

Beneficiation.—Concentration at Maykhura is done by the same plant that treated ore from the now depleted Chorukh-Dayron deposit (described subsequently). The most likely process of beneficiation is gravity and flotation separation, followed by electromagnetic separation and leaching in nitric acid. Phosphorus is removed as part of the final leaching process. Recovery is estimated to be 60%, based on other similar operations. About 408 metric tons of concentrate is produced annually.

Takfon Deposit

The Takfon skarn deposit is located in Uzbekistan, east of Samarkand, about 5 kilometers from a northeastly striking limb of an anticline, which is cut off in the east by another fault. The ore-forming minerals of Takfon are predominantly disseminated scheelite, pyrrhotite, and some sphalerite. There is no indication of mining operations in the literature reviewed.

Kabuty Deposit

The deposit is north of Dushambe, in Tadzhikistan. This area was explored during World War II. The mineralization is along a steep flank (80–85°) of the Gissarsky granodiorite pluton which has intruded the core of the anticline. The sedimentary section of the anticline has been metamorphosed to marble by the intrusion and the ore is concentrated in veins along faults. The major ore minerals are ferberite, pyrrhotite and scheelite. Garnet and pyroxenes are the primary gangue minerals. The deposit is most likely a prospect and is not mined at present.

Yubileynoe Deposit

The deposit is located in the Mogoltau Mountains of Tadzhikistan, about 120 kilometers southeast of the city of Tashkent.

The deposit is a scheelite skarn localized along a fault zone. Primary mineralization is chalcopyrite, molybdenite and scheelite with albite, calcite, garnet, and quartz as gangue minerals. The ore body is approximately 1,700 meters long, 0.5–9.0 meters thick, and extends 500–1,000 meters deep.

All mining at Yubileynoe is underground, most likely by cut-and-fill method. By some accounts mining started in 1977. Others cite 1980 as the probable year of initial production (137). The beneficiation plant produces an estimated 157 metric tons of concentrate per year.

Chorukh-Dayron Deposit

The deposit is situated in the 125-kilometer-long Kuraminsk mineralized zone in Tadzhikistan, close to the Yubileynoe deposit, about 15 kilometers north of Leninabad. The zone includes various other tungsten skarn deposits, such as Ayna-Bulak, Ingyrchak, and Tamchi. The scheelite skarn deposit consists of 14 ore bodies, all of which have been reportedly almost mined out by 1977. Development of the Chorukh-Dayron mine started in 1941 and mining began in 1945; the ore was concentrated nearby at Mogoltau (114). In 1956, the Chorukh Mine of the Dayron Mine Administration increased production of tungsten, mostly scheelite, and molybdenum ores by 10.5%, compared to 1955 output (128; 138). Columbium, copper, and tantalum may also be present, as well as iron, lead and zinc. The deposit is subdivided into a number of smaller ore zones. Some mineralized fissure zones (Glavnaya, Novaya, Diagonal'naya localities) contain mostly scheelite. Other zones (Shurale, Central'naya, Yuzhny Yangi-kan localities) contain fluorspar, molybdenite and scheelite. The highest Chorukh-Dayron concentration of scheelite is associated with garnet and epidote. The concentrator presently treats tungsten ore from the Maykhura deposit (125).

KAZAKHSTAN

Kazakhstan is more known for its numerous copper, copper-molybdenum and tin mines than for its tungsten. Occurrences of tungsten, molybdenum, tin, and various other rare metals in Kazakhstan are closely associated with granites. The granitic massifs occupy an area of about 110,000 square kilometers, or 14% of the total area of Kazakhstan and 25–30% of the massifs are located in northeastern Kazakhstan (139, p. 22).

According to Soviet literature, tungsten was first discovered in Kazakhstan at Altuayt (Kuzyudyr) in 1926. The Kounrad molybdenum (and tungsten) deposit was discovered in 1928, Kyzyltau in 1932, and in 1936 many others were found. The deposits were surveyed in 1917–30. The in-depth study of the metallogeny of Central Kazakhstan began, however, only after 1950, when more than 50 deposits were studied (139, p. 3).

Central Kazakhstan

Tungsten mineralization in Central Kazakhstan is confined to an area to the northwest of Lake Balkhash. According to some Soviet geologists, the tungsten and rare metals deposits of Central Kazakhstan are similar to those of Gorny Altay, Transbaikal, Northeast Siberia, and Caucasus. They are also similar to deposits of North America, Central and South America, Southern Asia and Korea (139, p. 367). The region has a complex geological history; faulting and metamorphism occurred during the Hercynian orogeny. Many of the tungsten deposits of Central Kazakhstan are concentrated in the area around Akchatau and northeast of it. The deposits are of the greisen, vein or stockwork types including the Akchatau, Batystau, Baykhatin, Baynazar, Boguty, Dzhanet, Dzheltau, Keng Kiik; Koktenkol, Maykul, Nura-Taldy, Segiz-Sala, Seltey, Shalgiya, Tayshek, Verkne-Kayrakty, and others (4, p. 67).

Akchatau Deposit

The Akchatau deposit is the second largest deposit in Kazakhstan, after Boguty. The deposit is located about 200 kilometers southeast of Karaganda. It is a pegmatoid greisen deposit and part of the western Akchatau granite massif. The massif is 26 by 10 kilometers in areal extent, and where it crops out in the west is 5 by 4 kilometers. More than 300 greisen vein bodies make up the deposit, which in turn may be subdivided further. Within these greisen bodies, 22 ore clusters have been identified. The dimensions of individual wolframite segregations vary from hundredths of a millimeter up to 20–50 millimeters and more, nests from a few centimeters up to 1 meter, and lenses up to 10–20 meters with a thickness of up to 10 centimeters. The vertical range of mineralization in the main ore belt is 100–200 meters, and up to 250 meters deep (61, pp. 193–195).

The primary ore minerals of the Akchatau deposit are biotite, bismuthinite, chalcopyrite, feldspar, fluorspar, molybdenite, scheelite, sphalerite, topaz, turmaline, and wolframite. Vertically, wolframite is distributed extremely unevenly in the veins but is confined to the central portions of the veins. Distribution of wolframite in greisens is more even. The content of WO_3 in wolframite is 74.12–75.65%, FeO, 9.0–13.5%, and MnO, 9.66–14.11%, and the ratio of ferberite to huebnerite is 54:46. On the whole, the content of tungsten and molybedenum is highest in the upper portions of the deposit. A notable feature of the Akchatau deposit is the intense weathering of the deposit to depths of 10–15 meters from the surface. Down to depths of 5–8 meters molybdenite has been completely leached, and from 15–20 meters it has been partially leached or replaced by ferromolybdite, limonite and powellite (62, p. 196).

Mining.—By some accounts, the Akchatau deposit was discovered in 1936, and construction of the mine began in 1941 (114). The mine was upgraded and production increased in 1981 (140). All mining at present is underground, by sublevel stoping.

The new Dzhambul underground mine and concentration plant were put into operation at the Akchatau complex in 1982, but did not perform efficiently (36; 39).

Beneficiation.—The first stage of the Akchatau tungsten-molybdenum concentrator was put into operation in 1946 (141). The ore is upgraded by the flotation process. The sulfides are stockpiled and the coarse tungsten concentrate is further beneficiated by magnetic separation. It was reported in 1977 that the efficiency of the Akchatau complex was very low because of old equipment (142). In 1982, however, capacities were increased for tungsten and molybdenum ore extraction and processing (143). There are some indications that some of the ore may also be processed at the Akzhal (or Akzhalsk) plant. The estimated annual production of the Akchatau plant is 105,000 metric tons of tungsten concentrate.

Akmaya Deposit

The tungsten minerals of this small deposit occur in a stockwork. Some of the ore veins are 80 meters long and 70 centimeters thick, with wolframite as the principal ore mineral, also including some bismuthinite, cassiterite, molybdenite, and scheelite. The gangue minerals are feldspar, quartz, and sericite. The deposit was explored during the 1940–47 period (16). No information on mining of this deposit was found in the reviewed literature.

Balkhash Beneficiation Plant

The Balkhash mining complex in Central Kazakhstan is the largest copper producing combine in the Soviet Union. In addition to its primary role of treating copper and molybdenum concentrates, the plant also processes copper-molybdenum concentrates containing wolframite. The mining complex also, reportedly, sends some of the copper-molybdenum-tungsten ore to the Uspensky plant for beneficiation, and wolframite-molybdenite ore to the Akchatau plant. Bismuth and rhenium are produced as byproducts of the molybdenite-wolframite concentrate treatment at Balkhash. A mine was reportedly also under construction at Balkhash in 1972, and was to become operational in 1975 (89, p. 186).

Karaoba Deposit

The deposit is situated approximately 100 kilometers northwest of Lake Balkhash, and west of the railway junction at Mointy, in the Betpak Dala Desert. The greisen stockwork deposit consists of many quartz veins, most of which are in granites and granite-porphyries, making up a small massif (4, p. 24). There are three mineralized zones within the Karaoba granite massif: 1) the Tsentral'ny (Central) polymetallic area, composed of wolframite, cassiterite-bismuthinite, and molybdenite; 2) the Zapadny (Western) molybdenite zone; and 3) the Molibdenovy (Molybdenite) zone in the upper portion of the massif (144, pp. 84–85; 145). Wolframite occurs in the upper part of the massif in all zones, predominantly in north-trending quartz veins that are 10 centimeters–1.5 meters thick, and 10–100 meters long. There are approximately 50 such mineralized veins. More than 80 minerals have been identified at the Karaoba deposit (139, p. 64). In addition to wolframite, there are also bismuthinite, cassiterite and molybdenite. The gangue minerals are albite, calcite, feldspar, fluorite, muscovite, quartz, siderite, and topaz. The content of wolframite and bismuthinite is lower in the thicker veins, while the molybdenite content is higher.

Mining.—The Karaoba polymetallic deposit was discovered in 1946, investigated in more detail in 1957, and underground mining of tungsten may have started in 1975 (16; 32; 57, p. 68; 144, p. 84). Karaoba was earlier mined as a placer deposit. Mining is reportedly by shrinkage stoping method.

Beneficiation.—The ore at Karaoba is beneficiated by the flotation method. The concentrates are shipped most likely by rail south to the Chirchik plant in Uzbekistan or north to the Chelyabinsk plant in the Urals. Concentrate production is estimated to be 110 metric tons per year.

Koktenkol Deposit

This molybdenite-wolframite greisen stockwork is part of the Hercynian faulted ranges and the Akchatau granites in Kazakhstan. The mineralization is in a north-northwest trending tectonic zone, which in the southern part intersects with another east-west trending zone. The deposit lies partly in a Devonian metamorphosed volcanic sequence, in proximity to the granites. The mineralization along the flanks of the deposit extends to 900 meters deep. The mineralization is primarily molybdenum, with accompanying bismuth, copper and tungsten, concentrated in quartz and quartz-feldspar veinlets, which are from 1 millimeter–15 centimeters thick. The veinlets dip at 5–10° in the southern region of the deposit and are almost vertical in the north. The highest molybdenite content is along the periphery of the granite, being 0.01–0.03% molybdenite. In the south, the deposit is cut by quartz veins containing molybdenite and wolframite, with a few huebnerite veins 0.5–1 meter thick.

The primary minerals are molybdenite, wolframite, some bismuthinite, huebnerite and pyrite. The gangue minerals are muscovite and quartz. Reserves of molybdenum were estimated at about 1,000 metric tons metal content in 1970's. Tungsten ore is reportedly concentrated at the Uspensky plant.

Kounrad Deposit

Kounrad and Vostochny (Eastern) Kounrad, in eastern Kazakhstan north of Lake Balkhash, are the largest known copper-molybdenum deposits of the Soviet Union. Traces of tungsten occur in granite greisen in quartz veins. The tungsten occurs mostly in Northern, Southern, and in "Vol'framovye Sopki" (Tungsten Hills) of Vostochny Kounrad. Tungsten was discovered here in 1935, but there is no indication of any sizeable mining (146, p. 113).

The production of molybdenum at Kounrad began in 1941, and the ore was sent to the Balkhash beneficiation plant. The polymetallic copper and molybdenum-bearing ore also contains bismuthinite, cassiterite, chalcopyrite, galena, huebnerite, magnetite, scheelite, sphalerite, and wolframite. In 1972 the Vostochny Kounrad mine, in addition to molybdenum ore, reportedly supplied tungsten and bismuth ore to the Balkhash plant (57, p. 69).

Uspensky Beneficiation Plant

This plant, located at Uspensky, about 135 kilometers south of Karaganda, processes copper, molybdenum and tungsten ores from the Koktenkol and Baynazar deposits and the surrounding regions of Kazakhstan. The plant also treats some tungsten-containing ore for the Balkhash mining complex.

Verkhne-Kayrakty Deposit

The Verkhne-Kayrakty (or Kayraktin) deposit is located about 135 kilometers south of Karaganda and is part of the Akchatau ore field. The main ore body strikes in an east-west direction, with a south-southeast dip. The predominant minerals of the deposit are scheelite, wolframite, pyrite, and molybdenite. The wolframite content decreases with depth, while the molybdenite content increases. Scheelite is the predominant tungsten ore mineral. Quartz and feldspar are the gangue minerals.

The deposit was discovered in 1945. Reportedly the reserves are very large, but the wolframite and molybdenite content of the ore is low.

Mining.—Primary source literature does not describe the mining and beneficiation operations at Verkhne-Kayrakty. Most likely it is underground and began some time before 1978. Reportedly, work began in 1983 on a new Kayrakty mining and metallurgical complex, which was based on renovation of the Verkhne-Kayrakty mining facility; the concentration plant had already supposedly been completely renovated (91).

Beneficiation.—Figure 9 illustrates the presumed concentration process at Verkhne-Kayrakty, which is complex due to the polymetallic nature of the ore (51). Annual production of the tungsten concentrate is estimated to be 188 metric tons.

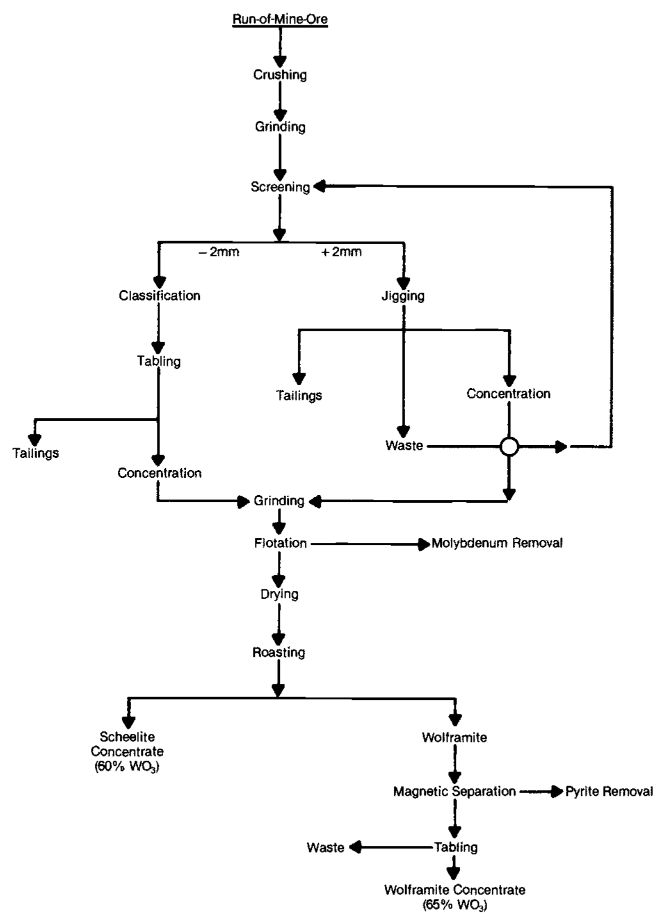

Figure 9. Flowchart of the Verkhne-Kayrakty Beneficiation Plant.

East Kazakhstan

About 70 tungsten mineralization localities were known in southeastern Kazakhstan by 1930, of which less than one-half were either mined or partially worked. It seems that at present none are in production.

Geologically, the Kalba-Narym region of southeastern Kazakhstan is a Hercynian orogenic block. The tungsten and rare-earth mineralization occurs in the Late Devonian-Permian granites. The tungsten/rare-earth mineralization is mostly of the greisen type, with the following mineralization suites: 1) cassiterite-huebnerite in biotite granites (at Kaindinskoe, Karashskoe, Komsomol'skoe, and Ubinskoe localities); 2) cassiterite-scheelite with tourmaline in basic granites (at Bulandinskoe, Kozlovskoe, and Leninskoe localities); and 3) at times just wolframite (at Bol'shevitskoe, Mokhnatudinskoe, Razdol'nenskoe, and Sebinskoe localities). Other ore localities in East Kazakhstan mentioned in Soviet literature are Cherdoyatskoe, Gremaychee, Malochernovinskoe, Palatsky and Tsentral'noe. Most of the ore bodies are aureoles of small, shallow vein systems. Some of the deeper veins are 800–2,500 meters long and several meters thick. Virtually no published information was found on these deposits.

South Kazakhstan

Boguty Deposit

The Boguty (or Bogutin) stockwork deposit is situated about 100 kilometers east of Alma-Ata, along the eastern offshoot of the Zailiysk Alatau Range.

The surrounding region consists of faulted Middle Ordovician sandstones and shales, which were intruded by granites of the Boguty massif. Scheelite and molybdenite occur at the southern edge of the granite massif, in quartz veins and fissures, which are contained in a zone more than 25 kilometers long. The richest stockwork is 1,600 meters long, from 20–30 meters thick in the southern part, and up to 200 meters thick in the north, making up the Boguty deposit. The highest concentration of mineralized fissures is at the granite-sandstone contact zone. Most of the quartz veinlets are from a few to 10 meters long, and 10–20 centimeters thick; only some are 15–200 meters long and 0.5–0.7 meters thick. In this sector, the veins and veinlets strike in a northerly-northeasterly direction, and dip to the northwest (62, p. 203).

The primary ore mineral in the veins is scheelite with some chalcopyrite, molybdenite, and wolframite. There are four mineralogically identifiable stages of scheelite formation (146, p. 153). The gangue minerals are chiefly muscovite and quartz with some feldspar, fluorite, potassium, and tourmaline. Bismuthinite, magnetite, gold, pyrrhotite, and topaz occur only rarely. Reserves of the Boguty deposit are estimated to be the fifth to sixth largest in the Soviet Union.

Mining and Beneficiation.—The Boguty scheelite placer was discovered in 1941 and was mined on-and-off until 1949. Wolframite was first found in 1943, but its significance was not established until 1969 (146, p. 148). The deposit was subsequently explored several times, the latest reportedly in 1971–74 (32). No reliable information is available on the mining of this deposit.

SOUTHWEST SIBERIA

The area northeast of Kazakhstan and northwest of Lake Baykal is referred to here as Southwest Siberia. The region includes the deposits of Gorny Altay, and the Kolyvan, Tuim, Dzhitsky and other tungsten deposits.

Gorny Altay

First indications of the presence of tungsten in Gorny Altay, the southernmost area of Southwest Siberia, date to 1869, when it was discovered in Kolyvan (147). Five years earlier, an article was already written about tungsten occurrence in the Kolyvan copper mine (148). Nothing was done, however, until the end of 1930, when Gorny Altay began to be explored in more detail and when molybdenum was first found (149–152). In 1933, the Kolbin complex became operational. It treated ore from the Ubinsk deposit, which contained 0.60% WO_3 (153). Under the second 5-year plan, the Kolbin concentration plant was to produce 48 metric tons of 50% WO_3 tungsten concentrate in 1934. The Kok-Kul tungsten vein deposit in the area was explored in 1934, and promised to be one of the richest (12).

Geologically, Gorny Altay is similar to Central Kazakhstan, in that tungsten and tungsten-molybdenum mineralization occur mostly in granitic greisens of Hercynian age. Up to 70% of the known tungsten deposits in Altay occur in Cambrian anticlines, and the rest in Devonian synclines; the deposits are aligned along a northwestly trending fault zone.

According to some Soviet sources, the prospects of finding new sizeable deposits in Gorny Altay are poor. Others feel that Gorny Altay has a tungsten potential that may be compared to the Kolyma Region in southeastern Magadan and to East Transbaikal. As yet unknown in Gorny Altay, for example, is the extent of the skarn tungsten deposits, and of the scheelite-bearing stockworks (4, p. 125).

The tungsten mineralization prognosis map in figure 10 shows that potential tungsten zones coincide with the location of Late Paleozoic granites. The distribution of faults, the density of dikes, the occurrence of tungsten-bearing igneous rocks were used by Soviet geologists in the construction of the map. Forty geologic maps were used in the compilation of the map, subdivided into 640 sections. Of those, 170 tungsten deposits and mineralizations

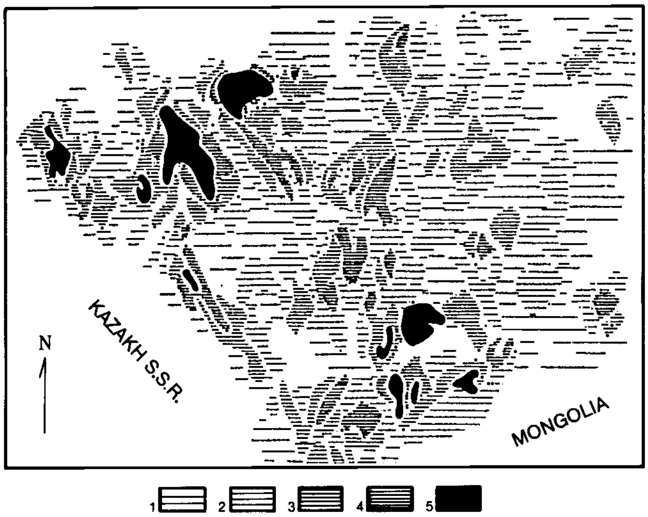

Figure 10. Tungsten Mineralization Prognosis Map for Gorny Altay.

were concentrated in 80 sections, The Belokurikhinsk, Bugusunsk, Kalguta, Sinyushinsk, and the Talisk granitic massifs are the most promising tungsten-bearing localities (4, pp. 126–127; 154–156).

Kolyvan Deposit

The Kolyvan deposit is the best known and perhaps the largest in Gorny Altay. The ore from the deposit was worked and processed during World War II, but tungsten mining is most likely at a low level now. The WO_3 content of the ore ranged from 0.2–1.2% (57, p. 82). According to some sources, the occurrence of wolframite in Kolyvan was first described in the Imperial Russian literature (155, p. 7). Exploratory work for wolframite began in 1930. In 1933, the deposit grade of wolframite was reevaluated from 0.40% WO_3 to 0.60%–0.70% WO_3. More attention was given to it also because of its proximity to another promising deposit, the Beloretsk (11). In addition to tungsten, the ore also contains copper and molybdenum. Kolyvan was a significant copper-mining district already in 1894. The plant reportedly has been treating some non-tungsten ores also from the West Transbaikal region since 1916, and may still be operating.

Tuim Deposit

The deposit is located in the north of the Khakass Autonomous Republic of Southwest Siberia, southern Krasnoyarsk region to the northeast of Gorny Altay. The ore is composed mostly of chalcopyrite, molybdenite, pyrite, and some magnetite. The Tuim mine started production of tungsten ore from the Kiyalych-Uzen'sk deposit with low efficiency in 1956 (157). The beneficiation plant processes wolframite-molybdenite and some magnetite ore from the Tuim and Kiyalych-Uzen'sk deposits. The plant also treats copper and molybdenum ores. No information was found on either the deposits or the mining activity.

The Novosibirsk tin plant west of Tuim, reportedly produces tungsten concentrate as a byproduct (40).

Dzhetsky Deposit

The deposit is located in the Vostochny (East) Sayan Range, northeast of Tuim. Exploratory drilling has indicated the presence of molybdenite-wolframite mineralization in an Early Paleozoic granitic stockwork at Dzhetsky, southern Krasnoyarsk region. The predominant mineralization in this region and in West Sayan, the Tuva A.S.S.R., is however, molybdenum with some copper, without much tungsten. No other information is available on the deposit or its mining.

TRANSBAIKAL

The Transbaikal region of southern Siberia may be divided into West Transbaikal (Buryat A.S.S.R.) and East Transbaikal (Chita Oblast') regions. The Transbaikal also encompasses the Okhotsk-Mongolia area to the south. Tungsten deposits of Transbaikal and their major economic types have been amply described in literature (71; 158–160). Most of the tungsten deposits are associated with greisenized granites of the Gudzhir (West Transbaikal) and Kukulbei-Kharalgin (East Transbaikal) ore complexes. In Transbaikal, molybdenum-tungsten and tin-tungsten deposits make up the two major mineralization suites. The Dzhida and Bom-Gorkhon deposits are representative of the molybdenum-tungsten type, while deposits in the Kukulbei-Kharalgin granites (Bukuka, Belukha, Dedovogorsk, Sherlovogorsk, deposits, etc.) are representative of the tin-tungsten types (161).

Transbaikal for long has been considered one of the largest tungsten-bearing regions of the Soviet Union, although in the 1970's its share of production has decreased significantly. Transbaikal was already known during the Imperial Russian time as one of the richest regions for tungsten metals, but their exploration was slow because of lack of mechanized equipment (11, p. 5). Whatever was accessible from the surface and placers was mined at first and only a few underground mines began to be developed in the early 1970's. Intensified exploration and exploitation of deeper deposits may make this region once again an important tungsten producer (71). Reportedly, about 900 tungsten deposits and mineralization occurrences were known here in 1975 (57, p. 82).

West Transbaikal

Although there are many tungsten deposits in West Transbaikal, located mostly in the Sayan-Baykal ore belt, only a few apparently are of economic significance. The more important deposits are part of the so-called West Transbaikal Rare Metals Province. To this Province belong the tungsten deposits of Baybinsk, Bom-Gorkhon, Buluktay, Dzhida, and Gardinsk. The greisen tungsten vein deposits of Mesozoic age associated with the Gudzhir granite porphyry complex are also rich in bismuth, copper, molybdenum, tin and zinc (156).

Dzhida Deposits

The Dzhida (or Dzhidin; Dzhidinsk) deposit is located about 400 kilometers west of the city of Ulan-Ude in

Buryat A.S.S.R. The deposit is at the southeastern terminus of the East Sayan Mountains at the southern end of Lake Baykal, close to the Mongolian border. It is the largest known molybdenum-tungsten deposit in Transbaikal and third largest in the Soviet Union. In 1929, huebnerite was discovered in quartz pebbles here. At the mouth of the Gudzhir River; in 1932, the Gudzhir and Inkura deposits were investigated further (162, pp. 3–14). In the same area, the Bom-Gorkhon deposit began to be worked in 1971. Probably there are a number of other smaller deposits being exploited in the area. Tungsten mineralization of economic signficance may occur, for example, in the Kurbino-Eravninsky ore belt, just north of Ulan-Ude.

The Dzhida deposit includes a number of smaller tungsten and molybdenum vein and stockwork ore bodies that appear to be genetically related (59, p. 28; 62, p. 210; 107, p. 659; 144, p. 52; 163; 164). The Dzhida deposit consists of 3 smaller deposits; 1) the Pervomaysk molybdenum stockwork; 2) the Inkura tungsten stockwork; and 3) the Kholtoson tungsten vein deposit (Figure 11) (57, pp. 83–84; 144, p. 54). The paragenesis of the deposit is supposedly similar to the Karaoba deposit of Central Kazakhstan. Mineralization at 400–450 meter depth is in granites and granite porphyries, located at the intersection of the northwest-southwest fault and dike zones.

The Inkura greisen deposit contains numerous quartz-sulfide-huebnerite veins. Most of the major veins to the southeast of the Inkura stock are located along a major fault, extending to the west-southwest and collectively are known as the Kholtoson tungsten deposit. Veins of this type also occur in the Pervomoysk molybdenum stock to

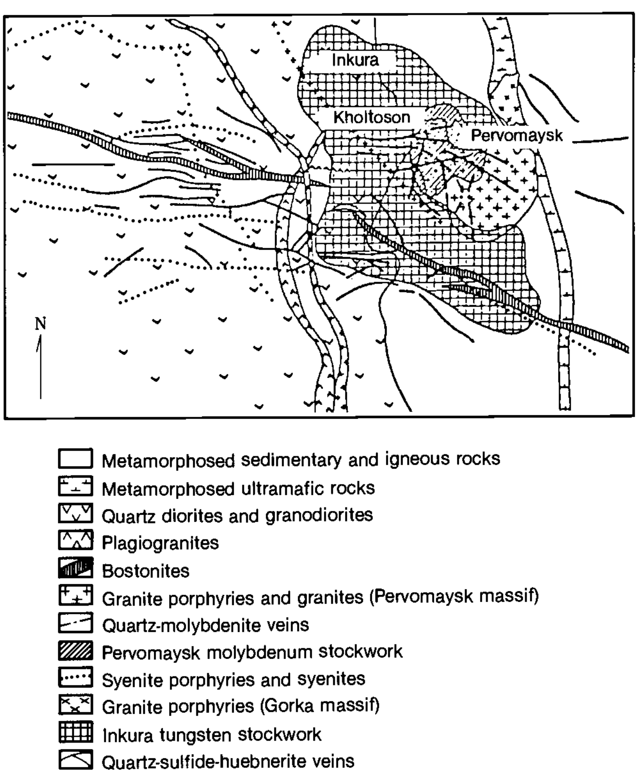

Figure 11. Schematic Geological Map of the Dzhida Ore Field.

the east. The more mineralized western part of the Peromaysk stock is made up of thin, randomly oriented veinlets, steeply dipping to the south, containing feldspar, muscovite, quartz, and sulfides. Essentially all of these veinlets contain huebnerite and scheelite which occur in the intensely fractured zone. Of these veinlets, about one-half are less than 0.5 centimeters, 40% are from 0.5–5 centimeters, and 10% are more than 5 centimeters thick. Tungsten and molybdenum concentration is highest in the uppermost Pervomaysk granite prophyry (62, p. 21; 165).

A new molybdenum-tungsten deposit of economic significance was reportedly discovered recently south of Dzhida. The mineralization in the stockwork is up to 100 meters deep, and the ore is mostly molybdenite with lesser amounts of scheelite.

Mining.—The Dzhida mining complex is located on the righ (south) bank of the Dzhida River, just east of the city of Zakamensk, along the Transsiberian railroad, and about 250 kilometers south of the city of Irkutsk. Mining is on the northern slope of the Dzhidinsk Range. The first stage of the tungsten-molybdenum mining complex became operational in 1941 (114). A new open pit was reportedly put into operation in January of 1973 (166). The mines are located in the leucogranites and granitic prophyries of the Pervomaysk and the Inkura stocks (107, p. 658).

The Dzhida huebnerite placer deposit was mined in 1935 and was an important producer during World War II, but was depleted largely by the mid-1950's (97, pp. 11–13). There are also other small tungsten placer deposits in the area, which were worked in the late 1930's (162, p. 3; 167). They are: Gudzhir, Inkura, Malo-Kholtoson, and others. They also were important producers during World War II, but are now inactive.

Beneficiation.—The ore from the Dzhida deposit is concentrated at the Zakamensk plant. Zakamensk city was founded in 1938, and was known as Gorodok until 1959. Dzhida is the largest mining and processing facility of tungsten and molybdenum in Transbaikal and third largest in the Soviet Union. The plant processes tungsten ore from the Kholtoson mine and molybdenum-tungsten ore from the Inkura mine (168). A small coal-fired power station at Bayangol to the north supplies electricity to the mining and beneficiation complexes (117, p. 262). The plant also produces intermediate products and most likely produces bismuth as a byproduct (121, p. 110). From 1964 to 1969, the Dzhida tungsten and molybdenum complex, reportedly, increased production of tungsten concentrate on the average of 2% per year (2). The tungsten concentrate from the Dzhida field is mostly huebnerite. The ore is concentrated by gravity and flotation. The concentrates are most likely trucked to Ulan-Ude and from there are shipped by rail to an ammonium paratungstate plant for chemical upgrading.

Inkura Deposit

This Inkura deposit, is a tungsten-bearing stockwork borders with the Pervomaysk molybdenum deposit just east of Dzhida. In the south, the deposit is terminated by a fault, which contains the richest tungsten-bearing veins of the Kholtoson deposit. The ore pinches out to the north. The surface dimension of the Inkura deposit is about 1 square kilometer. The Inkura deposit is a network of steeply dipping quartz-feldspar-muscovite, feldspar, and quartz-sulfide veins, containing huebnerite and some scheelite. Where the enclosing rocks are schists and hornfelses, the veins are filled with feldspar and carbonates;

where the containing rocks are granite porphyry dikes, the veins are filled with quartz and huebnerite, without feldspar. Tungsten mineralization seems to be confined to the concentric or radial veins in the massif. In the center of the stock most of the veins strike more or less east-west and dip 70–85° south. These veins are contained in a band which is 40–50 meters wide at a great depth below the surface; they are shallower and are better defined in the northern and southern parts of the stockwork. The best grade ores in the northern and southern sectors of the Inkura stockwork are in bands that change little in grade both in plan and in section; mineable ore has been encountered in drilling at depths of 450–600 meters. At depth, however, huebnerite has been replaced by scheelite (62, pp. 211–212; 107, pp. 659–660). The commercial grade of the Inkura tungsten ore is reportedly only 0.145%–0.157% of WO_3 (161).

Placers cover the surface of the Inkura stockwork and may contain commercial amounts of huebnerite (107, p. 660).

Mining.—The region's ore belt was known prior to World War II, but the Inkura deposit itself was known to exist at the end of the 1940's and the beginning of the 1950's, from detailed drillings (144, p. 60). The Inkura surface mine has been producing molybdenum-tungsten ore since 1973, and was expanded in 1975. The mine supplies ore to the Zakamensk beneficiation plant (57 p. 33; 61; 169).

Kholtoson Deposit

This Kholtoson deposit, is a tungsten-bearing vein deposit is part of the Dzhida ore field, and consists of numerous quartz-sulfide-huebnerite veins in quartz diorites. Some of the veins also extend to the eastern part of the ore field, into the Pervomaysk granite porphyries and schists (144, p. 67). The most significant concentration of the ore is along the northwesterly-southeasterly trending fault, in which the mineralized veins may be traced for up to 2.5 kilometers; the vein field is about 1 kilometer wide. There are over 140 known mineralized veins, 70 of which are reportedly of economic significance. These quartz-huebnerite veins have an east-west trend and have a dip of 30–50° to the south; locally these dips may be as much as 55–85°. The northwesterly and northeasterly striking veins are of little economic significance. Most of the veins average 0.8 meters thick, but some are 2–12 meters thick. Some of the veins also contain small quantities of scheelite. The richest tungsten-bearing veins extend to a depth of more than 200 meters. The quartz-sulfide-huebnerite veins are of greatest economic significance and also contain chalcopyrite, galena, and sphalerite. The primary ore minerals of the deposit are aikinite, cassiterite, chalcopyrite, galena, huebnerite, scheelite, sphalerite, and tetrahedrite. The gangue minerals are fluorite, gilbergite, microcline, quartz, and sericite, with some triphylite and ankerite. Huebnerite in the Kholtoson deposit occurs irregularly, either in sporadic accumulations or in pockets. In veins, huebnerite is at times replaced by scheelite, and at times by tungstite (WO_3 H_2O). The contents of huebnerite in ore ranges from 0.01–10% WO_3, averaging about 1%, with the highest content occurring in thicker veins (62, p. 212; p 107, p. 660; 144, p. 67).

Mining of tungsten ore may have started at Kholtoson in 1930. The deposit was under development and could have been worked underground since the 1960's (144 p. 60).

Pervomaysk Deposit

This West Transbaikal Pervomaysk greisen stockwork is a small body of granite located on the eastern flank of the Dzhida orefield. The quartz-molybdenite veins appear to be similar to those of Climax, United States, and are steeply dipping, thin, randomly oriented, and filled mostly with quartz and molybdenite, with some wolframite (107, p. 662; 144, p. 60.) Information is not available on tungsten mining at Pervomaysk.

Bom-Gorkhon Deposit

The Bom-Gorkhon granodiorite massif is located in Chita Oblast' in West Transbaikal along the right bank of the Khilok River, the western terminus of the Chegan-Khureysky Range. The massif extends for about 20 kilometers in a northeasterly direction, is 7–8 kilometers wide, and is located at the intersection of the northeast and northwest faults. The following smaller deposits are identified within the periphery of Bom-Gorkhon: 1) the Dokhe-Khalyartinsky molybdenum mineralization; 2) the Klyuchevsky huebnerite-molybdenite-rare earth metals stockwork, within a biotitic garnite greisen; and 3) the Bom-Gorkhon tungsten deposit of huebnerite-rich quartz-sulfide veins, within a porphyritic biotite granite. The huebnerite-rich quartz veins of the Bom-Gorkhon granite are made of two ore bodies: 1) the northeasterly trending veins, with 15–25° dips to the southeast; and 2) the northwesterly trending veins dipping to the northeast. The largest veins extend up to 800 meters deep, are 0.1–3 meters thick, and are complex in structure. The primary ore minerals are cosalite, huebnerite, molybdenite, scheelite, sphalerite, and some chalcopyrite and hematite; cassiterite occurs only rarely. The gangue minerals include fluorspar, quartz, at times apatite, microcline, and triplite. Huebnerite is distributed unevenly in the veins, and is concentrated at the intersection of faults (62, pp. 206–209).

Mining.—According to some sources, the Bom-Gorkhon deposit has been worked as a surface mine since 1971. The pit is generally described as about 100 meters deep, and 2 kilometers long, but some pits have been described as being 500 meters deep (57, p. 88). Other sources indicate that there is also underground mining.

Beneficiation.—The Bom-Gorkhon plant is the second largest in Transbaikal, after Dzhida. The run-of-mine ore is crushed and ground, separated by gravity and flotation, producing huebnerite concentrate. The mining complex is located close to the Transsiberian Railway and the concentrate is most likely shipped to various Soviet tungsten plants for chemical upgrading to APT.

East Transbaikal

Until 1968, East Transbaikal (mostly Chita Oblast') was an important tungsten producer, but the production has been rapidly declining since then. The tungsten reserves are concentrated mostly in skarns, with some in placers. The following tin-tungsten mineralization districts are known in East Transbaikal (from west to east): 1) Chikoy (Shumilovka deposit, and others); 2) South Daursky (Khapcheranga, Sokhonddo, and others); 3) Aginsky (Uronaysky, and others); 4) Durulguevsky and others); and 5) Kukulbeysk, (Antonovogorsk, Belukha, Shakhtama, Sherlovogorsk). Of those, the Chikoy, Aginsky and Kukulbeysk are economically the most significant tungsten producing districts in East Transbaikal. Reportedly, there are at least 118 tungsten mineralized localities in the Chita Oblast', classified into the following types and number of each: cassiterite-wolframite quartz veins, 84; greisen, 20; scheelite skarn, 13; wolframite-cassiterite-sulfide mineralization, 1. The polymetallic ore belt of eastern East Transbaikal contains also vein deposits of as yet unknown economic significance, belonging to the polymetallic mercury-antimony-tungsten mineral suite, such as Barun-Shiveya and Novo-Kazachinsk deposits (57, pp. 89–90; 170–171).

Chikoy Ore District

The Chikoy district in southwestern Chita Oblast' contains at least three known tungsten ore fields: 1) Shumilovsko-Gornachikhsky: 2) Krestovsko-Senkinsky; and 3) Verkhne-Chikoy. No specific information is available on mining in this area.

Studenchesky Deposit

The Studenchesky deposit is the largest of the Shumilovsko-Gornachikhsky ore field in the Chikoy district of East Transbaikal. Wolframite occurs in quartz veins and greisen bodies, which are up to 290 meters long, 0.7–5 meters thick, with an average WO_3 content of 0.2%. A quartz-greisen stockwork nearby, 500 by 300 meters in area, also contains wolframite and cassiterite in granite (57, p. 91).

Verkhne-Chikoy Deposit

The Verkhne-Chikoy deposit is made up of quartz-wolframite veins and wolframite-rich greisen bodies, containing the following smaller deposits: 1) Burkalsky; 2) Gremuchinsky, a greisen 10 to 55 meters thick; and 3) Budunsky deposit (57, p. 91). The deposit was most likely never mined.

South-Daursky Ore District

At least three tin-tungsten ore fields are known: 1) Verkhne-Ingodinsky; 2) Sokhondo-Bukuka; and 3) Bylyrinsky. Tungsten mineralization of about 0.1% WO_3 content is part of the polymetallic sulfide-cassiterite mineralization suite, but is of secondary importance. The Levo-Ingodinsky greisen deposit, for example, is almost 2.5 kilometers long, with up to 0.7% Sn and 0.1% WO_3 metal content. The Ugdyrinsky cassiterite-wolframite-cobalt-nickel deposits consist of ore bodies from 5–10 meters thick and up to 500 meters long, with 0.1–1% WO_3 content. The deposits were discovered in 1968 (57, p. 91).

The tin-tungsten deposits of Sokhondo and Khapcheranga are also part of this ore district. The Sokhondo deposit was worked in the 1930's and 1940's, but is essentially inactive at present. The Khapcheranga complex now primarily produces and processes tin ore, but the plant also treats some tungsten ore (57, p. 91).

Aginsky Deposit

Large tungsten deposits in East Transbaikal are found in the Aginsky ore district. The wolframite occurs in granitic greisens and in wolframite-rich quartz veins, close to the surface of a muscovite-granite stock. The primary mineral suite is composed of wolframite, columbite-tantalite, and rare-earth minerals. Mining was reportedly expanded here in 1966–70, including the construction of another ore-processing plant. Tantalum has also been reproduced as a byproduct since 1965 (117, p. 267). Some of the ore from the Orlovsk (or Orlov; Orlovsky) mine nearby may also be processed at the Aginsky beneficiation plant (57, p. 92). In 1983, tungsten concentrate production was reported from the opening of the second stage of the Orlovsk complex in Chita Oblast' (172).

The Uronaysky ore field in the same area reportedly has 29 tungsten-bearing deposits, mostly of the greisen-skarn type, including the Chargurtuy and Balakskoe deposits (57, p. 92).

Durulguevsky Ore District

The ore district is of greisen stockwork type, criss-crossed by thick wolframite-bearing quartz veins, whose WO_3 content is from 0.2–0.4%. In the district, the Medzheginsky I deposit is the largest, consisting of two wolframite-bearing stocks, up to 50 meters in width. At least 10 quartz veins with wolframite mineralization are known, containing up to 2.8% WO_3 and 5.8% Sn. The Medzheginsky II wolframite-cassiterite deposit nearby contains up to 3.2% WO_3 and 1.6% Sn. Probably neither of the two deposits is presently mined. The tin-tungsten ore of the Dedovogorsk (or Dedova Gora) deposit, also in the same district, has been mined on and off since the 1930's and 1940's. A beneficiation plant at Dedovogorsk was reportedly opened in the 1970's (57, p. 92).

Spokoyny Deposit

The deposit is located about 50 kilometers southeast of the city of Chita, in East Transbaikal. Tungsten occurs in greisens mostly at the roof of moscovite granite massif. Wolframite occurs in quartz veins with mica, forming complex intergrowths with the latter. The veins generally are 1–30 meters thick, but at least one 90 meters thick has been reported; but all veins extend only to a 20-meter depth, and all are considered small. Wolframite occurs also in fine segregations and small concentrations, often giving a streaky appearance to the greisen. Fluorite, muscovite, quartz and wolframite are the principal minerals; minor minerals are apatite, bismuthinite, cassiterite, chalcopyrite, pyrrhotite, scheelite, sphalerite, tourmaline and zircon (62, p. 197–199).

Mining.—The Spokoyny mine in located not far from other working mines, and by some accounts it was operating until the 1970's (57, p. 89). Others consider Spokoyny a prospect only, which is being developed.

Kukulbeysk Ore District

The district is situated north-northeast of Khadabulak, about 90 kilometers to the northwest of the China-Mongolia-U.S.S.R. borders. The district contains the Antonovogorsk, Belukha, Bukuka, Kolanguy, Sherlovogorsk, and other deposits. The mine and beneficiation plant at Sherlovogorsk (or Sherlovaya Gora) was in operation in the 1930's and is most likely still open today. The plant processed mostly tin-bearing ore, but may also be producing some wolframite. In 1915, the average WO_3 content of the Sherlovogorsk deposit was 0.5% (173).

Transbaikal Tungsten Mining Complex

The Transbaikal Tungsten Mining Complex began operation in the 1930's at Khadabulak, in the south of the Chita Oblast' in East Transbaikal. The beneficiation plants probably still treat tungsten ore from the Kukulbeysk ore district. The following beneficiation plants are administratively part of the complex: Antonovogorsk, Belukha, Bukuka, Dedovogorsk, Kunalev, and Zun-Undura (57, p. 90).

Antonovogorsk Deposit

The Antonovogorsk (or Antonova Gora) deposit is located on the southern flank of the Unda Valley, in southeastern Chita Oblast'. The greisen tungsten deposit is in a small, fine-grained granitic body, and part of the Kukulbeysk massif. Wolframite occurs in a series of parallel quartz veins, cutting the granite in a northeasterly-southwesterly direction. The thickest veins in granite are from 800–1,000 meters long, on the average 0.6–0.7 meters thick, and 60 meters deep. The veins form bands in the upper portions of the granite and are complex in structure. Wolframite is the primary ore mineral, but is distributed sporadically. Secondary minerals include bismuthinite, chalcopyrite, galena, molybdenite, scheelite and sphalerite. Cassiterite occurs only rarely (62, p. 205). Small wolframite placers have also been reported in the area.

Mining.—The mine and beneficiation plant were operational at an increased rate in the 1930's and 1940's, but at a reduced rate in the 1970's (57, p. 93). The concentrate is most likely shipped by rail via the Kharanor Station and the Transsiberian railway to the West for further processing.

Bukuka Deposit

The deposit is located about 180 kilometers southeast of the city of Chita and 100 kilometers from the Chinese border of Chita Oblast'. The deposit is controlled by an east-west trending fault cutting through an Upper Jurassic sedimentary sequence. It is a polymetallic greisen deposit composed of molybdenite-wolframite and huebnerite-sulfide mineralization (4, p. 33). There are three separate ore bodies within the deposit; two groups of at least 80 quartz-vein types, and a third consisting of 2 stockworks. Veins are of complex mineralogical composition, the principal minerals being bismuthinite, chalcopyrite, galena, pyrite, sphalerite, and wolframite with little molybdenite. Calcite, fluorspar, muscovite, quartz, topaz, and some apatite are the principal gangue minerals. In all, there are over 60 ore and gangue minerals in the tungsten-bearing veins (57, pp. 216–219). The average WO_3 content of the Bukuka deposit was 0.3–0.5% in 1915 (173).

Mining.—The Bukuka mine and beneficiation plant are located east of the Olovyannay Railway station. It is assumed that Bukuka is a working underground mine, which could have started production in 1920–30. Some sources state that it was discovered prior to World War I and was intermittently mined until its closure in 1959 (144, p. 12). Others speculate the mine is still operational today.

Beneficiation.—The Bukuka plant was, reportedly, operational in the 1930's, but others state it was operational only in the 1970's (57, p. 93). The ore was most likely beneficiated by a gravity and flotation process, the sulfides stockpiled, and the concentrate upgraded into various products.

Belukha Deposit

The Belukha (or Belukhinsk) deposit is part of the Kukulbeysk ore district, located in the Chita Oblast' of Eastern Transbaikal. The deposit is crisscrossed by quartz veins, and wolframite mineralization occurs in northwesterly trending veins. The ore zone encompasses about 100 veins, and is 250 meters long, 0.5 meters thick and 250 meters deep.

Mining.—Mining at Belukha started in the 1920's with periods of more intensified production in the 1940's and again in the 1970's (57, p. 95). All mining was underground.

Beneficiation.—The Belukha plant is situated east of the Olovyannaya Railway station. The beneficiation process at Belukha is essentially the same as at the Bukuka plant. Belukha reportedly also processes bismuthinite and wolframite ores from other mines of the Kukulbeysk ore district. Some scheelite may also be recovered.

Polymetallic, Placer and Other Deposits

Other smaller tungsten-bearing localities in East Transbaikal, some of which contain up to 1.2% WO_3 are: Arbuy, Izybrinoe, Khaltuyskoe, Khurbulskoe, and Ochekanskoe. At Levo-Amudzhikansk and Malo-Kudechinsk of the Mogocha area, the WO_3 content ranges from 0.1–3.9% WO_3, as sampled from rock debris. There are also several placer deposits, containing from 1–1.2% WO_3, the largest being at Ingaritinsk (57, p. 95).

Small occurrences of tungsten are also known between the Gazimur and the Argun rivers, close to the Chinese border, in southeastern Chita. The area is not well known and was first surveyed systematically for minerals only in 1971. All of the tungsten mineralization is confined to skarns and quartz veins, as at Nortuysk, where veins contain up to 3% WO_3. The veins are reportedly 300–500 meters long, and 1–2.5 meters thick extending up to a depth of 200 meters. The Verkhne-Ushmunsk and Monokansk deposits are also of local significance. The more important scheelite-bearing skarn deposits are Ostrinsk, consisting of a zone 100 by 400 meters, and Arbukansk, 250 by 700 meters in area extent (57, p. 95).

The polymetallic mercury-antimony-tungsten skarn deposits as yet are not well known in the U.S.S.R. In East Transbaikal such mineralization localities occur at Barun-Shiveya, Dondor, Novo-Ivanovsk, and Novo-Kazachinsk. The first two are characterized by their high ferberite content, and Novo-Kazachinsk contains both ferberite and scheelite. The WO_3 content in those deposits is between 0.33–1.84%. The deposits occur in a strongly faulted area and were formed in the Late Mesozoic Period. Geologically, they are the youngest such deposits in the region (57, p. 95).

Barun-Shiveya Deposit

The Barun-Shiveya deposit is one of the largest polymetallic mercury-antimony- tungsten deposits, located in a highly faulted zone on the southern slope of the Mogoytuy Range, between the cities of Aginsky and Mogoytuy of East Transbaikal. The skarn deposit occurs in an Lower Paleozoic quartz-sericite-schist sequence, at the intersection of several large fault zones, the mineralized quartzitic horizons being at times from 30–90 meters thick. The richest mineralization is concentrated in lenses, but also occurs in breccias of the faulted zones. Banded structures also occur occasionally and are the result of alteration of ferberite and antimonite ores. Such bands are usually less than 3–4 centimeters thick. In the vicinity of Rudnay Gora, the mineralized zone is 1,700 meters long and up to 200 meters in depth (62, pp. 220–222).

The primary ore minerals of the Barun-Shiveya deposit are antimonite (stibnite), cinnabar, and ferberite. Small quantities of arsenopyrite, chalcopyrite, pyrite, siderite, and sphalerite are also present. Quartz is the most abundant gangue mineral. The ferberite mineralization phase, in the Barun-Shiveya deposit is later (younger) than the antimonite phase and earlier (older) than the principal phase of cinnabar deposition. In this respect this deposit differs from other deposits of similar mineral composition in Caucasus, Bolivia, and the U.S.A., where tungsten mineralization appears earlier than the stibnite phase, and only rarely in the same phase (62, p. 222).

The mining of the Barun-Shiveya deposit started in the late 1960's (57, p. 96). It is uncertain whether the ore is processed at the same facility or is shipped elsewhere.

The polymetallic molybdenum and copper-molybdenum formations of East Transbaikal are a significant source of Soviet molybdenum production. Scheelite and wolframite also occur in those zones, but in small quantities. Scheelite, for example, occurs with molybdenite in the Shakhtama deposit, while both scheelite and wolframite occur as secondary minerals in the Bugdaya (or Bugdainsk) deposit. The Bugdaya is reportedly the largest polymetallic stockwork deposit of Mesozoic age in the U.S.S.R., but is of little economic significance because of the widely disseminated occurrence of the mineral concentrations (57, pp. 97–98).

The gold-molybdenum polymetallic mineralization of East Transbaikal, in addition to significant occurrences of molybdenite, also contains traces of scheelite, such as in the Davenda deposit. There are no indications, however, that any tungsten is produced. The molybdenum and molybdenum-tungsten polymetallic mineralization is localized in the Stanovoy Ranges of northeastern Chita Oblast'. In addition to molybdenite, the formation also contains small quantities of wolframite, as in the Daurkachan deposit (57, p. 101). No mining of tungsten is known in this area.

PRIMOR'YE TERRITORY

The Primor'ye Territory (or Primorsky Kray; the Maritime Territory), is located in the extreme southeastern corner of the Soviet Union. The Territory is a new but significant contributor to the tungsten industry of the country. Economically, quartz-scheelite and the scheelite-sulfide skarns are the most important ones in Primor'ye (174, p. 5). The Territory encompasses the Western, Central and Eastern tungsten-bearing ore belts; of which the Western ore belt is the richest. The skarn and greisen deposits are concentrated along the West Sikhote Alin fracture zone, controlled by extensive northeasterly-southwesterly striking faults. The Central tungsten ore belt also is known to contain gold, mercury and rare earths mineralization. The Eastern ore belt, situated about 60 kilometers east of the Central Sikhote Alin lineament zone, contains some tungsten as part of the tin mineralization (175, p. 122).

In more detail, the following tungsten-bearing mineralization assemblages are distinguished in the Primor'ye region: 1) sulfide-scheelite skarns (Vostok-2 deposit), and scheelite-apatite greisen (Bikinsky deposit); 2) sulfide-scheelite greisens of insignificant economic importance (Kimorskoe, Khankayskoe, Il'morskoe; 3) quartz-wolframite/scheelite veins in granites with beryl (Chimchiguzskoe, Rudnoe); also with cassiterite and molybdenite of marginal economic importance (Zabytoe); 4) complex quartz-topaz-wolframite greisen mineralization with copper, lead, silver, tin, and zinc (Vershinnoe); 5) quartz-scheelite mineralization with gold (Anuchino, Negametninskoe, Sinegorsk), of no current economic significance. Other deposits mentioned in Soviet literature in this Territory include Armu-Imansky, Furmanovsky, Lermontov, Rudnoe and Yulinskoe (57, pp. 103, 105).

Vostok-2 Deposit

The deposit is situated on the western slope of the Sikhote Alin Mountains, about 375 kilometers northeast of the port of Vladivostok. The main deposit and mine are located about 200 kilometers east of the Transsiberian Railway. The Vostok-2 mine is close to a rail spur line which runs southeast to the port of Rudnaya Pristan' on the Sea of Japan. The deposit is the largest known in Primor'ye and the second largest in the U.S.S.R. (176). Most of the tungsten in the deposit is associated with quartz-sulfide-scheelite mineralization within the Sikhote Alin folded ranges. Mineralization is along a contact of a stock with Upper Permian limestones and hornfelses, consisting of quartz-scheelite and scheelite-sulfide segregations within the greisenized and skarnified rocks. The ores form compact, narrow bodies, traceable along the strike for more than 600 meters. The main orebody has a northeasterly strike and dips northwestward at 50° to 88°. The ore bodies, as a rule, are characterized by clear boundaries with the country rock. The thickness of the mineralized skarn zone is up to 120 meters. Individual mineralized veins are 5–15 meters thick, are from 150–800 meters long on the surface, and up to 650 meters in depth (4, p. 33; 62, p. 190).

Scheelite is the primary tungsten ore mineral. Scheelite forms isometric, irregular grains and idiomorphic crystals from 0.05–6 millimeters, and at times, up to 3 centimeters in size and larger. Molybdenum and copper at times occur in considerable quantities in the Vostok-2 deposit, together with rare earth elements. Wolframite occurs rarely. The primary ore minerals of the scheelite-sulfide ore are: arsenopyrite, chalcopyrite, pyrrhotite, scheelite, sphalerite and some precious metals; actinolite, apatite, pyroxenes and quartz are the dominant gangue minerals. The scheelite content is about 2% (3, p. 168; 57, p. 105; 62 p. 191; 174, pp. 132, 147–150).

The tungsten ore reserves of the Vostok-2 deposit are the second largest in the Soviet Union after Tyrny-Auz in Caucasus. In 1983 the in situ resources were estimated to be about 22,025,000 metric tons of tungsten ore at 0.58% WO_3. The ore grades vary from 0.14–1.0% WO_3, the mean taken at 0.58% WO_3 (50, p. 23).

Mining.—The Vostok-2 mine and beneficiation plant are the largest tungsten mining complex in Primor'ye and the second largest in the U.S.S.R. Mining is both on the surface and underground. The surface operation may have started in 1972 and closed in 1981, due to ore depletion. The underground operation may have started in 1982. The mining is most likely well mechanized and utilizes newer equipment, such as drills, load-haul dumpsters, etc. Blasthole, and cut-and-fill may be the predominant mining methods. The orebody consists of 3 veins, 10 meters thick, 475 meters long and 650 meters deep, and is reached via a mine shaft (51).

Beneficiation.—The ore from the Vostok-2 mine is processed at the Primorsky tungsten ore beneficiation plant, which by some accounts began to be constructed in 1967; in 1969, the first batch of rich ore was sent by helicopter for a trial beneficiation run. The start of a 5-year construction project was set first for 1971 and then for 1972, and was constantly delayed (95; 177–178). The first stage of the complex was commissioned in August of 1976 (179). The beneficiation plant may have reached its full capacity only in 1980 (180). Ore beneficiation is accomplished by conventional crushing and grinding, followed by removal of sulfides. Fine scheelite is recovered by further flotation as a low grade concentrate.

Rudnoe Deposit

The Rudnoe deposit is located south of Vostok-2 and is part of the Furmanovsky ore district. The stockwork consists of three separate ore bodies: Kamenistoe, Tsentralnoe and Zabytoe. The mineralization is in small fissures and veins, most of them about 1 centimeter thick, with a few up to 1 meter thick. The primary ore minerals are arsenopyrite cassiterite, ferberite, scheelite, and wolframite. The gangue minerals are calcite, biotite, muscovite, potassium feldspar, and quartz (56, p. 106). No definitive information is available on this deposit or any mining activity there.

Armu-Imansky Deposit

The deposit is located south of Vostok-2, in the northern part of the eastern orebelt of the Central Sikhote Alin fault zone. It is a small tin-tungsten deposit and reportedly a surface mine and an ore processing plant were started here in 1975 (57, p. 106). No further information is available on this deposit or plant.

Lermontov Deposit

The Lermontov (or Luchegorsk) tungsten deposit is located about 200 kilometers south of Khabarovsk, close to the Transbaikal Railway north of the Vostok-2 deposit.

Lermontov is a large and a complex polymetallic greisen-skarn deposit. Tungsten occurs primarily as scheelite in a granite stock, emplaced at the intersection of several major faults (175, p. 124).

The deposit was explored in 1972, and a surface mine may have started operation in 1974 (181). The deposit was explored again in 1976. The ore is most likely crushed in place and transported 25 kilometers south to the Primorsky complex for beneficiation.

Khabarovsk Region

The Khabarovsk region (Kray) is included in the Primor'ye Territory in this report because geographically it is situated just north of Primor'ye. In the upper Amur River area, wolframite and scheelite occur with tin (cassiterite) and gold. The best known tin-tungsten deposits of this Sikhote Alin fault zone are Bolsherechenskoe, Festivalnoe (or Festival'nyy), Solnechnoe (or Solnechnyy), and Uchaminskoe. In the lower Amur River area to the north, the following cassiterite-wolframite greisen deposits are: Ochensky-Dzhegdagskoe, Pokrovsko-Troitskoe, and Zimovinskoe (57, p. 107).

Soinechnoe and Festival'noe Deposits

The Solnechnoe and Festival'noe skarn tin-tungsten-lead-copper deposits are located in the Komsomolsk ore district of southern Khabarovsk. Although the Komsomolsk district was originally primarily known as a tin district, it is now considered as a polymetallic ore region, as most of the ores are now known to contain bismuth, cadmium, cobalt, indium, lead, silver, and zinc. The deposits are concentrated at the intersection of several regional faults (182).

Solnechnoe Deposit

The Solnechnoe deposit, of Khabarovsk region crops out along a deep river valley, and much of the ore is thought to have been removed by erosion. The deposit extends along the strike for about 8 kilometers, and its thickness ranges from a few to 115 centimeters, the depth of mineralized section is several hundred meters. Not all of the deposit is commercial, with horizons of altered and poorly mineralized rocks separating those of good ore grade. The deposit is thus composed of many separate ore bodies, some of which are overlain by younger basalts. In the mineralized zones, cassiterite occurs in quartz veins and veinlets. In addition, the veins also contain segregations of arsenopyrite, scheelite, and wolframite, but in smaller amounts than cassiterite. The content of copper, lead, silver and zinc is insignificant in the Solnechnoe deposit in contrast to the Komsomolsk ore bodies nearby (107, pp. 654–655).

The structure and shape of the Festival'noe ore bodies are quite complex. They are steeply dipping, linear deposits, complicated in both plan and section by bands, swells, pinch-outs and numerous separations. The complexity of the mineralization of the Festival'noe deposit resembles, reportedly, on a small scale, the Cornish tin deposits. In portions of the Festival'noe veins, the mineral composition is almost the same as in veins of the Solnechnoe deposit. In the quartz-cassiterite veins at Festival'noe, arsenopyrite is common, but wolframite and scheelite are rare. Sulfides, such as chalcopyrite, galena, pyrrhotite, sphalerite and stannite are also uncommon. The grade of the ore is 0.6% WO_3 (183).

The sulfide minerals at Festival'noe contain larger amounts of trace elements than do those at Solnechnoe. The primary minerals in the deposit are: arsenopyrite, cassiterite, chalcopyrite, magnetite, pyrite, pyrrhotite, scheelite, and wolframite. Secondary minerals are: boulangerite, bismuthinite, galena, loellingite, marcasite, sphalerite, and stannite. Rare minerals are: bournonite, cobaltite, gold, matildite, silver, stibnite, and teallite (107, pp. 655–657; 184).

Mining.—The Solnechnoe and Festival'noe mines are in the vicinity of the city of Komsomol'sk-na-Amure. From all indications, mining at present is by surface operations. Newly explored reserves of the Solnechnoe deposit were reported to be double the size of those being depleted (185).

Beneficiation.—Tungsten concentrate is processed here as a byproduct. The plant began to be built in 1957 for beneficiation of tin and became operational in 1963 (186–187). Between 1976–80, the Solnechnoe complex increased tungsten production 12%, and between 1976–81 it increased tungsten recovery in ore by 7.4% (185).

Umalta Deposit

The Bureinskiy Range of southwestern Khabarovsk has several sizeable molybdenum deposits, some of which contain tungsten. One of the larger tungsten-containing occurrences is the Umalta deposit, situated along the right bank of the Bureya River to the northwest of the Festivalnoe deposit. The mineralization zone in a biotite-granite is about 400–500 meters wide, trends in a north-northwesterly direction for about 4 kilometers, and is crosscut by veins. The northeast-trending mineralized veins were traced 200 to 230 meters below the surface, are 200–350 meters long, and on the average are 1 meter thick. The northwest-trending veins are shorter, 100 meters, and thinner, 50–60 centimeters. The primary ore minerals are molybdenite, with pyrrhotite and wolframite, and at times scheelite. Fluorspar, quartz, and sericite are the major gangue minerals. From 1936 to World War II, the deposit was the second largest producer of molybdenum in the U.S.S.R. (57, p. 108). The plant concentrated wolframite and scheelite only as a byproduct. No information is available on its current mining and beneficiation operations.

NORTHEAST SIBERIA

This geographical sector of the Soviet Union embraces the following vast regions: Yakutiya, Magadan Oblast', Chukotka, and Kamchatka. All are well known tin-tungsten provinces, and since 1977 became also known for molybdenum and copper-molybdenum occurences. Tungsten minerals in this area occur mostly in the molybdenum and tin ores, and are produced as a byproduct. An exception is the Iul'tin mining and beneficiation complex, the only significant tungsten-producing facility in Magadan. In addition to the tungsten deposits mentioned in this section, minor quantities of tungsten occur in association with molybdenum in a number of other deposits in Northeast Siberia. For example, wolframite in tourmaline-quartz veins occurs at Tugchaksk in the Ulakhan-Sissky granodiorite, at Takylkansk of Polousny region, and at Bekemsk of the Verkhne Indigirsk region.

Yakut A.S.S.R.

Tungsten deposits of greisen type are known in the northeastern part of Yakutiya, situated at the edge of the Kolyma granite massif. Tungsten mineralization is associated with the tin ore and occurs in the alaskite and granite porphyries, the Polyarnoe and Isteedi being two such deposits. Columbium, tantalum and scandium are also often present in the ore. The Chalbinsky and Omchikandy are two other tin-tungsten deposits, occuring in the porphyritic biotite granites (57, p. 110). The information on this region is only sketchy, and the area is as yet not well explored.

Agilinsk Deposit

The Agilinsk deposit in Yakutiya is made up of granitic ore bodies intruded into a Permian-Jurassic sedimentary sequence, and crisscrossed by east-west trending veins. Tungsten mineralization here is associated with copper ore. The richest tungsten ore occurs in the granodioritic quartz-scheelite veins. The primary ore minerals are chalcopyrite, pyrrhotite, and scheelite; the gangue minerals are apatite, calcite, fluorspar, pyroxene, quartz, and vesuvianite (57, p. 110). From all indications, the deposit is not exploited at the present time.

Verkhne Basysardakha Deposit

This molybdenum-tungsten deposit is located along the northeastern flank of the Polousny Range, in the upper reaches of the Basysardakha River. The molybdenite and scheelite occur in quartz veins of a greisen zone. The veins are up to 10 meters long and 10–15 centimeters thick, with some being 1–1.5 meters thick. The molybdenum content is about 0.4% on the average, and tungsten about 0.01 to 1.%. Arsenic, bismuth and copper also occur at this locality. The deposit is not mined at present (57, p. 110).

Magadan Oblast'

This area of Northeast Siberia includes Upper Kolyma, Magadan, and Chukotka regions. Small amounts of tungsten mineralization are known in all of those regions. By some accounts, the Alyaskitov mine was producing tungsten in Magadan already in 1941 (188). The Iul'tin tungsten deposit in Chukotka is, however, the most significant. Molybdenum and tin are the primary ores in this area, occurring in greisen-type deposits, and tungsten is produced only as a by product. By 1975, tungsten concentrate output in Magadan was expected to be 8.3% higher than in 1970 (189).

Chukotka Area

Tungsten in Chukotka occurs in the northern foothills of the Chukotskoe Nagorye, in the Amguemsky and Krasnoarmeysky ore districts, the former being the largest district. The major tin-tungsten ore fields of the area are Iul'tin, Severny, and Svetloe (190). The exploration at Chukotka was curtailed sharply after 1956, except for the Severny and Svetloe deposits, which were discovered in 1983 by A.P. Nikolsky (3, p. 178).

Severny Deposits

The Severny (or Northern) ore field contains the Svetloe, Solnechnoe and Tenkergin deposits in Chukotka. Some deposits are only tens of meters below the surface (such as Zavetone, Obilnoe), while others are hundreds of meters deep. The Iul'tin deposit is the deepest, at 780 meters, and Svetloe at 590 meters (3, p. 252).

Tin-tungsten mineralization in the Svetloe deposit occurs in quartz veins, in greisens. Tungsten occurs at great depths, while tin is concentrated in the upper horizons. The deposit was mined until 1976. The mine, at present, may operate periodically, and the ore is shipped to the Iul'tin complex for beneficiation. The ore from the Tenkergin (Tenkergin River) mine has also been processed at the Iul'tin complex since 1959 (57, p. 112).

Lul'tin Deposits

The Iul'tin ore field (Iul'tin Creek) is located along the Amguema River in the Ekiatapsky Mountains in the southwest of the Chukotka peninsula, the Magadan Oblast'. The Iul'tin ore field contains several tungsten deposits, such as Iul'tin and Dolinnoe. In addition to the cited references, the ore field has been described in numerous publication (72, pp. 61–63).

Mineralization at Iul'tin is in quartz veins intruded into greisenized granite, which was detected by drilling at 400 meters below the surface in the 1960's. The granites at Iul'tin cover an area of about 400 square kilometers. (3, pp. 152, 158). Most of the veins are small, not longer than 100–150 meters along strike, and 0.3–1.0 meter thick. Because of their small size and complex structures, groups of veins have been termed as separate ore bodies. In all, the Iul'tin region contains 104 such ore bodies, making up three groups: Vodorzadel'naya, Yuzhnaya and Vostochnaya. Some of the ore bodies are 1,250 meters long along strike (62, p. 200).

The primary ore minerals of the Iul'tin deposits are cassiterite, with chalcopyrite, pyrrhotie, wolframite and up to 2% arsenopyrite; scheelite is present in insignificant amounts. Quartz makes up 85–90% of the gangue minerals. The ore contains up to 0.04% columbium, 0.1% tin, 0.02% scandium, and 0.1% arsenic. The tungsten and tin concentrations increase with depth, as does manganese (62, p. 201). The content of iron in tungsten decreases with depth (3, p. 323).

The combined reserves of the Iul'tin deposit were estimated in 1978 at 11,000 metric tons of tungsten content at an average grade of 0.8% WO_3 (57, p. 113).

Mining.—The Iul'tin deposit was discovered in 1937 and is probably the most important Soviet tungsten discovery since World War I (3, p. 157). It has been mined since 1954. Associated wolframite placers were mined also in the beginning. The Iul'tin mine and beneficiation complex is the only large tungsten mining complex in Northeast Siberia, and has been modernized repeatedly. The mining complex is linked to the Eqvekinot sea port on the Bering Sea by a 175 kilometer paved road, its main supply and shipping route.

The underground mine is reportedly accessed by a shaft for men, materials and supplies, and the ore is most likely mined by shrinkage stoping along the veins. The ore is hauled by rail.

Beneficiation.—The high capacity Iul'tin beneficiation plant processes the ore from the local mines, and also from areas farther away, such as the Sveltoe and Tenkergin mines to the south. The beneficiation plant started operating in 1959 and was upgraded in 1975, and again in 1978–81. It reportedly started processing tungsten ore from the Tenkergin deposit in October 1975.

The beneficiation process reportedly consists of a two-stage crusher, followed by jigs and shakers to produce coarse and fine concentrate. The fines are concentrated by gravity. The concentrates are then passed through the flotation stage for the removal of sulfides, followed by a tin recovery circuit, dewatering, drying, screening and magnetic separation to produce the final concentrate. The concentrate is reportedly of high grade.

Appendix A.—Geographic Listing of Soviet Tungsten Deposits and Mineralization Sites, Their Location, Type and Associated Minerals

Location and Deposit Name	Deposit type. Tungsten Ore. (minor tungsten minerals and/or associated metals shown in parentheses).
Urals:	
Aydyrlinsk	Skarn. Scheelite. Huebnerite. (Au).
Balkan	Skarn/Vein. Scheelite. Huebnerite. (Au).
Bazhenovsk	Skarn. Scheelite.
Boevsk	Skarn. Scheelite. Huebnerite. (Au).
Buranov	Skarn/Pegmatite. Scheelite. (Mo; Au; Bi).
Gumbeika	Skarn/Pegmatite. Scheelite. (Mo; Au; Bi).
Igisansk	Skarn/Pegmatite. Scheelite. (Mo; Au; Bi).
Kras'evsk	Vein. Scheelite. Huebnerite. (Au).
Krasny Ogorodnik	Skarn. Ferberite
Kumaksk	Skarn. Scheelite. Huebnerite. (Au).
Novo-Berezovsk	Greisen. Scheelite. Wolframite. (Au).
Porokhovsk	Skarn. Scheelite. Huebnerite.
Pripolyarny	Greisen. Scheelite.
Pyankovsk	Skarn. Scheelite. Huebnerite. (Au).
Saburovsk	Skarn. Scheelite. Huebnerite. (Au).
Tal'beysk	Skarn/Vein. Wolframite. (Hg).
Torgovsk	Skarn/Vein. Wolframite. (Mo; Bi).
Trebin	Skarn/Vein. Scheelite. (Au).
Velikopetrovsk	Greisen. Scheelite. Wolframite. (Au).
Vostok	Skarn. Huebnerite. (Mo).
Yugo-Konevsk	Skarn/Vein. Scheelite. Huebnerite. (Au).
Caucasus:	
Chensky	Skarn/Vein. Wolframite. Scheelite. (Mo).
Chorukhsky	Skarn. Wolframite. (Scheelite). (As).
Kti-Teberda	Skarn/Vein. Scheelite. (Wolframite). (As).
Kvanarsky	Skarn. Scheelite. (Wolframite). (As).
Tyrny-Auz	Skarn/Greisen. Scheelite. (Mo; Au; Sn; Sulfides).
Central Asia:	
Aksayskoe	Skarn. Wolframite. (Mn).
Arkhamaydan-Sarymat	Skarn. Scheelite. (Wolframite). (Cu).
Ayna-Bulak	Skarn. Scheelite.
Besh-Arkha	Skarn. Scheelite. (Pb).
Chorukh-Dayron	Skarn. Scheelite. (Mo; Cu; Ta).
Davlyatmey	Skarn. Scheelite. (Sn; As).
Ingichke	Skarn. Scheelite. (Wolframite). (Cu; Mo).
Ingyrchak	Skarn. Scheelite.
Kabuty	Skarn. Scheelite. (Ferberite).
Kanyaz	Skarn. Scheelite. (Wolframite). (Cu).
Karatyube	Skarn. Scheelite.
Kashkasu	Skarn. Scheelite. (Au; Mo).
Khal-Kuyryuk	Skarn. Scheelite. (Pb).
Koytash	Skarn. Scheelite. (Mo).
Kumbel'	Skarn. Scheelite. (Au; Mo).
Kumykh-Tash	Skarn. Scheelite. (Pb).
Lyangar	Skarn. Scheelite. (Mo).
Maykhura	Skarn. Scheelite. (Wolframite). (Sn; Sulfides).
Melik-su	Skarn/Vein/Stock. Scheelite. (Pb).
Myutenbay	Skarn. Scheelite. (Sn; As).
Petinsk	Skarn. Scheelite. (Wolframite). (Cu).
Rars	Skarn. Scheelite. (Wolframite). (Cu).
Saya Lagernoe	Skarn. Scheelite. (Pb).
Takfon	Skarn. Scheelite.
Tamchi	Skarn. Scheelite.
Tossor	Skarn. Wolframite. (Mn).
Ugat	Skarn. Wolframite. (Mo).
Ukak	Skarn. Scheelite.
Yakhon	Skarn. Scheelite.

Appendix A.—Geographic Listing of Soviet Tungsten Deposits and Mineralization Sites, Their Location, Type and Associated Minerals (continued)

Location and Deposit Name	Deposit type. Tungsten Ore. (minor tungsten minerals and/or associated metals shown in parentheses).
Yangi-Kana	Skarn. Scheelite.
Yubileynoe	Skarn. Scheelite. (Wolframite). (Mo; Sulfides).
Kazakhstan:	
Akchatau	Greisen/Vein. Wolframite. Scheelite. (Ferberite, Huebnerite). (Mo; Sn; Bi).
Akmay (Akmin)	Greisen/Stock. Wolframite. (Scheelite). (Mo; Bi; Sn).
Altuyat	Greisen. Wolframite.
Balkhash	Greisen. Wolframite. Scheelite.
Batystau	Greisen. Wolframite. Scheelite. Ferberite. Huebnerite. (Mo; Sn).
Baykhatin	Greisen. Wolframite. Scheelite. (Mo; Bi).
Baynazar	Greisen. Scheelite. Wolframite. (Mo).
Boguty	Greisen/Vein. Scheelite. (Wolframite). (Mo).
Bol'shevitskoe	Greisen. Wolframite.
Boshchekul	Greisen. Wolframite. Scheelite. (Mo; Bi).
Bulandinskoe	Greisen. Scheelite. (Sn).
Cherdoyatskoe	Greisen. Scheelite. (Sn).
Chikola	Pegmatite. Wolframite. Scheelite.
Dzhambul	Greisen. Wolframite.
Dzhanet	Greisen. Wolframite. Scheelite. (Mo; Bi).
Dzheltau	Greisen. Wolframite. Scheelite. (Mo; Bi).
Gremyachee	Greisen. Wolframite. Scheelite. (Sn).
Imertanka	Pegmatite. Wolframite. Scheelite.
Kaibsky	Greisen. Wolframite.
Kaindinskoe	Greisen. Huebnerite. (Sn).
Kalba-Narym	Greisen. Wolframite. (Scheelite). (Sn).
Karaoba	Greisen/Vein/Stock. Wolframite. Scheelite. (Mo; Bi; Sn).
Karashskoe	Greisen. Huebnerite. (Sn).
Karkaralinskoe	Greisen. Wolframite. Scheelite.
Keng Kiik	Stockwork/Vein. Wolframite. Scheelite. (Mo; Bi).
Koktenkol	Greisen/Stockwork. Wolframite. (Mo).
Komsomol'skoe	Greisen. Huebnerite. (Sn).
Kounrad (Vostochny)	Stockwork/Vein. Scheelite. Wolframite. Huebnerite. (Cu; Mo; Bi).
Kozlovskoe	Greisen. Wolframite. Scheelite. (Sn).
Kyzyltau	Stockwork/Vein. Scheelite. Wolframite. Huebnerite.
Leninskoe	Greisen. Wolframite. Scheelite. (Sn).
Malochernovinskoe	Greisen. Wolframite. Scheelite. (Sn).
Maykul	Stockwork/Vein. Wolframite. Scheelite. (Mo; Bi).
Monchnatudinskoe	Greisen. Wolframite.
Nura-Taldy	Stockwork. Wolframite. Scheelite. (Mo; Bi).
Ortauskoe	Stockwork/Vein. Wolframite. Scheelite. (Sn; Mo).
Palatsky	Greisen. Wolframite. Scheelite. (Sn).
Razdol'nenskoe	Greisen. Wolframite.
Saranskoe	Greisen. Wolframite. Scheelite. (Mo; Bi).
Sebinskoe	Greisen. Wolframite.
Segiz-Sala	Stockwork/Vein. Wolframite. Scheelite. (Mo; Bi).
Seltey	Stockwork/Vein. Wolframite. Scheelite. (Mo; Bi).
Shakshagaylinskoe	Greisen. Wolframite. Scheelite.
Shalgiya	Stockwork/Vein. Wolframite. Scheelite. (Mo; Bi).
Shetskoe	Greisen. Wolframite. Scheelite.
Tayshek	Stockwork. Wolframite. Scheelite.
Tsentral'noe	Stockwork/Vein. Wolframite. Scheelite. (Sn; Mo).
Ubinskoe	Greisen. Huebnerite. (Sn).
Verkhne-Kayrakty	Greisen. Scheelite. Wolframite. (Mo).
Southwest Siberia and Gorny Altay:	
Aturkol'sk	Greisen. Wolframite.
Balokurikhinsk	Greisen. Wolframite.
Bartunkov	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Beloretsk	Skarn. Scheelite. (Mo; Sn).
Buguzunsk	Greisen. Wolframite.
Bystrynskoe	Greisen. Wolframite.

Appendix A.—Geographic Listing of Soviet Tungsten Deposits and Mineralization Sites, Their Location, Type and Associated Minerals (continued)

Location and Deposit Name	Deposit type. Tungsten Ore. (minor tungsten minerals and/or associated metals shown in parentheses).
Chindagat	Skarn. Wolframite. (Huebnerite). (Mo; Sn).
Chingekatsk	Greisen. Wolframite.
Dzhetsky	Greisen/Stockwork. Wolframite. (Mo).
Kal'guta	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Kaltarovskoe	Skarn. Scheelite. (Mo).
Kazontsevskoe	Greisen. Wolframite.
Kiyalyah-Uzen'sk	Greisen. Wolframite. (Mo).
Kok-kul	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Kolbin	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Kolyvan	Greisen. Wolframite. (Cu; Mo).
Lededskoe	Greisen. Wolframite.
Maganat	Skarn. Scheelite. (Mo).
Mul'chikhinskoe	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Novo-Kolyvan	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Olympiadskoe	Skarn. Scheelite. (Mo).
Osinovskoe	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Osipovskoe	Greisen. Wolframite.
Osokinskoe	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
Plitinsk	Skarn. Scheelite. (Mo; Sn).
Shinokskoe	Greisen. Scheelite.
Shirgaytinskoe	Skarn. Scheelite. (Mo; Sn).
Sinyushinsk	Greisen. Wolframite.
Spornaya	Greisen. Scheelite.
Takarevskoe	Greisen. Scheelite.
Talitsk	Greisen. Wolframite.
Tuim	Skarn. Wolframite. (Mo).
Urzarsky	Greisen. Scheelite.
Verkhne-Slyudyanskoe	Greisen. Wolframite. (Huebnerite). (Mo; Sn).
West Transbaikal:	
Arykhskoe	Skarn. Scheelite.
Baybinsk	Greisen. Scheelite. Huebnerite. (Mo).
Bom-Gorkhon	Greisen/Vein. Huebnerite. (Wolframite). (Mo; Sn; sulfides).
Buluktay	Greisen. Scheelite. Huebnerite. (Mo).
Dzhida	Vein/Stock/Placer. Wolframite. Huebnerite. (Mo; Sn).
Gardinsk	Greisen. Scheelite. Huebnerite. (Mo).
Gudzhir	Greisen/Placer. Huebnerite. (Mo; Bi; Sn; Cu).
Inkura	Greisen/Stock/Placer. Huebnerite. (Scheelite). (Mo; Sn).
Kholtoson	Greisen/Vein. Huebnerite. (Scheelite). (Sulfides).
Klyuchevsky	Greisen. Huebnerite. (Mo).
Malo-Kholtoson	Placer. Wolframite.
Pervomaysk	Greisen/Stock. Wolframite. Huebnerite. (Scheelite). (Mo; Sn).
East Transbaikal:	
Adun-Cholon	Pegmatite. Wolframite. Scheelite.
Aginsky	Greisen/Vein. Wolframite. (As; Nb).
Aldakachan	Greisen. Wolframite.
Antonovogorsk	Greisen/Vein/Placer. Wolframite. Scheelite. (Mo; Bi; Sulfides).
Arbukasnsk	Skarn. Scheelite.
Arbuy	Greisen. Wolframite.
Balakskoe	Skarn. Wolframite.
Barun-Shiveya	Skarn/Vein. Ferberite. (Hg; Sb).
Belukha	Greisen/Vein/Stock. Wolframite. (Bi;Sulfides; Mo).
Budunsky	Greisen. Wolframite. (Sn).
Bugdaya	Greisen. Scheelite. Wolframite. (Mo; Cu).
Bukhiktay	Greisen. Scheelite. Wolframite. (Mo; Cu).
Bukuka	Greisen/Vein/Stock. Wolframite. Huebnerite. (Bi; Sulfides; Mo).
Burkal'sky	Greisen. Wolframite. (Sn).
Bystrinsky	Skarn. Scheelite.
Charanorsk	Greisen. Wolframite.
Chargurtuy	Skarn. Wolframite.

Appendix A.—Geographic Listing of Soviet Tungsten Deposits and Mineralization Sites, Their Location, Type and Associated Minerals (continued)

Location and Deposit Name	Deposit type. Tungsten Ore. (minor tungsten minerals and/or associated metals shown in parentheses).
Chikoy	Greisen. Wolframite. (Sn; Mo).
Daurkachan	Greisen. Wolframite. (Mo).
Davenda	Greisen. Scheelite. (Mo).
Dedovogorsk	Greisen/Vein. Wolframite. (Sn).
Dondor	Skarn. Ferberite. (Scheelite). (Hg; Sb; Sn).
Duldurga	Greisen. Wolframite.
Durkachan	Greisen. Wolframite.
Durulguevsky	Greisen/Vein. Wolframite. (Sn).
Gazimur-Argun	Skarn/Vein. Wolframite.
Gremuchinsky	Greisen. Wolframite. (Sn).
Ingiratinsk	Placer. Wolframite.
Izybrinoe	Greisen. Wolframite.
Kazakovsky Priisk	Greisen. Wolframite.
Khaltuyskoe	Greisen. Wolframite.
Khapcheranga	Greisen. Wolframite. (Sn).
Kharanor	Pegmatite. Wolframite. Scheelite.
Khurbulskoe	Greisen. Wolframite.
Kukulbeysk	Greisen. Wolframite.
Kolanguy	Greisen. Scheelite. (Mo).
Kunalev	Greisen. Wolframite.
Levo-Amudzhikaansk	Greisen. Wolframite.
Levo-Ingodinsky	Greisen. Wolframite. (Sn).
Malo-Angatuyevsk	Greisen. Scheelite. Wolframite. (Mo).
Malo-Kudechinsk	Greisen. Wolframite.
Medzheginsky I&II	Greisen/Stock/Vein. Wolframite. (Sn).
Molodeyzhnoe	Greisen. Wolframite.
Monokansk	Skarn/Vein. Wolframite.
Nortuysk	Skarn/Vein. Wolframite.
Novo-Ivanovsk	Skarn. Ferberite. (Hg; Sb).
Novo-Kazchinskoe	Skarn. Ferberite. Scheelite. (Hg; Sb).
Ochekanskoe	Greisen. Wolframite.
Oldanda	Greisen. Wolframite.
Orlovsk	Greisen. Wolframite. (Ta; Nb).
Ostrinsk	Skarn. Scheelite.
Privalov	Greisen. Scheelite. (Mo; Cu).
Shakhtama	Greisen. Scheelite. (Mo; Cu).
Sherlovogorsk	Greisen. Scheelite. (Mo; Cu).
Shumilovka-Gornachinsky	Greisen. Wolframite. (Sn; Mo).
Sokhondo	Greisen. Wolframite. (Sn).
Soktui	Pegmatite. Wolframite. Scheelite.
Spokoyny	Greisen/Vein. Wolframite. (Scheelite). (Sn; Bi).
Studenchesky	Greisen/Stock. Wolframite. (Sn).
Tutchaltuy	Greisen. Wolframite.
Ugdyrinsky	Greisen. Wolframite. (Sn; Co; Ni).
Uronaysky	Skarn/Greisen. Wolframite. (Ta; Nb).
Usmunsk	Greisen. Wolframite.
Verkhne-Chikoy	Greisen/Veins. Wolframite. (Sn).
Verkhne-Ushmunsk	Skarn. Wolframite.
Yuzno Daursky	Greisen. Wolframite. (Sn).
Zun-Undura	Greisen. Wolframite. Huebnerite. (Sulfides; Sn; (Mo).
Primor'ye:	
Alekseevkoe	Skarn. Scheelite. (Mo; Bi).
Anuchino	Greisen. Scheelite. (Mo; Sulfides).
Anuchinskoe	Greisen. Scheelite. (Au).
Armu-Imansky	Greisen. Scheelite. (Sn).
Bikinsky	Greisen. Scheelite. (Mo; Sulfides).
Bol'sherechenskoe	Skarn. Wolframite. Scheelite. (Sn; Au).
Chapaevsky	Greisen. Wolframite. (Mo; Sn).
Chimchiguzskoe	Greisen/Vein. Wolframite. Scheelite.
Dzhaur	Skarn/Greisen. Scheelite. (Wolframite), Sn; Cu; (Bi).
Festivalnoe	Skarn/Vein. Wolframite. Scheelite. (Sn; Au; Pb; Cu).

Appendix A.—Geographic Listing of Soviet Tungsten Deposits and Mineralization Sites, Their Location, Type and Associated Minerals (continued)

Location and Deposit Name	Deposit type. Tungsten Ore. (minor tungsten minerals and/or associated metals shown in parentheses).
Furmanovsky	Greisen. Scheelite.
Il'morskoe	Greisen. Scheelite. (Sulfides).
Il'movka	Greisen/Skarn. Scheelite. (Wolframite). (Sn: Cu; (Bi).
Julinskoe	Greisen. Scheelite.
Kamenistoe	Skarn. Wolframite. Scheelite. Ferberite. (Sn; (Mo).
Khabarovsk	Greisen. Wolframite.
Khankayskoe	Greisen. Scheelite. (Sulfides).
Kimorskoe	Greisen. Scheelite. (Sulfides).
Kirovsk	Greisen. Wolframite. (Mo; Sn).
Leningradskoe	Greisen. Wolframite. (Mo; Sn).
Lermontov (Luchegorsk)	Greisen/Skarn. Scheelite.
Mao Chan	Greisen. Wolframite. (Mo; Sn).
Negametninskoe	Greisen. Scheelite. (Au).
Novoselishche	Skarn. Scheelite. (Mo; Bi).
Ochensky-Dzhegdagskoe	Greisen. Wolframite. (Sn).
Olga	Greisen. Wolframite.
Pokrovsko-Troitskoe	Greisen. Wolframite. (Sn).
Rudnoe	Greisen/Stock/Vein. Scheelite. Wolframite. (Sn; Au; Pb; Cu).
Sergeevsk	Greisen. Wolframite.
Shinengou	Greisen. Scheelite. (Mo); (Sulfides).
Sinegorsk	Greisen. Scheelite. (Au).
Solnechnoe	Skarn/Vein. Wolframite. Scheelite. (Au; Pb; Cu).
Stolbovoe	Skarn. Wolframite. Scheelite. Ferberite. (Sn); (Mo).
Tsentral'noe	Skarn. Wolframite. Scheelite. Ferberite.
Tigrinoe	Greisen. Wolframite.
Uchaminskoe	Skarn. Wolframite. Scheelite. (Sn; Au).
Umalta	Greisen/Vein. Wolframite. (Scheelite). (Mo).
Ust-Mikulinskoe	Greisen/Vein. Wolframite. (Scheelite). (Mo).
Vershinnoe	Greisen. Wolframite. (Sn; Pb; Zn; Cu; Ag).
Vostok-2	Skarn/Placer. Scheelite. (Wolframite). (Mo; Cu; Sulfides).
Yuylinskoe	Greisen. Scheelite.
Zabytoe	Greisen/Vein. Scheelite. (Sn; Mo).
Zimovinskoe	Greisen. Wolframite. (Sn).
Northeast Siberia:	
Agilinsk	Greisen/Vein. Scheelite. (Cu).
Alyaskitov	Greisen/Vein. Scheelite.
Amguemsky	Greisen. Wolframite.
Augskoe	Greisen. Wolframite.
Bekemsk	Greisen/Vein. Wolframite.
Chalbinsky	Greisen. Placer. Wolframite.
Dolinnoe	Greisen. Wolframite. (Cu; Sn).
Isteedi	Greisen. Scheelite. (Sn).
Iul'tin	Greisen/Vein/Placer. Wolframite. (Cu; Mo; Sn).
Obilnoe	Greisen/Vein. Wolframite. (Sn).
Omchikandy	Greisen. Placer. Wolframite.
Polyarnoe	Greisen. Scheelite. (Sn; Bi).
Severny	Greisen/Vein. Wolframite. (Sn).
Solnechnoe	Greisen/Vein. Wolframite. (Sn).
Svetloe	Greisen/Vein. Wolframite. (Sn).
Takalkan	Pegmatite. Scheelite. Wolframite.
Takylkansk	Greisen/Vein. Wolframite.
Tenkergin	Greisen/Vein. Wolframite. (Sn).
Tuguchaksk	Greisen/ Vein. Wolframite.
Turman	Greisen. Wolframite.
Ubinsk	Greisen. Scheelite. (Mo; Sn).
Ulchan	Pegmatite. Scheelite. Wolframite.
Verkhne Babysardakha	Greisen/Vein. Scheelite. (Mo; Bi; As; Cu).
Zavetnoe	Greisen/Vein. Wolframite. (Sn).

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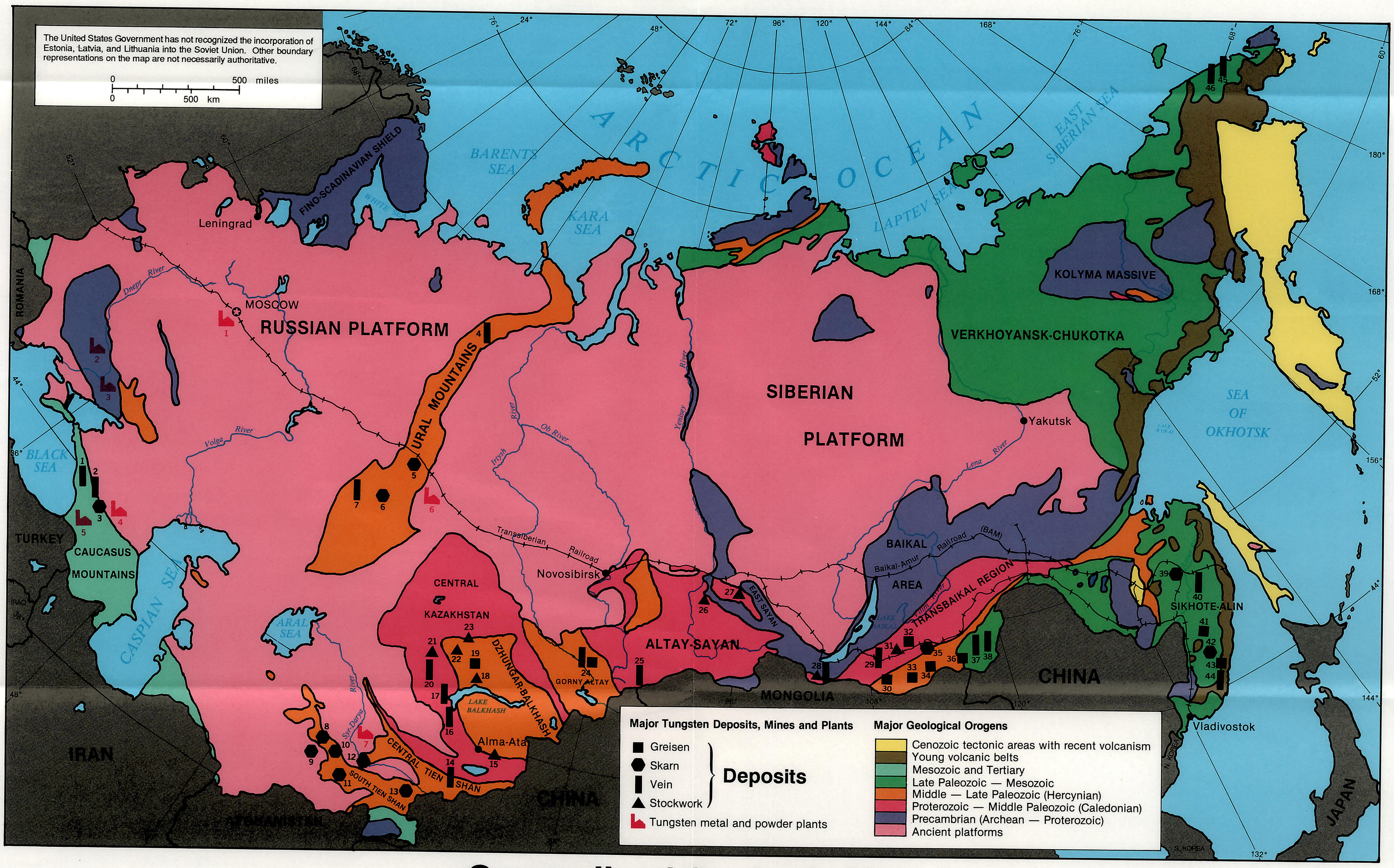
Names and boundary representation are not necessarily authoritative.

Generalized Geographic Map



Generalized Geologic Map

Figure 12. Generalized Geographic and Geologic Maps of the U.S.S.R. showing the Distribution of Major Tungsten Deposits and Plants. Major Tungsten Deposits and Plants (Names in parentheses indicate some localities nearby): 1—Kti-Teberda; 2—Chensky (Chorukhsky; Kvanarsky); 3—Tyrny-Auz; 4—Torgovsk; 5—Boevsk (Balkan); 6—Gumbeika (Buranov); 7—Aydyrlinsk (Velikopetrovsk); 8—Lyangar; 9—Ingichke (Karatyube; Yakhtin); 10—Koytash (Ugat); 11—Maykhura (Takfon; Kabuty); 12—Chorukh-Dayron (Mogultau; Yubileynoe); 13—Melik-su; 14—Kumbel; 15—Boguty; 16—Dzheltau (Maykul); 17—Kaibsky (Baykhatin; Keng Ki ik); 18—Kounrad (Vostochny Kounrad; Balkhash); 19—Akchatau (Dzhambul) 20—Karaoba; 21—Shalgiya; 22—Akmay; 23-Koktenkol (Verkhne-Kayrakty; Baynazar; Uspensky); 24—Kalba-Narym Province (Akzhal; Kaindinskoe; Bulandinskoe); 25—Gorny Altay (Kolbin; Kok-kul; Kolyvan; Ubinsk); 26—Dzhetsky; 27-Tuim (Kiyalich-Uzen'sk); 28—Dzhida (Inkura; Kholtoson; Pervomaysk; Zakamensk); 29—Bom-Gorkhon; 30—Chikoy (Shumilovka); 31—Buluktay; 32—Spokoyny; 33—Sokhondo (Khapcheranga; Daursky); 34—Durulguevsky (Dedovogorsk) 35—Orlovsk (Uronaysky; Aginsky); 36—Sherlovogorsk; Antonovogorsk); 37—Kukulbeysk (Belukha; Bukuka); 38—Gazimur-Argun; 39—Mao Chan (Umalta) 40—Solnechnoe (Festival'noe); 41—Lermontov (Primorsky); 42—Vostok-2; 43—Armu-Imansky; 44—Rudnoe (Kamenistoe; Tsentral'noe; Zabytoe); 45—Iul'tin; 46—Severny (Svetloe; Tenegergin). Tungsten Metallurgical Plants: 1—Moscow; 2—Kirovgrad; 3—Zaporozhie; 4—Nal'chik; 5—Ordzhonikidze; 6—Chelyabinsk (Novomoskovsk); 7—Chirchik.

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