BRITISH COLUMBIA DEPARTMENT OF MINES

Hon. E. C. CARSON, *Minister* JOHN F. WALKER, *Deputy Minister*

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An Introduction
to
METAL MINING
in British Columbia

by

OFFICERS OF THE DEPARTMENT OF MINES

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THE GOVERNMENT OF
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This Bulletin is intended to provide an outline of metal mining in British Columbia. It is written to serve as a background for more particular study; for that reason a historical summary is included, as well as brief sections on geology, ore-dressing, and metallurgy. The need for brevity has required much generalization.

This Bulletin is issued in response to many requests for information of a non-technical nature that are constantly being received from the public in general, and from tourists and schools in particular. It is hoped that the information contained herein may be helpful in a preliminary approach to the study of metal mining and may also be of interest to the general reader.

AN INTRODUCTION

TO

METAL MINING IN BRITISH COLUMBIA

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AN INTRODUCTION TO METAL MINING IN BRITISH COLUMBIA

Mining is the second largest industry in British Columbia, measured by the value of its annual production. The industry produces refined metals, metal-bearing ores or concentrates for export, fuels, building materials, various chemicals, and partly, or completely processed industrial materials. The scope of the industry includes search for the various deposits, recovery of the materials from them, and processing of those materials to a point when they are acceptable to other industries, as in the form of refined metals, screened and washed coal, finished clay products, or cement. During the ten year period ending in 1941, the annual value of the mineral production of British Columbia averaged over $56,000,000, including:

Metallics, nearly	$48,000,000
Fuel, more than	6,000,000
Non-metallics, more than	800,000
Clay and clay products, more than	300,000
Other structural materials, nearly	1,500,000

From the foregoing table it is apparent that metal mining has been pre-eminent in British Columbia's mineral production. Gold production, averaging more than $16,000,000, constituted slightly over a third of the value of the metallics and more than a fourth of the total value of all mineral products. However, because of expanding industrialization and growing population it is likely that production of structural and industrial materials will increase.

In 1942 British Columbia produced the following metals: arsenic, antimony, bismuth, cadmium, copper, gold (both lode and placer), indium, lead, mercury, platinum (placer), silver, tin, tungsten ore, and zinc. Of these, gold, silver, copper, lead, and zinc are, as in past years, of principal importance. Cadmium and bismuth for the last 15 years and antimony since 1939, have been produced as by-products from the Trail smelter. Tin, added to the list in 1941, is recovered as an additional by-product from the ore of the Sullivan mine. Mercury, and tungsten ore, although not new, began to be produced in important quantities only during 1941-42. Arsenic is recovered from copper concentrates which are shipped to the smelter at Tacoma.

The following pages are intended to familiarize the reader with the metal mining industry of British Columbia by providing a background of the history of its development and an outline of geological processes, the physical geology of the Province, the treatment of ores and the principle sources of the metals.

The early history of mining in British Columbia is very nearly the same as that of the early development of the Province in general. The first great increase in population was the result of mineral discoveries, and for many years after prospectors and miners led the way in exploration. Settlement of the land followed the construction of trails, roads and later of railroads which were primarily built to serve mineral-bearing districts.

Before gold was discovered the white population of the Province consisted of a few hundred men who trapped or bartered with the Indians, chiefly along routes established by the earliest explorers. In 1855 placer miners, spreading north from the rich but already waning gold fields of California, discovered placer gold at Fort Colville in northern Washington. This news spread rapidly and soon after, "flour" gold was found in the gravel bars of the Fraser River near Yale, and by 1858 hundreds of miners were pushing their way up the river in search of coarser gold that they believed must exist nearer the headwaters. In 1860 the first important discoveries in the Cariboo were made at Quesnel Forks, Keithley Creek and Antler Creek, and in 1861 the celebrated Williams and Lightning Creeks were found.

The penetration of the Cariboo, first by hundreds and soon by thousands, was extremely rapid, considering the physical difficulties entailed. Men were active in many other districts as well. Placer gold was discovered in 1860 at Rock Creek on the Kettle River, and within the next five years in the Okanagan, at Fort Steele, on the Big Bend of the Columbia River, probably at Scotch Creek on Shuswap Lake, in the Omineca, and at many other points in the southern section of the Province. The next important discovery was made at Dease Lake in 1873 and other discoveries have been made from time to time since then.

The army of miners that invaded the country in the early '60's had to be fed, clothed, and supplied with tools. In order to carry on the greatly expanding trade it became necessary to construct trails and roads. The famous Cariboo Trail first went by way of Harrison, Anderson and Seton Lakes to Lillooet, and then over Pavilion Mountain to Clinton. Later the Royal Engineers built a road through the Fraser Canyon that enabled wagons to be hauled the entire distance by way of Cache Creek and Clinton. After the Canadian Pacific Railway was completed in 1886 a road from Ashcroft connected with the original road at Cache Creek.

It was in the early '60's also that the Dewdney Trail was built across the mountains, from Hope to Princeton and through to the Kootenays. This was the first trans-provincial trail, constructed primarily to serve the placer miners and enable them to travel to Victoria without crossing the boundary-line into Washington. Other trails were built, and a more or less regular boat service was provided on some of the waterways, such as Kootenay, Okanagan and Arrow Lakes and Columbia River.

During this period large tracts of country were rapidly opened up, but unfortunately the diggings rich enough to support hundreds of individual miners were soon worked out. The greatest recorded placer production was in 1863, which meant that the diggings reached their peak three years after discovery. The Cariboo continued to prosper, owing principally to the fact that hydraulic mining was introduced there in 1879, but by that year activity in most of the other camps had dwindled, and over half of the few men remaining in them were Chinese. The heyday of placer mining for the individual miner was over by 1885, with the single exception of the important Atlin field, discovered in 1898.

Fortunately, this early slump did not last for very long. Transcontinental railways were being built and rich lode discoveries were being made in the northwestern States, and a trans-Canada railway was projected to develop similar discoveries in British Columbia. It seems probable that the early British Columbia placer prospectors spread stories of the veins of gold-bearing quartz and of base metals which they had seen but at that time could not hope to work. By the early 1880's lode prospecting was under way, and within ten years many important discoveries were made.

The earliest report of work actually being done on a lode-deposit concerns the Blue Bell, on Kootenay Lake, where lead ore was observed by fur traders 100 years ago. The first production 1843
came from Silver Mountain, near Hope, where rich silver ore was discovered in 1868 and ore was shipped to San Francisco and Swansea, Wales, about two years later. A stamp mill was erected in the Cariboo in 1876, but this and other desultory attempts made to mine the abundant quartz veins in that district met with little success until recent times.

Intensive prospecting started on Kootenay Lake about 1882, and in the next five to ten years spread throughout the Kootenays generally, the Slocan, Boundary and Rossland districts, and through the "Railway Belt" of the Canadian Pacific Railway which reached Vancouver in 1886. By 1896, with access provided to the Kootenay by the Canadian Pacific and Great Northern railways, and with smelters in operation at Trail and Nelson, mining was booming throughout southern British Columbia.

These smelters were followed, during the next ten years, by others at Northport, Grand Forks, Boundary Falls, Greenwood, Marysville, Texada Island, Ladysmith and Crofton. A small plant at Pilot Bay on Kootenay Lake was operated for a short period, but had closed by 1897. The four earliest smelters of all, built in 1889 and '90, have dropped almost completely from memory. The first to be erected was at Woodbury Creek, on Kootenay Lake, and the others were at Vancouver, Revelstoke and Golden.

The Rossland district was rapidly prospected in the early '90's and attained maximum production around 1905. A rapid decline in output was experienced near the end of the war of 1914-18 and by 1925 the camp was practically abandoned. At Phoenix in the Boundary district, the first discovery of copper was made in 1891 and mining reached its peak in 1913. In 1919, the Granby Company suspended operations in this district and the smelter at Grand Forks was closed; the Company's main activity was then centred at Anyox.

The famous Sullivan mine near Kimberley was staked in 1892. Although ore was produced in small amounts during the early stages of development, great difficulty was experienced in treating it because of the fine-grained admixture of the lead and zinc minerals. The smelter erected in 1902 at Marysville proved unsuccessful and ceased operations a few years later. The problem of treatment was finally overcome in 1923 when differential flotation was successfully employed on a large scale in a new concentrating mill at Kimberley, and the vast ore reserves became available.

In 1900, the Britannia copper deposits were discovered near the head of Howe Sound and mining and gravity concentration were carried out on a moderate scale for several years. Later a flotation plant was built but the large production which has been maintained to the present did not start until the completion in 1923 of the present flotation mill, built after fire destroyed the earlier one. Copper Mountain, another large producer, near Princeton, was partly developed in 1913 but did not produce much copper until the erection of a concentrating mill at Allenby in 1920. Operations were suspended during the depression because of the low price of copper but were resumed in 1937.

By 1900 lode mining was well under way in the southern and central sections, but it was more than ten years later before the northern part of the Province received much attention. This was of course due to the difficulties of transportation in a rough, new country. However, once a few discoveries had been made roads and trails were rapidly built. A few years after the Grand Trunk Railway (now the Canadian National) had been completed to Prince Rupert, the Portland Canal area to the north became an important mining centre. The large copper deposit at Anyox was brought into production in 1914 and continued to produce until 1935. The rich gold-silver deposits now known as the Silbak-Premier started to produce important quantities of ore in 1920.

A summary of the foregoing pages illustrates the fact that the earliest mining was done by individual placer miners. They were followed by miners who worked lode deposits of copper, lead, zinc, gold and silver and shipped their ores to the smelters and, in some instances, produced gold bullion which was shipped directly to the mint. Most of the earliest developed base metal ores were amenable to direct smelting and the mines could be worked only if they were large enough to support a smelter of their own or if the ore could be cheaply transported to some smelter nearby. Certain gold ores, however, particularly those containing no other metal of value, were treated and the gold extracted in a relatively inexpensive plant at the property, either by the time-honoured method of amalgamation or by the process of cyanidation. For this reason some early gold mines were able to operate far from railway transportation; the mines at Camp McKinney and Hedley are examples. With improvements in the technique of ore treatment during the last 20 years base metal as well as gold mines have been able to work at distances from smelters impossible during the early days. There is now no active copper smelter in British Columbia and concentrated copper ores are shipped for refining to Tacoma. The great smelter at Trail is primarily designed to treat ores of lead and zinc, but several other metals are produced as by-products.

Some of the earlier discoveries are worked out and others have ceased operations owing to unfavourable metal prices. Some copper mines operated prior to 1918, when the price of copper was high, but were uneconomical either before or after, when normal metal prices prevailed. The decline in price of silver during the last 12 years or so has closed many small mines in which silver is an important constituent of the ore. Apart from the increase in price of many metals brought about by the war the rise in price of gold ten years ago has had a profound effect on Canadian economy as a whole and has greatly increased the value of mine output in British Columbia. In recent years there has been relatively little production of lead and zinc apart from the large output of the Sullivan mine. Copper has come from two or three large mines, but gold has been produced on a scale not dreamed of before.

In 1933 and 1934 the price of gold advanced from $20 to $34 an ounce. This enabled many old mines, once abandoned as unprofitable, to be reopened, and led to increased prospecting for gold ores, while at the same time there was a revival of placer mining in old districts.

During the early '30's, production from the Pioneer and Bralorne lode deposits in the Bridge River area expanded very greatly. A similar rapid rise in output from lode deposits occurred in the old Cariboo camp, at a slightly later time. In the Hedley district operations were started in 1904, production reached a climax about 1913 and practically no activity occurred during the '20's. However, the camp was revived during the middle '30's and at the present time it is once more a major gold producing centre of the Province. The most outstanding gold discovery in recent years is the Zeballos camp on the west coast of Vancouver Island, which became an important producer in 1938.

Although interest has been centred chiefly on gold during the last few years, the present war has created great demands for other metals and already there has been a greatly increased production of base metals, as well as new development of some of the so-called "Strategic Metals." Outstanding examples among the last group are the production of mercury in large amounts from a recently discovered deposit at Pinchi Lake, north of Fort St. James, the recovery of tin from the complex ore of the Sullivan mine, the production of scheelite concentrates from the Red Rose mine near Hazelton, and the discovery and rapid development of the tungsten ore of the Emerald mine near Salmo.

Although there has been some prospecting in the Cassiar-Omineca mountains, much of this region remains virtually unexplored. The construction of the Alaska Highway has made the northern part more accessible and it is possible that important discoveries will be made there in the future. The Stikine Mountains and parts of the eastern flank of the Coast Mountains also constitute more or less unexplored territory which may merit investigation.

Although much interest naturally centres in those parts of the north that remain virtually unexplored, chances for new production still remain in the well known southern parts of the Province. All mining is a wasting asset, and any mineral deposit, no matter how large, will eventually be worked out, but changes in metal prices and in technological methods may revive old camps that have been abandoned. A rise in metal prices often results in the reopening of old mines and the finding of new ones, but advances in technical knowledge may have the same result. Improvements in metallurgy make possible the working of a deposit that in former years proved to be uneconomic, and growth of geological knowledge will lead to new discoveries in even the oldest and best known mining camps.

The distribution of ores and the nature of their occurrence is an important branch of geology, and every prospector and miner makes use of some part of geological knowledge in the search for and development of mineral deposits. Most discoveries have been made as the result of direct observation, or frequently of chance, but it is certain that other deposits exist that are still hidden from view in the rocks at the earth's surface. The value of geological knowledge is to assist in finding these hidden deposits and also to make the extraction of ore in a known deposit as complete as possible. Great advances have been made in this direction in recent years but future mining progress depends on an even greater application of geological principles.

GEOLOGICAL PROCESSES

Geological knowledge is applied in mining, first in locating and tracing the boundaries of an ore-deposit, and subsequently during the entire period of development. Just as milling and smelting follow mining in a necessary and dependant step in the sequence of converting the raw materials of the earth into finished and usable products, so is mining dependant upon geological principles both for its existence and to some extent for operating efficiency.

Geology is the study of the rocks and other materials of the earth's surface, and of the physical and chemical processes at work there. The surface of the earth may appear unchangeable when viewed broadly in the light of historical time but in the vast scale of geological time it is constantly changing. For example: sea and land may change places, mountain ranges may rise and be worn down, glaciers may cover a large part of the globe and subsequently melt away, new rocks may form from old, huge ruptures may tear and dislocate the rocks, yet the daily rate of change is generally too slow to be appreciated. Molten rock matter may rise from depth along channelways to the earth's surface and form volcanoes or great lava plateaux, or it may move upward as a large body to a higher level in the earth's crust to form a batholith and cause profound alteration of the adjacent rocks. Although these phenomena may seem almost fanciful in the light of ordinary experiences, all have occurred at one time or another during the geological history of British Columbia.

Everyone has been impressed by the large amount of gravel, sand and mud carried by streams during spring freshets. The quantity of such material transported yearly by streams, ultimately to be deposited in the sea, is enormous. The materials themselves are derived from the wearing down of the surface of the earth; natural agents such as wind, rain, snow and ice, changes in temperature, growth of vegetation and chemical reactions slowly produce debris for the streams to carry away. In the course of time the land is worn down and the seaways near shore are filled. We have proof that in the past lofty mountains have been worn almost flat and that the products of weathering have accumulated as sediments to thicknesses of five miles and more. Of course the ocean basins would never become filled, but if other geological processes

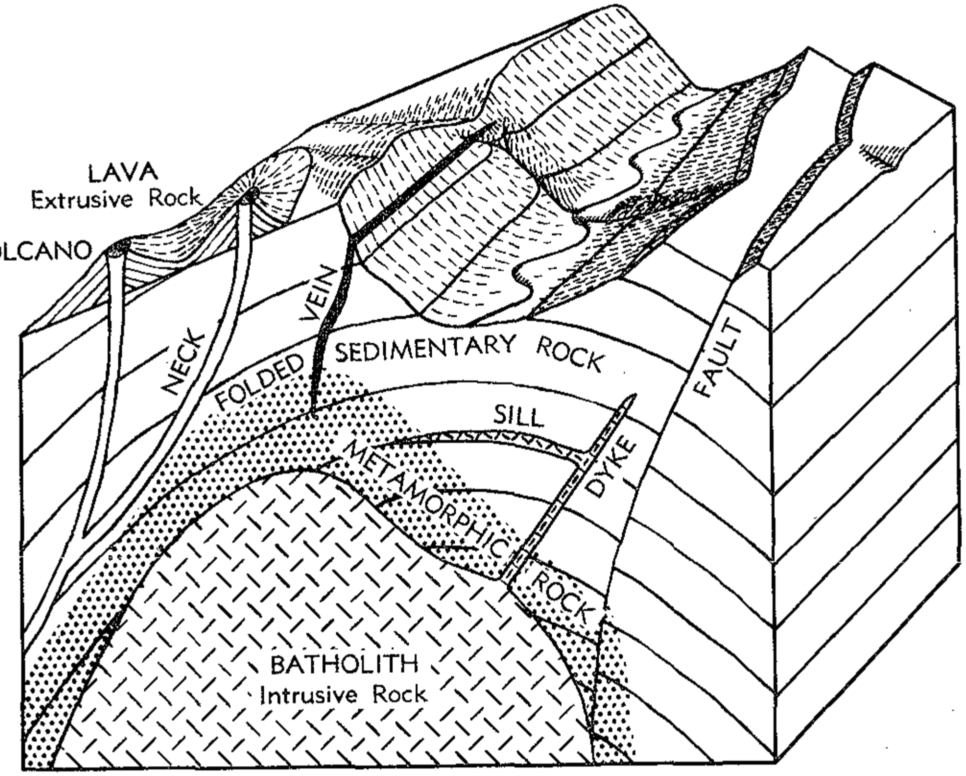

Figure 1. Block diagram illustrating the geological structure of a segment of the earth's surface.

were inactive the land areas of the globe would, in time, be worn down to monotonous, low-lying plains.

However, segments of the earth's crust may rise, sink, or move laterally. The presence of fossil shells and remains of other sea life in rocks above sea level, even in the highest mountains, proves indisputably that many parts of the land once lay beneath the sea. Ancient sea basins have been filled with river-borne debris to depths of several thousand feet, and the rocks formed from the consolidation of the sediments have in some cases been raised thousands of feet above sea level, as the marine fossils found in the Rocky Mountains so magnificently testify.

All rocks forming the earth's crust may be subdivided into three main classes: sedimentary, igneous and metamorphic.

Gravels, sands, silts and muds deposited in layers or beds on the bottom of the sea or of large lakes become compact and hard, forming sedimentary rocks such as conglomerates, sandstones, shales and limestones. These rocks, originally laid down in beds that were practically level, may be raised above sea level by warping of the earth's crust. As a result of this or subsequent movement, the beds are tilted from their earlier horizontal positions. Often they are folded into a series of arches and sags called anticlines and synclines. These folds may be widely spaced and open, or may be tightly compressed. Tightly compressed folds may be arranged in huge fan-like structures containing many complex smaller crenulations.

In many regions folded rocks are broken and displaced along fractures called faults along which the movement may be measured in inches or in miles. Faulting produces shocks that are familiarly known as earthquakes. The destructive earthquake at San Francisco was caused by a displacement of 20 feet along the San Andreas fault-zone. In general, the more complicated the folds and the more numerous the faults the more the entire rock mass is said to be deformed. Some large faults or zones of faulting are known, either directly or by inference, to extend to great depths and to tap reservoirs of molten rock-matter far beneath the surface.

Figure 1 illustrates diagrammatically an ideal section of the earth's crust. Folded sedimentary rocks are intruded by a batholith which has produced metamorphic rock near its upper surface. Some magma has escaped to the surface to form volcanoes and some penetrates the sedimentary rocks as a dyke and a sill. A mineral-bearing vein has also been formed. Erosion has cut into the upper section of the folded rocks, but the deepest stream valley does not yet expose the underlying batholith.

The other two principle classes of rocks are the igneous and the metamorphic.

The interior of the earth is hot. This is known from the increase in temperature with depth observable in mines and deep bore holes, and from the existence of volcanoes. Volcanoes may eject ash and vapours or may pour out molten lava which solidifies to form igneous rock. The molten rock matter, known beneath the surface of the earth as magma, comes from great depths and may find its way to the surface through large or small volcanic vents. However, not all magmas reach the surface, but some cool and solidify at depths of several thousand feet. The solidified lavas poured out on the surface of the earth are called extrusive rocks and the bodies of igneous rock produced by magma that solidifies without reaching the surface are called intrusive rocks.

At great depths magmas cool very slowly and the rock produced is made up of coarse grains, whereas an intrusive body that solidifies near the surface is fine-grained, and the rock produced by the relatively rapid cooling of a lava flow is still finer and may even be glassy in texture. The deep-seated, coarse-grained igneous rocks include granite, syenite, gabbro and many others. Common forms of bodies of intrusive rock such as batholiths, dykes, sills and necks are represented diagrammatically in Figure 1, the various forms are classed according to their size, shape and relation to the intruded rocks.

Many complex reactions take place in a magma chamber, and more happens than the simple cooling of the magma within it, or the escape of some magma through volcanic vents. Hot fluids from the magma may penetrate the surrounding rocks for great distances. At the same time, there may commonly be some earth movement. As a result of increase in temperature, exchange of material, and movements, the surrounding rocks may become greatly altered or metamorphosed. For example, sedimentary rocks may be altered to metamorphic rocks, such as sandstone to quartzite, limestone to marble, or shale to slate, schist or gneiss. Even igneous rocks may be greatly altered, yielding igneous gneisses.

The origin of many mineral deposits is traceable to igneous activity. Although the details are not dealt with here, the essential facts are that the ores were derived from deep, hot sections of the earth and were carried upwards through the agency of heated fluids, to be deposited beneath the surface of the earth as mineral-bearing veins or masses within the rocks. Erosion, the wearing down of the earth's surface, in the course of time exposes part of some mineral-deposits. Such mineral-deposits are usually found in mountainous areas or in the eroded bases of geologically ancient mountains, in the vicinity of igneous rocks, and commonly in older sedimentary or igneous rocks that have been metamorphosed and deformed.

The two most important types of mineral deposit found in British Columbia, other than placer, are veins (most commonly quartz veins) and replacement deposits. Quartz veins are fillings of fractures in the rock by quartz containing various amounts of ore-minerals. The size and continuity of the vein are controlled by the character of the fracture it fills, whereas the character of the mineralization depends upon physical and chemical factors which prevailed at the time of formation.

Replacement deposits are formed in general by the piece-meal solution of the rock and deposition in its place of ore and gangue minerals. They are found chiefly in rocks such as limestone and greenstone which are the most susceptible to this form of chemical action. The deposits are apt to be irregular in outline and to be discontinuous, in contrast to the tabular form of most veins.

In order to better understand the distribution of the various mineral-deposits, and the reasons for their segregation, a general outline of the physical and geological features of the Province follows.

PHYSICAL GEOLOGY OF BRITISH COLUMBIA

British Columbia is made up of a number of mountain systems and a central, rolling or hilly area known as the region of "Interior Plateaux" (see Fig. 2). Little of the land is either low-lying or level and much consists of lofty mountain ranges; the name Interior Plateaux is given to the central region not because the ground is level but because the summits are flat-topped.

The majestic ranges of the Rocky Mountain system extend from Montana northwestward for 400 miles along the eastern border of the Province, and for an additional 500 miles entirely within British Columbia; the mountains die out south of the Liard River, about 40 miles south of the Yukon boundary. The Rocky Mountains are bounded on the west by a remarkably long and straight valley that extends along a north-westerly line continuously throughout the length of the Province, and persists into Montana and the Yukon; it is known as the Rocky Mountain Trench, and has few counterparts in the world.

Three northerly-trending mountain systems in the south-eastern part of the Province lie west of the Rocky Mountain Trench and terminate against it to the north. The Purcell Mountains lie east of the Purcell Trench, west of which are the Selkirk Mountains, forming the backbone of the Kootenays.

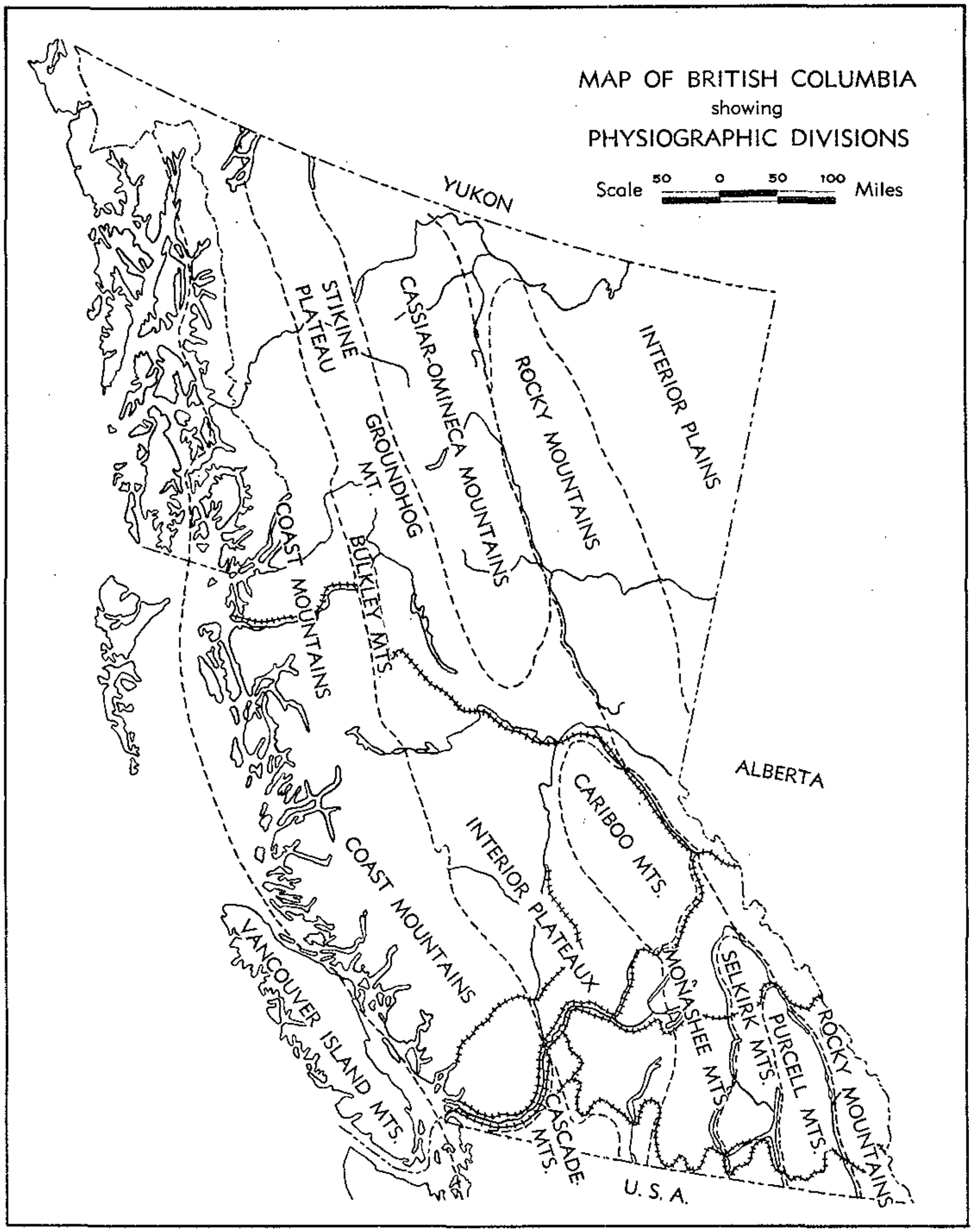

Figure 2. Principal physiographic divisions of British Columbia.

The Monashee Mountains lie west of the Columbia River and east of the headwaters of the North Thompson River. The Cariboo Mountains lie within the Big Bend of the Fraser River. The Cassiar-Omineca Mountains are farther to the northwest and extend into the Yukon.

The Coast Mountains form a rugged chain along the western border of the Province, they are continuous with the Cascade Mountains which lie south of the Fraser River and extend southward into California. The Vancouver Island Range is a smaller counterpart that corresponds with the Olympic Mountains in Washington. The Bulkley and Groundhog Mountains, particularly the former, are closely related to the Coast Mountains and constitute in a sense eastward bulges of them; together they form a connecting cross-link with the Cassiar-Omineca Mountains.

The Interior Plateaux are sharply constricted between the Cascade and Monashee Mountains in the south but broaden rapidly to embrace the central part of the Province and, north of Prince George, reach the Rocky Mountain Trench. They are cut off by the Bulkley Mountains but, north of the Groundhog Mountains, the Stikine Plateau is generally considered to be a northern continuation of them. The plateau region grades insensibly into the mountains on all sides, the distinction being made on the basis of sharpness of summit outline and not on elevation above sea-level. The Interior Plateaux form an extremely important geographic unit, including as it does deep valley bottoms which support orchards and farms, and rolling upland surfaces on which there is much grazing land, such as in the Cariboo and Chilcotin.

The Rocky Mountains are geologically the youngest in the Province. They are made up almost entirely of extensively folded and faulted sedimentary rocks, ranging from Precambrian to Cretaceous in age. Igneous rocks may exist far beneath the surface in the "root zones" of the mountains, but very few are exposed at the surface. The scarcity of igneous rocks at the surface indicates that at the present stage in erosional history the Rocky Mountains are as a whole not favourable for the discovery of many mineral-deposits. The Monarch and Kicking Horse lead-zinc ore-bodies at Field are not far from one of the few exposures of intrusive igneous rock in this mountain system in British Columbia.

In contrast to the Rocky Mountains the Coast Mountains are made up largely of granite and related igneous rocks. The granitic "core" of these mountains is not so extensive as once thought because recent surveys have revealed large areas of metamorphic rocks within the heart of the system and in the flanking ranges. The Vancouver Island Mountains are smaller counterparts of the Coast Mountains. Many mineral-deposits have been discovered on the flanks of and within the Coast

Mountains, in metamorphic rocks derived from Paleozoic and lower Mesozoic volcanic and sedimentary rocks. The northermost part of the Cascade Mountains that extends into British Columbia also consists principally of metamorphosed Paleozoic and Mesozoic rocks, intruded by large granitic masses, and contains important ore-deposits at Hedley and Princeton.

The Bulkley Mountains, which also have a granitic core, may be considered to be a north-easterly extending projection from the Coast Mountains. The geology is similar, although the Bulkley Mountains perhaps contain less granite. Many ore-deposits have been discovered in them in the neighbourhood of Hazelton. The Groundhog Mountains are predominantly sedimentary and contain undeveloped coal seams.

The Cassiar-Omineca Mountains constitute the third largest system. Rocks of many types and ages are intruded by one large and a number of smaller granitic batholiths. Thus far mining has been restricted to the winning of placer gold, but in recent years there has been an increasing amount of more general prospecting and some interesting discoveries have already been made. Transportation facilities have been improved, particularly by the construction of the Alaska Highway, and parts of the area have been mapped.

Between the Omineca and Cariboo Mountains there is about 75 miles of plateau, into which the two systems merge. The Cariboo Mountains extend from near Prince George, past Barkerville, to the head of the North Thompson River. There are a few bodies of igneous rock intruded into ancient sedimentary rocks many of which are Precambrian in age. The Cariboo has long been famous for its placer mining, and in comparatively recent years lode-gold mining has become important. Strangely enough, there are still parts of this region that have been little prospected.

The Monashee Mountains, in the northern part of the system, are similar to the Cariboo Mountains, and there is no well marked dividing line between the two. In the central part, in the vicinity of Shuswap Lake, there is much granite and highly metamorphosed rock represented by gneiss and schist. In the south, large bodies of granite are separated by metamorphosed remnants of former sedimentary and volcanic rocks. Great mineral wealth has been obtained from the southern part of these mountains at Phoenix, Greenwood, Rossland and Beaverdell.

The Selkirks, within the Big Bend of the Columbia River and between Kootenay and Arrow Lakes, are composed of lofty ranges. The folded sedimentary rocks include many that are Precambrian in age. Granite is not abundant in the northern section, but in the southern part batholiths of Nelson granite cover large areas. The Slocan and Nelson mining camps, and others, lie within the Selkirk Mountains.

The Purcell Mountains are separated from the Selkirks to the west by the Purcell Trench, and from the Rockies to the east by the Rocky Mountain Trench. The mountains are geologically similar to the Selkirks but they contain fewer large bodies of granite. The great Sullivan mine is on the eastern flank of the Purcells just west of the Rocky Mountain Trench.

The Interior Plateaux region cannot be described simply, as a unit. The climate, topography, and geology vary in different sections. Boundary lines between plateaux and mountains are drawn with difficulty in many sections, because the two land forms inter-grade. However, the plateaux contain only a few mountain peaks, and the upland areas are flat-topped, although they may rise steeply as much as 4,000 feet above the major valley bottoms.

The geology is complex in the section south of the Thompson River between the Coast and Monashee Mountains. Ancient mountains were worn down to a plain-like surface in Tertiary time, so that the root-zones of granitic and metamorphic rocks were exposed. Sediments were deposited in lake basins, and great quantities of lava flowed out upon the surface of the land. The region was later uplifted, and the stream valleys were cut down to the levels we now see. The result of this complex history is that the plateaux consist of a diversity of rock types ranging widely in age. There are several important mining camps in this region.

North of Kamloops and Ashcroft there is much lava-capped country, north-west of which is the huge ranching country of the Cariboo and Chilcotin. Still farther to the north-west lie the timbered, hilly regions north of the Nechako River. North and north-east of Prince George is a broad expanse of rolling forest land. Little is known of these areas, geologically, as investigations have been confined mainly to the mountain borders. Granitic bodies are not plentiful. It is probable that there are few areas of flat-lying, undeformed rocks. There has been little mining in this general region. In many sections search for minerals is hampered by the cover of non-productive lava flows and by the mantle of debris left by the melting of the glaciers.

North-west of the little known area rather vaguely referred to as the Groundhog Mountains is the Stikine Plateau, which appears to be a counterpart of the larger regions to the south. Much of this area has never been mapped, and travel through it is difficult because of the scarcity of trails.

The early prospectors who explored the country many years ago did not have even this broad outline--generalized and incomplete as it is--of the physical features of the Province. Nevertheless their practical concepts of geology, together with experience gained in mining camps of other regions, enabled them to make discoveries that shaped the early history of British Columbia.

EXTRACTION AND TREATMENT OF ORES

Nature of Ores.

Few metals occur in the native or metallic state in any quantity but are chemically combined with other elements in the form of minerals. Gold, platinum, silver and copper are known to exist in rock in the metallic state but only gold as a rule occurs in sufficient abundance to be mined as such. The metal-bearing minerals (including metallic, or "free" gold) do not occur in nature as segregations of one mineral alone, but in conjunction with other minerals in rock-enclosed bodies known as mineral-deposits.

Many metal-bearing minerals are known but relatively few of them are ore-minerals. An ore-mineral is one from which the metal can be extracted by some process at a profit, owing either to the fact that it is abundant or to the fact that the process of extraction is commercially feasible. Since the ore-minerals do not occur singly in quantity, it follows that an ore is any mineral aggregate from which one or more metals can be extracted at a profit under existing conditions of market and of mining and metallurgical technique.

The ore-minerals always occur with other worthless minerals, known as gangue-minerals, and the parts of a mineral deposit that contain no metals of value are known in the aggregate as gangue or waste. It is only rarely that the whole of a mineral-deposit is economic and constitutes ore. More often only certain parts of a mineral-deposit are mined; these are the ore-shoots.

To illustrate these points more fully the nature of a lead ore will be considered. Lead does not occur in nature in the metallic state, but as the common ore-mineral, galena, a chemical combination of lead and sulphur. A commonly associated mineral of value is sphalerite, a combination of zinc and sulphur which, in addition, may contain some silver and gold. The ore-minerals are contained in or scattered through gangue, of which the commonest minerals are quartz and calcite. If this complex of minerals contains sufficient value in terms of the extracted and refined metals to more than offset the total costs of mining and treatment it is an ore, and is mined.

In the case of some gold ores the gold may be extracted in the form of gold-silver bullion in a relatively inexpensive plant at the mine and sold to the mint. Mercury ores are roasted and the metallic mercury is sold on the open market. Other ores, such as lead, zinc, and copper, are either shipped direct to a smelter or are first concentrated in a milling plant that is operated at or near the mine.

Mining.

In the broadest sense of the word mining includes all phases of the winning of metals from the earth: search for and discovery of mineral deposits, extraction from the rock of raw ore, and subsequent conversion of the ore into its valuable metal constituents. In the narrowest sense, as used here, mining consists of breaking ore from its place in the earth and transporting it to some convenient point at the surface. Generally, a long period of time, from one to three years or more, elapses from the time of discovery of an ore-deposit until actual mining takes place.

The underground operation of mining necessitates driving an opening from the surface (either an adit or a shaft) and from it driving others (drifts, crosscuts, winzes or raises) into or close to the ore-body to be mined. These workings give access to the ore-body at a number of points. A complete system of haulage, supply and ventilation is built. Working faces in adits or tunnels are advanced by drilling holes with compressed-air drills, loading with sticks of dynamite and blasting; the broken rock is loaded on cars and trammed to the surface.

When the ore-body is made accessible and is sufficiently developed mining proper is undertaken. Large openings called stopes are started in which the ore is broken in quantity by drilling and blasting and drawn through chutes into mine cars below. The stopes are blocked out in vertical intervals known as levels and, if large, are further subdivided by pillars supporting the roof. Ore from the stopes is trammed to the surface and dumped into bins whence it is drawn into a mill or hauled to a smelter.

Mining, like any industrial operation, is carried out on a carefully considered cost basis. Although mining costs are generally of first importance, the operator must also consider the cost of treating and handling ore and concentrates, the cost embodied in treatment losses, and the amortization of capital and equipment during the life of the mine. In general large ore-bodies can be mined more economically than smaller ones. However, even among mines of equivalent tonnages there is considerable variation in unit costs. Recovered values from British Columbia ores at mines equipped with mills range from less than $3 per ton to about $20 per ton. A few mines without milling plants ship ore of even higher grade. Recovered value refers to the refined metal after unavoidable treatment losses, and not to the value of the total metal content of the crude ore.

Milling or Concentrating.

Ore produced by many mines is so low in grade that it cannot, as mined, be shipped to a smelter; in other words, the value per ton may not be sufficient to repay the cost of mining and shipping. Such ore is concentrated to raise the grade to a point where it can be economically transported.

A simple if not highly effective method of concentration practiced at small mines and a few of moderate size is that of sorting. Pieces of waste are taken out by hand and discarded, underground or on the surface, and a picking belt is sometimes installed. In this way the grade of the ore is raised.

Most mines have their own milling plants, close to the ore-deposits, and under the same management. In the case of many gold mines the mill is a complete reduction plant, producing bullion, but in some gold mines and all base metal mines the mill is a concentrating plant, in which the raw ore is converted into a product containing a high percentage of the mineral or minerals of value. The process consists of physically separating the ore and gangue minerals and discarding the gangue as a waste product.

The simplest and oldest method of concentration is the separation of materials of different specific gravity by washing with water. This is the method employed by the placer miner for centuries, using pans, rockers and sluice-boxes to separate gold and other heavy metals or minerals from the lighter material of the stream-gravels. The same principle is used in "gravity mills" which were far more common a generation ago than they are now.

Every mill has a crushing and grinding division in which the ore is reduced to a fine powder, in order to completely free the ore and gangue minerals from one another. The remainder of the mill is concerned with the separation of ore from gangue.

In a gravity mill the heavy ore is separated from lighter gangue by pulsating jigs or shaking tables or both; in some instances the waste fraction is passed over blanket-covered tables or through lined boxes before being discarded. A great deal of water is needed for the operation of such a mill.

The flotation process, perfected during the last generation, has almost entirely superseded gravity concentration. Higher recoveries and cleaner products can usually be made, the process not depending on differences in specific gravity. Almost any mineral can be separated from any other, giving it a very widespread application. Also, two or more concentrates can be made from a single ore, which is sometimes an advantage in smelting, and the combined concentrates are worth more than a single one would have been.

The flotation process depends upon the fact that of all the many chemical reagents there are those that will adhere to some minerals and not to others, and that the reagent-coated mineral particles will themselves adhere to oily bubbles. In practice the finely ground ore and water, known as pulp, has certain reagents and some oil or oily substance added to it. The thin pulp is agitated and aerated, and mineral-coated bubbles rise to the surface as a thick froth which is skimmed off: the residue is either retreated or discarded as waste. The concentrate so produced can, by the addition of other reagents, be further subdivided if it consists of more than one mineral. A copper ore containing 1 per cent copper and not amenable to direct smelting can be made to produce a concentrate containing 25 per cent copper which is easily smelted. An ore of lead and zinc will, by flotation, yield both lead and zinc concentrates which may then be smelted separately.

Some mills use a combination of flotation and gravity methods. Some heavy mineral may be extracted in pulsating jigs from the ore before it is too finely ground, particularly if that mineral is brittle and tends to be converted into a slime by fine grinding; the reject of "tailing" from the flotation cells may be passed over shaking tables to effect a further recovery to that obtainable by flotation alone. Every milling plant is designed to treat a particular ore most efficiently, and is built only after exhaustive laboratory tests are made on representative ore.

As already stated many gold mills are complete reduction plants, as it is possible to produce the metal without the necessity for smelting, although in some instances only a part of the gold is recovered and the remainder, contained in concentrates, is shipped to the smelter for extraction. If the gold is free and relatively coarse-grained some may be trapped in jigs and most of the remainder is amalgamated with mercury. Gold will dissolve in cyanide solution, and many mines make an almost complete recovery by cyanidation; the finely ground pulp is treated in large tanks and the gold is precipitated from solution by zinc dust. Certain metals in the ore, notably copper, interfere with the cyanidation process but may be previously extracted from the pulp; a copper-gold concentrate is produced by flotation and the balance of the gold is extracted by cyanide.

Amalgamated gold is recovered by retorting and the vaporized mercury is condensed and used over again. The gold precipitated from cyanide solution is purified in a furnace by firing with flux to remove zinc and other impurities. The molten gold, which always contains some silver, is cast into bricks known as bullion and is shipped to the mint for final refining into pure gold and pure silver.

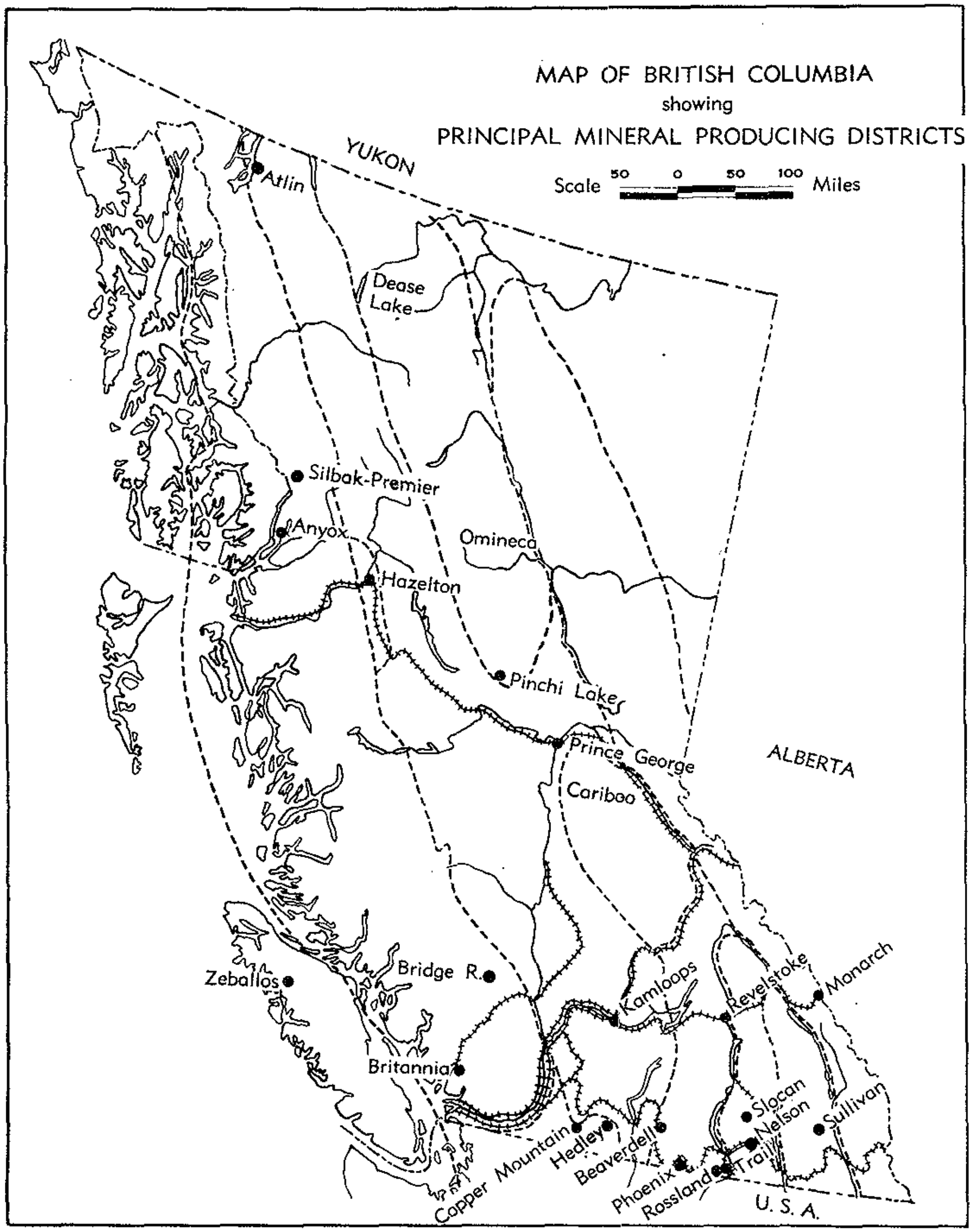

Figure 3. Principal mineral producing districts of British Columbia.

Smelting.

The products of the mine and concentrating mill are crude ore and concentrates in which the minerals are still chemically combined with other elements, notably with sulphur. Consequently, further treatment is necessary in order to break up the chemical compounds (ore-minerals) and recover the metals contained in them. Smelting is the branch of metallurgy that uses heat to melt the ores and concentrates and to reduce them to the various metals. No detailed account of smelting processes will be given, but the following simplified description of lead smelting and brief references to copper and zinc smelting may be of interest.

Lead ores or lead concentrates, consisting essentially of lead sulphide (galena) and more or less gangue, are first roasted to burn off much of the sulphur and to oxidize the lead. The roasted material with suitable added fluxes is then heated in a blast furnace with coke or other material that has a greater affinity for oxygen than has lead. Oxidation of the lead compounds is completed in the blast furnace, and the lead oxide is then reduced to metallic lead. The lead is liquid at this temperature, and settles to the bottom of the furnace. The gangue minerals and the fluxes put into the furnace also melt; this molten material, called "slag," being lighter, floats on top of the lead and is drawn off from the furnace through openings some distance above the bottom. The molten lead is drawn off from the bottom of the furnace through a siphon and is cast into bars which undergo a further refining process in order to make the metal of high purity required by industry.

Copper smelting resembles lead smelting in many ways but has some important differences. Preliminary roasting of concentrates followed by smelting in two stages produces "blister" copper, this is refined to metal of high purity.

Zinc smelting is a distillation process. Natural oxide ores, or sulphides roasted to produce the oxide, are heated with a reducing agent in retorts to drive off the zinc as a vapour that is subsequently condensed to a metallic powder. In many zinc treatment plants, including the one at Trail, roasted concentrates are leached with sulphuric acid. The zinc is extracted from the concentrates as a solution of zinc sulphate, which is purified and then sent to tank rooms where the passage of an electric current through the solution causes the zinc to become plated on aluminum cathodes suspended in the tanks.

SOURCES OF METALS

The principal metal-producing camps and districts are illustrated in Figure 3.

Gold.

Gold, which in the days of the earliest placer mining was the only metal produced, has for the past few years been the most important metal in terms of value. Production comes from both placer and lode-mining.

Placer mining was once done entirely by the individual with sluice-box, pan or rocker. Although there are still a number of such operations, production now comes largely from hydraulic mines. A few operators move the gravel with mechanical equipment such as dragline shovels. In other operations, notably in the Atlin district, the gravel is mined underground, brought to the surface, and washed in sluice-boxes.

The greatest centre of placer production is the Cariboo, where mining has been continuous since 1861. The largest Cariboo operation is the Lowhee hydraulic pit. The Bullion hydraulic operation, now closed, was among the largest in the world. Atlin district is the next important producer, and the Omineca district, centring on Germansen Creek is third. Other active centres are the Cassiar (chiefly in the vicinity of Dease Lake), Tulameen and Similkameen Rivers, and various sections of the Kootenays and lower Fraser and Thompson Rivers.

More than 90 per cent of the gold is produced from lode-mining which has increased steadily during the last ten years. This includes gold recovered from ores of the other metals, principally copper.

The Bridge River area is the largest producer, contributing annually about a quarter of the total. The two mines at present operating are the Bralorne and the Pioneer. The Bralorne, which normally mines and mills about 500 tons of ore per day, is the largest gold mine in the Province.

The Nelson area, which is the next in importance, produces mainly from the Sheep Creek district. The next four areas are almost equal producers of gold, namely Cariboo (Wells), Portland Canal, Hedley, and Zeballos. The Silbak-Premier mine in the Portland Canal area produces an ore in which silver amounts to a fifth of the gold value, a much higher ratio than in any of the other larger gold mines.

The copper mines at Britannia and Copper Mountain each contribute an important quantity of gold, although the amount per ton of ore mined is very small. Another source worth special mention is the old mining camp of Rossland. The rich gold-copper ores of this celebrated camp were once considered worked out, but in recent years a number of small operators have made a splendid contribution through mining remnants in the old workings and dumps.

The rest of the gold is produced from a number of scattered properties, mined for their gold content alone, primarily for other metals, or because of the combined values.

Silver.

British Columbia produces about half the silver output of Canada. Of this amount, a large percentage comes from the Sullivan mine at Kimberley, which is worked primarily for lead and zinc. Thus, as in most other parts of the world, silver is mainly a by-product metal.

Silver was produced in important quantities from the lead-zinc-silver mines of the Kootenays during the early years when the average price of silver was about 60 cents per ounce. The value of the Provincial output, but not the quantity, rose sharply during the period 1914-1919. Shortly after, when the problem of milling the ore of the Sullivan mine was solved, silver production greatly increased.

There has been a decline in activity of many of the smaller silver-bearing base metal mines, as a result of low prices in comparatively recent years; nevertheless, the silver production of the Province has been maintained at normal level by the Sullivan and other deposits. Although the silver content of the Sullivan ore is low, the mining of 6,000 tons a day in 1939 resulted in an output ten times that of the next ranking single producer. The Silbak-Premier mine on Portland Canal and the Highland Bell mine at Beaverdell produce about equal amounts and vie for second place, although the former is primarily a gold mine. The Highland Bell has the distinction of being the only mine in the Province that relies almost entirely upon the silver content of the ore. The large tonnages of copper ore mined at Britannia and Copper Mountain contribute a small but important amount of silver. Mines in the Nelson and Slocan areas produce small amounts. The remaining production is derived from sources scattered throughout the Province, of which the gold mines of Bridge River, Cariboo and Hedley contribute a significant part.

Lead and Zinc.

Lead and zinc production must be considered together because the two metals are so intimately associated in nature that separate mining of either is possible in very few ore-deposits. The largest single producer is the Sullivan mine, at Kimberley, owned by the Consolidated Mining and Smelting Company of Canada, Limited. The ore is milled to produce both lead and zinc concentrates which are shipped by railway to the Company's smelter, at Trail, for smelting and refining.

Additional production comes chiefly from Base Metals Mining Corporation at Field, the Lucky Jim, Standard and others in the Slocan and the Highland Bell at Beaverdell. A further production of zinc will be contributed by the re-opening of the Kootenay Florence at Ainsworth. An important amount of lead, but no zinc, comes from the Portland Canal district, a small additional supply from about Hazelton, and from the southern coastal area.

Copper.

Copper was first produced from the gold-copper ores of Rossland, and somewhat later the large deposits at Phoenix and Deadwood in the Boundary district were mined.

The Britannia mine, in operation for over 40 years, has been the largest copper producer. The ore is concentrated by flotation. The Copper Mountain mine, near Princeton, produces ore which is also concentrated by flotation, and shipped to Tacoma. These two properties produce almost the entire output of copper.

The Anyox mine, formerly a large producer, was abandoned in 1935 owing to depletion of the ore reserves.

Copper from other sources is almost negligible in amount, although some is contributed by the gold mines at Hedley.

Antimony.

Antimony has recently been produced as a by-product of the Trail smelter. The small percentage of this metal contained in many of the lead-zinc-silver ores is recovered during the process of refining the lead bullion. In addition, a small, sporadic output of high-grade antimony ore has been made.

Bismuth.

Bismuth is another by-product of the refinery at the Trail smelter. No deposits are known that are considered mineable for their bismuth content alone.

Cadmium.

Cadmium is a third metal in the same category. It is closely associated with zinc, occurring in such small quantities, however that it is only obtained as a by-product in the treatment of the zinc.

Indium.

Indium has been produced in small amounts at Trail.

Tin.

Tin was first produced in British Columbia in 1941 from the ore of the Sullivan mine. An extremely small percentage has long been known to exist in this ore but no economic method of recovery could be devised. After much research certain modifications in practice were made in the milling plant, and a small but satisfactory amount of tin concentrate is recovered and is smelted to produce marketable tin.

Mercury.

Some mercury was produced in 1895 at Copper Creek, near Kamloops, and small amounts have been obtained from the same area and the Bridge River area in more recent years. In 1940, this strategic metal began to be produced in quantity from a deposit at Pinchi Lake, near Fort St. James. Further production appears to be likely from the area north of Pinchi Lake and possibly from the district north-east of the Bridge River.

Platinum.

During the period 1885-1890, British Columbia was an important world producer of platinum, when mining of the Tulameen and Similkameen placers was at its height. Small, sporadic, placer-gold operations on those rivers still account for most of the annual British Columbia output of from 20 to 30 ounces. A small amount comes from other placer grounds, notably the Cariboo. Platinum was only worth about 50 cents an ounce between 1860 and 1880 and was considered a nuisance by early miners in whose sluice-boxes it lodged. A pocketful of platinum would only provide one evening's entertainment for one miner in a saloon.

Tungsten.

Tungsten, one of the most important strategic metals, was mined in British Columbia in 1939. The metal itself is not produced here, but the ore is sorted or milled to a high-grade concentrate which is shipped east. Columbia Tungstens Ltd., at Wells, was a small producer in the past, but at present (March, 1943) the largest producer is the Red Rose mine at Hazelton. The important discovery of the Emerald ore-deposit at Salmo will soon contribute a substantial amount of tungsten concentrates. Other production comes or has come from the Cariboo, Bridge River and Revelstoke areas.

Arsenic.

There is normally a large production of arsenic, derived as a by-product from the smelting of other ores, which may or may not be marketable. However, the present war has expanded the demand so that arsenic from the copper concentrates of the Hedley gold ores is recovered and bought by the Tacoma smelter.