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Metal Production from Ore Deposits in Different Host Rocks in Montana

Robert F. Gale

METAL PRODUCTION FROM ORE DEPOSITS IN DIFFERENT HOST ROCKS IN MONTANA

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A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Geological Engineering

MONTANA SCHOOL OF MINES
Butte, Montana

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INTRODUCTION

Montana has yielded metals valued at more than 3 1/3 billion dollars. Most of the valuable minerals came from veins cutting some type of rock. It is known that many different kinds of rocks serve as host to the ore deposits of Montana, but the relative importance of each of these kinds of rock as a host for ore deposits has never been described in any published report. An analysis of this ore occurrence was chosen by the writer as the subject of a thesis for the Bachelor of Science degree in Geological Engineering at Montana School of Mines. This analysis, made during the winter of 1950-1951, has come entirely from published reports, a list of which is given in the Bibliography following the body of the text.

Many reports on the different mining districts in Montana were studied; the production figures, types of deposits, metals produced, and host rocks containing the deposits were assembled into a number of tables. The production figures quoted in the tables should be accepted with some reservation. In many instances, the only available report on a district was published a number of years ago, and further significant production may have occurred. Also, reliable records are not available for many districts, and the figures quoted are estimates. A number of the mining districts have deposits in several types of host rocks; here, the author apportioned the production according to the available information.

Information is not available or is not complete for a large number of less important mining districts. These districts and the available information concerning them are listed in a separate table.

The author wishes to express his gratitude to Mr. U. M. Sahinen, because his unpublished thesis on The Mining Districts of Montana, greatly expedited the task of assembling the information contained in this thesis.

MINING HISTORY AND PRODUCTION OF METALS

Gold

Although the Lewis and Clark Expedition of 1805 and 1806 reported the presence of gold in Montana, active mining did not begin until the discovery of gold on Gold Creek by the Stuart brothers in 1860. Evidently, the first discovery was not very profitable; but in 1862, gold was discovered at Bannack, and the era of the rich placers began. A year later, William Fairweather discovered gold in Alder Gulch, which developed into the richest placer ground in the world. An estimated $8,000,000 worth of gold was produced during the first year of mining here.

Soon after the discovery of gold at Alder Gulch, many other placer discoveries were made throughout Montana. Some of the important discoveries were Last Chance Gulch and German Gulch (1864), Highland (1865), and Confederate Gulch (1866). Placer mining in Montana reached a peak in 1866 when $18,000,000 worth of gold was recovered.

When the high grade placers were exhausted, the ditch period began. Many miles of ditches were constructed to provide the additional water needed to work the leaner placer deposits. In 1895, the first gold dredge built in the United States was launched at Bannack. Its success led to large scale dredging operations throughout the state. Several dredges are in operation at the present time. (45, pp. 2-3)

Lode mining in Montana began at Bannack in 1862. As the placers began "playing out", more and more lode claims were taken. One of the most important gold mines discovered in Montana is the Drumlummon mine at Marysville. Lode mining for gold has persisted to the present time. (2, pp. 1-2)

Minerals Yearbook, 1948 estimates that Montana has produced 17,215,336 ounces of gold valued at $386,989,972 since 1862. (62,pp. 1528) In yearly production, Montana ranks eighth among the gold producing states. (4, p. 420)

Silver

The first silver mines in Montana were discovered in 1863 at Blue Wing and Argenta. The Hope Mining Company constructed the first smelter in the state at Argenta in 1865. In 1875, the Granite Mountain Mine and the James G. Blaine mines were discovered near the town of Philipsburg. For several years, these two mines were the largest silver producers in the world.

The first lode locations in Butte were made in 1864. High grade silver ore was found on the Travona Lode, and a mill was soon constructed to treat the ore. By 1887, two hundred and ninety stamp mills were in operation. (2, p. 3) Today, Butte is the largest producer of silver in the United States; however, the silver is a by-product of copper and zinc ores. (2, pp. 3-4)

Montana leads all states in the total silver production.

(4, p. 454) From 1862 to 1948, Montana produced 762,406,729 fine ounces of silver worth $559,073,902. (62, p. 1528) It now ranks 3rd in yearly production among silver producing states.

Copper

The history of copper mining in Montana is centered almost entirely in Butte. As previously mentioned, Butte began as a silver camp. In 1880, Marcus Daly bought the Anaconda claim. His silver mining operations were unsuccessful, but at a depth of 340 feet, a rich copper vein was found. This turn of events caused widespread disappointment among mining men. Neither suitable transportation nor a satisfactory method of treating sulphide ores was available. Many mine owners felt that Butte's mining days were limited. However, Daly, with great optimism, purchased a number of surrounding claims and stated that Butte would be the richest hill on earth. He constructed a smelter at Anaconda to treat his copper ore. This plant was soon out of date, and he constructed a new and larger plant at the site of the present day smelter in Anaconda. W. A. Clark soon followed by constructing a smelter south of Butte to treat his ore. Shortly thereafter, a number of smelters were built in and around Butte. (45, pp. 5-7)

When F. A. Heinze organized the Montana Ore Purchasing Company, he obtained a number of strategic claims and started a wave of lawsuits by virtue of the apex law. Eventually, the Standard Oil Company, which had bought a controlling interest in the Anaconda Company from Daly, bought the interests of Heinze and Clark. (45, p. 6-7)

Butte has continued to the present time as one of the large copper producing areas of the world. From 1862 to 1948, Montana has produced 6,694,505 short tons of copper valued at $1,951,400,042. All but a very small fraction of this amount has been produced in Butte. (62, p. 1528) Montana ranks third in annual copper production in the United States. (4, p. 482)

Lead

It was previously mentioned that the first lead smelter was built at Argenta; however, like copper mining, lead mining was retarded by lack of transportation, and only the silver was shipped from the smelter at Argenta. In 1882, the Oregon Short Line Railroad was constructed, and mining then began on a much larger scale throughout the state. (45, p. 7) A smelter was built at Great Falls to treat the ores from Neihart and Monarch. In 1888, a lead smelter was constructed at East Helena by the American Smelting and Refining Company, and this plant is still in operation. (2, p. 5)

Montana is eighth among the lead producing states. (4, p. 529) From 1862 to 1948, the state has produced 729,519 short tons of lead valued at $88,494,878. (62, p. 1528)

Zinc

For many years, zinc was considered worthless in Montana. Most of the silver and lead ores contained some zinc, the amount of which usually increased with depth. Although the silver content remained constant, some mines were forced to close because of the severe penalty levied by smelters for treatment of zinc-bearing ores.

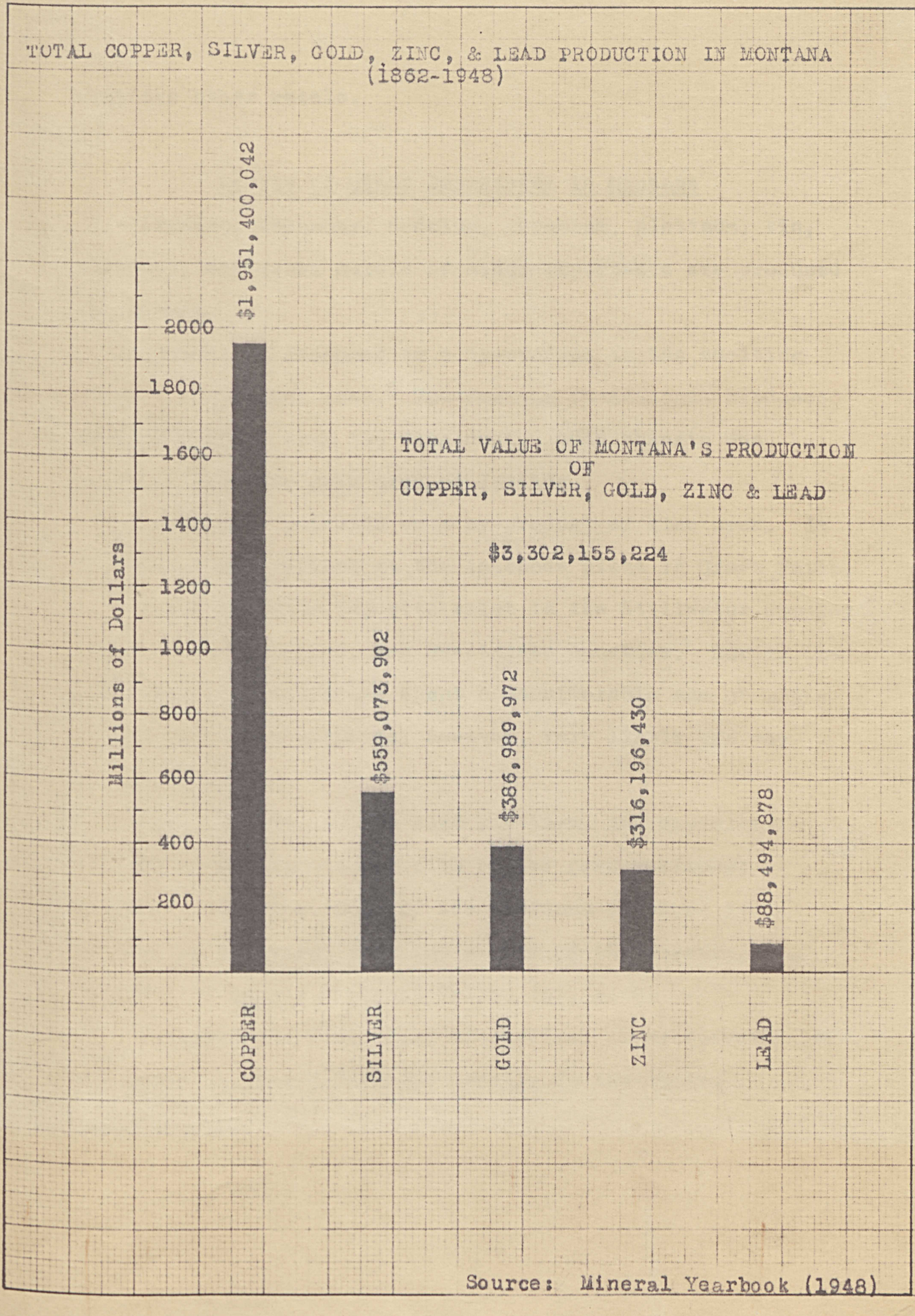
With the development of flotation, zinc could be separated from lead. Zinc then came into its own as a valuable mineral. An electrolytic plant was built at Great Falls in 1916 and has been in operation to the present day.

The Butte district also is the most important zinc producer in Montana, but much zinc has been produced at Basin, Wickes, Neihart, and Philipsburg. (2, pp. 4-5) Montana has produced 1,967,062 short tons of zinc valued at $316,196,430. (62, p. 1528)

Manganese

Montana produces two-thirds of the manganese mined in the United States. Butte and Philipsburg are the major producers. Philipsburg is the sole producer of battery grade oxide ores in this country. Manganese is known in other districts in Montana; however, none of the deposits appear to be large, and very little ore has been shipped. (45, p. 8)

Total production figures for manganese are not available, but the production is believed to be small in comparison


TOTAL COPPER, SILVER, GOLD, ZINC, & LEAD PRODUCTION IN MONTANA
(1862-1948)
Millions of Dollars
2000
1800
1600
1400
1200
1000
800
600
400
200
$1,951,400,042
$559,073,902
$386,989,972
$316,196,430
$88,494,878
COPPER
SILVER
GOLD
ZINC
LEAD
TOTAL VALUE OF MONTANA'S PRODUCTION
OF
COPPER, SILVER, GOLD, ZINC & LEAD
$3,302,155,224
Source: Mineral Yearbook (1948)

with the other metals.

Metals of Minor Importance in Montana

Arsenic, antimony, cadmium, chromium, platinum, tin, tungsten, and other metals of minor importance are produced in Montana.

Arsenic is produced as a by-product in the smelting of gold and copper ores. The smelter in Anaconda produces arsenious oxide from the flue dust. Some arsenic was produced from the gold ores at Jardine.

Cadmium is obtained as a by-product of zinc ores. It is leached and refined at the Anaconda plant in Great Falls.

Large chromite deposits exist in the Stillwater complex in Stillwater, Carbon, and Sweetgrass counties. During the last war, the government spent a considerable sum of money to develop these deposits; however, very little ore was ever shipped.

Placers have yielded some platinum, and appreciable amounts of platinum occur with copper ores northwest of Missoula. However, most of the platinum produced in Montana is recovered from the slimes of the electrolytic refining of copper at Great Falls. (45, p. 9)

Tungsten has been mined at Jardine. Some tungsten is recovered in placer deposits locally in the state.

GENERAL GEOLOGY OF WESTERN MONTANA

Topography

Montana may be divided into three topographic areas of about equal size: first, the eastern or plains area; second, the central or isolated mountains area; and third, the western or mountainous area. The mining districts are found mainly in the western area, although some isolated districts are found in the mountains of the central area.

The eastern or plains area is part of the Great Plains of the United States and Canada. The gently rolling upland surface is disected by stream valleys and interrupted by badlands in certain parts of the area. The badlands have been formed by differential erosion of the nearly horizontal sediments. No metal mines are found in the eastern area.

In the central area, isolated mountains rise above the surrounding plains. The mountains are dome-shaped uplifts, which have a central core of igneous or pre-Cambrian rocks. Mining districts are found in some of the isolated mountains.

The entire western area is very mountainous. The northern part consists of many parallel, north-south trending ranges, which were formed by block faulting of broadly folded sediments. In the southern part, the ranges are broken up into diversely arranged groups of mountains. Large valleys lie between the various mountain ranges. These valleys are the sites of former lakes, which were partially filled with sediments, and then became drained. In the mountains, swift streams have cut deep valleys. Many of these valleys are glaciated. Usually, cirques and glacial lakes are found at the heads of these valleys. (45, p. 10)

Historical Geology

Western Montana has a complex and diversified geologic history. Near the close of Archeozoic time, the ancient sediments were folded, faulted, intruded by igneous rocks. A period of erosion followed. Montana then gradually subsided, and during early or middle Proterozoic time, the Cherry Creek series were deposited. Eventually, another period of mountain making occurred. The sediments were warped, folded, and highly metamorphosed; and again this orogeny was followed by a long period of erosion which produced a nearly level plain. As uplift continued to the west, the Belt series was deposited in a shallow sea that entered Montana from the North. The sea receded, and more erosion followed. However, the sea returned at the beginning of the Paleozoic era.

About the middle of the Cambrian period, the Flathead sandstone, now a quartzite, was deposited unconformably on the Belt series. Limestones and shales were deposited throughout the remainder of the Cambrian period. During middle Ordovician time dolomitic sediments were deposited in eastern Montana. The seas then retreated from Montana and did not return until the Devonian period. During the remainder of the Paleozoic era and throughout the Mesozoic era, the seas fluctuated. From the Proterozoic era until late Cretaceous time no large diastrophic movements occurred in Montana, although many interruptions in sedimentation occurred. (45, p. 16)

After the Colorado shale was deposited, a broad uplift began in western Montana during middle Cretaceous time. The rate of sedimentation to the east was accelerated. During upper Cretaceous time, uplift continued, and andesitic lavas and breccias flowed from vents throughout western Montana. The products of volcanism were carried eastward into the shallow Cretaceous sea. As mountain building continued, intense folding and faulting took place in western Montana, and the Rocky Mountain structures were developed.

At the close of the Cretaceous period, a large igneous body, called the Boulder batholith near Butte and the Idaho batholith farther westward, intruded the sediments and lavas of western Montana. As the igneous mass cooled, a segregation of products took place. The more siliceous part of the magma solidified last and formed the aplite dikes and quartz porphyry rocks which are found injected into the main quartz-monzonite mass. Upon additional cooling, fissures were formed in the granite and near-by sediments. These fissures allowed mineral bearing solutions and gasses to escape from the deeper portions of the batholith. During the upward journey of the solutions, minerals were deposited throughout the fissures. With the end of the igneous activity erosion uncovered much of the batholith, and then came flows of rhyolitic and basaltic lavas. During the uplift and igneous activity in western Montana, eastern Montana received enormous quantities of sediment from the disturbed area.

During middle Tertiary time, block faulting and possibly lava flows blocked the ancient drainage of western Montana. Large lakes formed in the obstructed valleys. These lakes soon filled with sediments. The lakes overflowed, new channels were cut, and the drainage pattern was changed. (23, pp. 10-12)

Since the draining of the lakes, geologic activity in Montana has been largely confined to erosion and some glaciation. (45, p. 17)

Sedimentary Rocks

Notes on the lithology are given in condensed form in Table I. The formations described lie in the Helena-Philipsburg area. This area contains the largest concentration of important mining districts in Montana.

Igneous Rocks

Three major stages of igneous activity occurred in western Montana between Cretaceous and Oligocene time: first, the andesite stage; second, the granite stage; and third, the rhyolite stage.

Table I - Geologic Formations of the Helena-Philipsburg Area

ERA	SYSTEM	FORMATION OR SERIES		CHARACTER
Cenozoic	Recent	Alluvium		Sand, Gravel, Clay. (Placer gold)
	Pleistocene	Glacial Drift		Moraine material.
	Tertiary	Lake Beds & Volcanics		Sand, Gravel, Clay, Volcanic ash.
Mesozoic	Cretaceous	Livingston	Montana gp	Lavas, Agglomerates, interbedded sediments. Sandstone and shale.
		Colorado group		Shales, Sandy shales, some sandstones.
		Kootenia		Sandstone, shale, some limestone.
	Jurassic	Ellis		Limestone, shale, sandstone.
Paleozoic	Permian	Phosphoria		Sandstone, shale, limestone, phosphate beds
	Pennsylvanian	Quadrant		Quartzites, sandstones, limestones.
	Mississippian	Amsden		Limestone, shale, sandstone.
		Madison		Limestone.
	Devonian	Threeforks		Shale, limestone.
		Jefferson		Limestone & dolomite.
	Cambrian	Red Lion	Dry Creek	Shale, limestone.
		Hasmark	Pilgrim	Limestone.
			Park	Shale.
			Meagher	Limestone, shale, dolomite.
		Silver Hill	Wolsey	Shale and limestone.
		Flathead		Quartzite.
Proterozoic	Algonkian	Belt series		Quartzite, argillite, limestone, hornstone, sandstone, shale, and slate.
		Cherry Creek series		Slates, marble, schists, and gneisses.
Archeozoic	Archean	Pony series		Schist and Gneiss

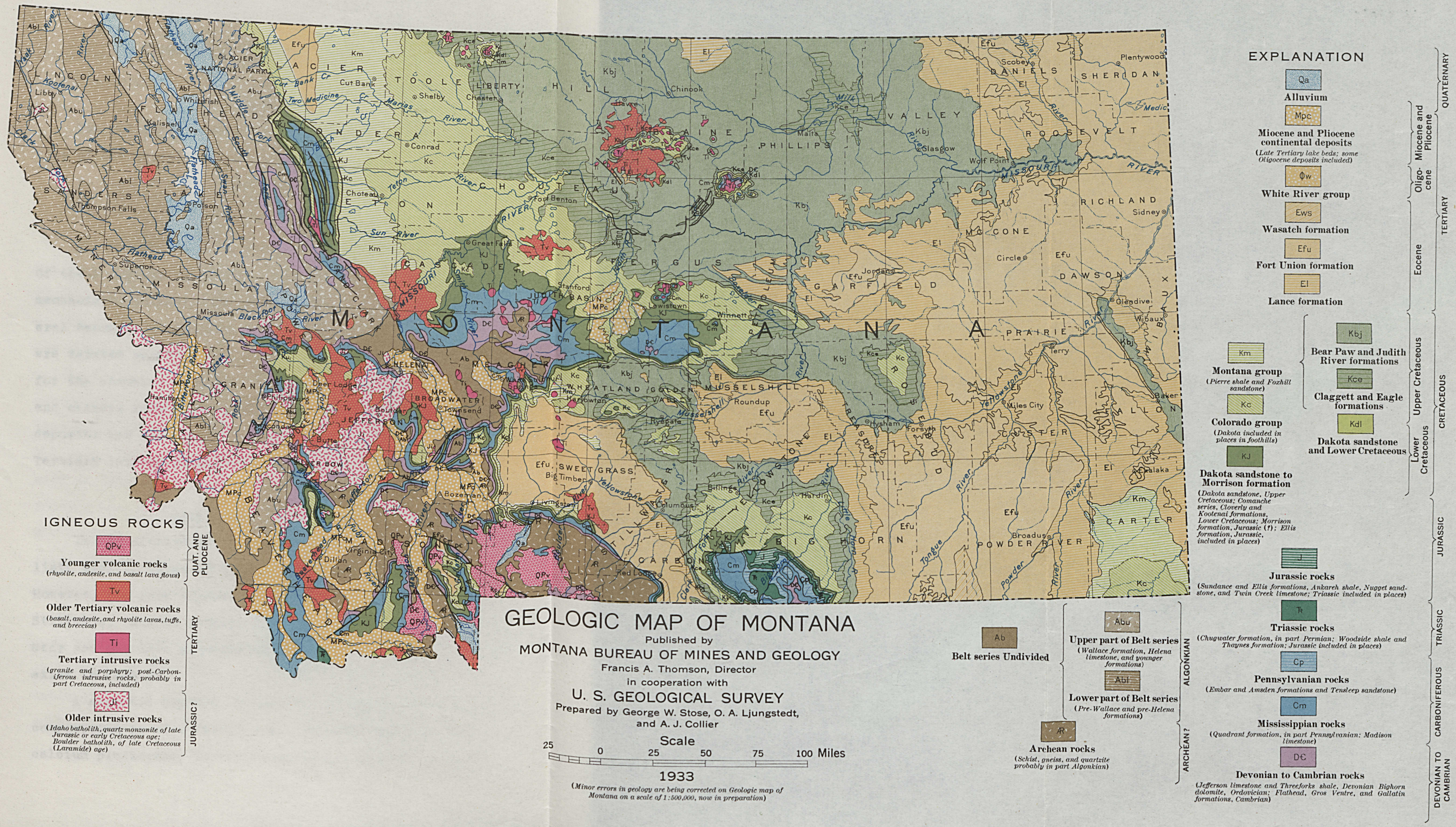
Source: (54, Plate 2)

Because of the wide variation in the composition and texture of the igneous rocks found throughout western Montana, it is beyond the scope of this paper to fully describe them. However, the predominate rocks formed during each stage will be given.

Igneous rocks formed during the andesite stage consisted of augite andesite, andesite porphyry, amygdaloidal andesite, basalt, andesitic breccia and tuff, gabbro, and diabase.

The main intrusive mass of the granitic stage was of quartz-monzonite composition. The smaller outlying stocks are generally of a grano-diorite composition. Aplite dikes, quartz porphyry, porphyry dikes, and pegmatites are common.

During the rhyolite stage, thick rhyolite lavas were extruded. Later lavas graded from andesites to basalts.


GEOLOGIC MAP OF MONTANA
Published by
MONTANA BUREAU OF MINES AND GEOLOGY
Francis A. Thomson, Director
in cooperation with
U. S. GEOLOGICAL SURVEY
Prepared by George W. Stose, O. A. Ljungstedt, and A. J. Collier
Scale
25 0 25 50 75 100 Miles
1933
(Minor errors in geology are being corrected on Geologic map of Montana on a scale of 1:500,000, now in preparation)
EXPLANATION
Qa Alluvium
Mpc Miocene and Pliocene continental deposits (Late Tertiary lake beds; some Oligocene deposits included)
Φw White River group
Ews Wasatch formation
Efu Fort Union formation
El Lance formation
Km Montana group (Pierre shale and Foxhill sandstone)
Kbj Bear Paw and Judith River formations
Kce Claggett and Eagle formations
Kc Colorado group (Dakota included in places in foothills)
Kdl Dakota sandstone and Lower Cretaceous
KJ Dakota sandstone to Morrison formation (Dakota sandstone, Upper Cretaceous; Comanche series, Cloverly and Kootenai formations, Lower Cretaceous; Morrison formation, Jurassic (?); Ellis formation, Jurassic, included in places)
J Jurassic rocks (Sundance and Ellis formations, Ankareh shale, Nugget sandstone, and Twin Creek limestone; Triassic included in places)
Tr Triassic rocks (Chugwater formation, in part Permian; Woodside shale and Thaynes formation; Jurassic included in places)
Cp Pennsylvanian rocks (Embar and Amsden formations and Tensleep sandstone)
Cm Mississippian rocks (Quadrant formation, in part Pennsylvanian; Madison limestone)
DC Devonian to Cambrian rocks (Jefferson limestone and Threeforks shale, Devonian; Bighorn dolomite, Ordovician; Flathead, Gros Ventre, and Gallatin formations, Cambrian)
Ab Belt series Undivided
Abu Upper part of Belt series (Wallace formation, Helena limestone, and younger formations)
Abl Lower part of Belt series (Pre-Wallace and pre-Helena formations)
AR Archean rocks (Schist, gneiss, and quartzite probably in part Algonkian)
QUATERNARY
Miocene and Pliocene
Oligocene
Eocene
TERTIARY
Upper Cretaceous
Lower Cretaceous
CRETACEOUS
JURASSIC
TRIASSIC
CARBONIFEROUS
DEVONIAN TO CAMBRIAN
ALGONKIAN
ARCHEAN?
IGNEOUS ROCKS
QPv Younger volcanic rocks (rhyolite, andesite, and basalt lava flows)
QUAT. AND PLIOCENE
Tv Older Tertiary volcanic rocks (basalt, andesite, and rhyolite lavas, tuffs, and breccias)
Ti Tertiary intrusive rocks (granite and porphyry; post-Carboniferous intrusive rocks, probably in part Cretaceous, included)
TERTIARY
Ji Older intrusive rocks (Idaho batholith, quartz monzonite of late Jurassic or early Cretaceous age; Boulder batholith, of late Cretaceous (Laramide) age)
JURASSIC?
MONTANA

TYPES OF ORE DEPOSITS IN MONTANA

General

The following processes are responsible for the formation of ore deposits in Montana.

1. Late magmatic segregation
2. Contact metasomatism
3. Hydrothermal solutions
   - Cavity filling (vein formation)
   - Replacement
4. Mechanical concentration (4, p. 69)

Of these various processes, hydrothermal solutions and mechanical concentration have formed the most valuable mineral deposits in Montana. All of the deposits in Montana are related genetically to some igneous body. (28) Except for the chromite deposits in the Stillwater Igneous Complex, and certain vein systems near Jardine, all of the major deposits are related to the late Cretaceous and early Tertiary igneous intrusions. (28 & 47)

Late Magmatic Segregation

In his classification of mineral deposits, Bateman lists several types of magmatic concentrations. (4, p. 71) However, the late magmatic segregation deposit of the Stillwater Igneous Complex and similar deposits near Silver Star are the only magmatic deposit known by the author to exist in Montana.

A magmatic deposit is actually an igneous rock whose composition is of value to man. In basic magmas, the calcium plagioclase crystallizes first, and the residual liquid becomes enriched in iron and chromium oxides. The liquid segregates, or drains out of the crystal interstices. Upon cooling, the residual liquid forms a large sill-like deposit parallel to the anorthosite, norite, or gabbro host rock. (4, p. 77)

Contact Metasomatism

Contact metasomatic deposits are formed by high temperature, mineral-carrying gasses which escape into the surrounding rocks during and shortly after the consolidation of the intrusive magma. The invaded rock is replaced by new minerals. The replacement is made on a volume for volume basis. Limestones and dolomites are generally more susceptible to replacement by contact metasomatic processes than other types of rocks.

Most contact metasomatic deposits are related to magmas with an intermediate composition; these deposits are rarely found associated with ultrabasic or very acidic magmas. The deposits are usually found very near or adjacent to the intrusive with which they are related, and they are generally relatively small, irregular, and difficult to exploit.

Contact metasomatic deposits have contributed moderately to Montana's mineral production. The ore-body of the Cable mine in Granite county is an excellent example of a contact metasomatic deposit. (4, pp. 82-92)

Hydrothermal Solutions

Hydrothermal processes are sub-divided into two major methods of mineral deposition: (1) cavity filling and (2) replacement. However, hydrothermal deposits are usually formed by a combination of the two methods. Deposits, formed by hydrothermal solutions, are responsible for a predominate share of the mineral wealth produced in Montana.

Of the various types of hydrothermal deposits in Montana, fissure veins are the most important. Fissuring results from stresses in the intrusive as it shrinks upon cooling. Also faulting forms fissures. Hot, ascending, mineral bearing solutions deposit minerals in the fissures. The wall rock may be replaced to a greater or lesser degree by metasomatic processes. The ascending solutions may continue on out into the sedimentary rocks through channels formed by faults, bedding planes or fractures. Fissure veins tend to change in composition and size when they pass from one formation to another. (4, pp. 94-124)

Butte is a classic example of the fissure vein type of deposit. Both cavity filling and replacement are responsible for the mineral deposition. Some of Butte's veins are 7,000 feet long and over 4,000 feet deep. Fissuring was formed both by tension fracturing and by faulting. (4, pp. 491-494)

Shear-zone deposits, bedding-plane deposits, stockworks, saddle-reefs, and ladder veins are minor variations of the fissure vein type of deposit. (4, pp. 124-129)

Breccia filling deposits are formed by the deposition of minerals from hydrothermal solutions in breccia filled volcanic pipes or in the openings made by a cave collapse breccia. (4, pp. 129-135)

Replacement deposits have been important in Montana. Although replacement and cavity filling go hand in hand, replacement processes are often predominately responsible for the resulting mineral deposit. Deposits formed by replacement processes are classified as (1) massive replacements, (2) lode replacements, and (3) disseminated replacements.

Replacement is a volume for volume exchange. Ascending hydrothermal solutions carry the minerals to the point of replacement and carry away the replaced material through fissures, bedding planes, faults, and fractures. Limestone and dolomite are more susceptible to replacement than other rocks. (4, pp. 137-154) Montana has many examples of replacement deposits. Philipsburg has produced a large quantity of ore from replacement deposits in limestone.

Supergene Enrichment

Supergene sulphide enrichment has been important in some of the Montana mining districts. Copper and silver deposits receive the greatest benefit from this process. Non-commercial deposits may be upgraded sufficiently to have commercial value, and rich deposits may be made even richer.

Oxidation and suitable hypogene minerals are necessary for supergene enrichment to take place. As ground water percolates down through the ore deposit, the oxidized minerals are taken into solution. Ferric sulfate and sulfuric acid are formed during the oxidation of iron pyrite, which is generally present. These two substances accelerate the process and aid in dissolving the valuable oxidized minerals. Below the water table, the copper or silver in solution replaces other metals in the hypogene sulfide deposit. The replacement is a volume-for-volume, not a molecule-for-molecule exchange.

In general, supergene enrichment will not take place if the oxidized zone contains carbonate rocks or if the solutions do not encounter sulfide minerals below the water table.

Ore deposits that have been enriched in this manner often bring disappointment to the mine owners. When the depth of supergene enrichment is exceeded, the deposits may become non-commercial in grade. (4, pp. 274-275)

Mechanical Concentration

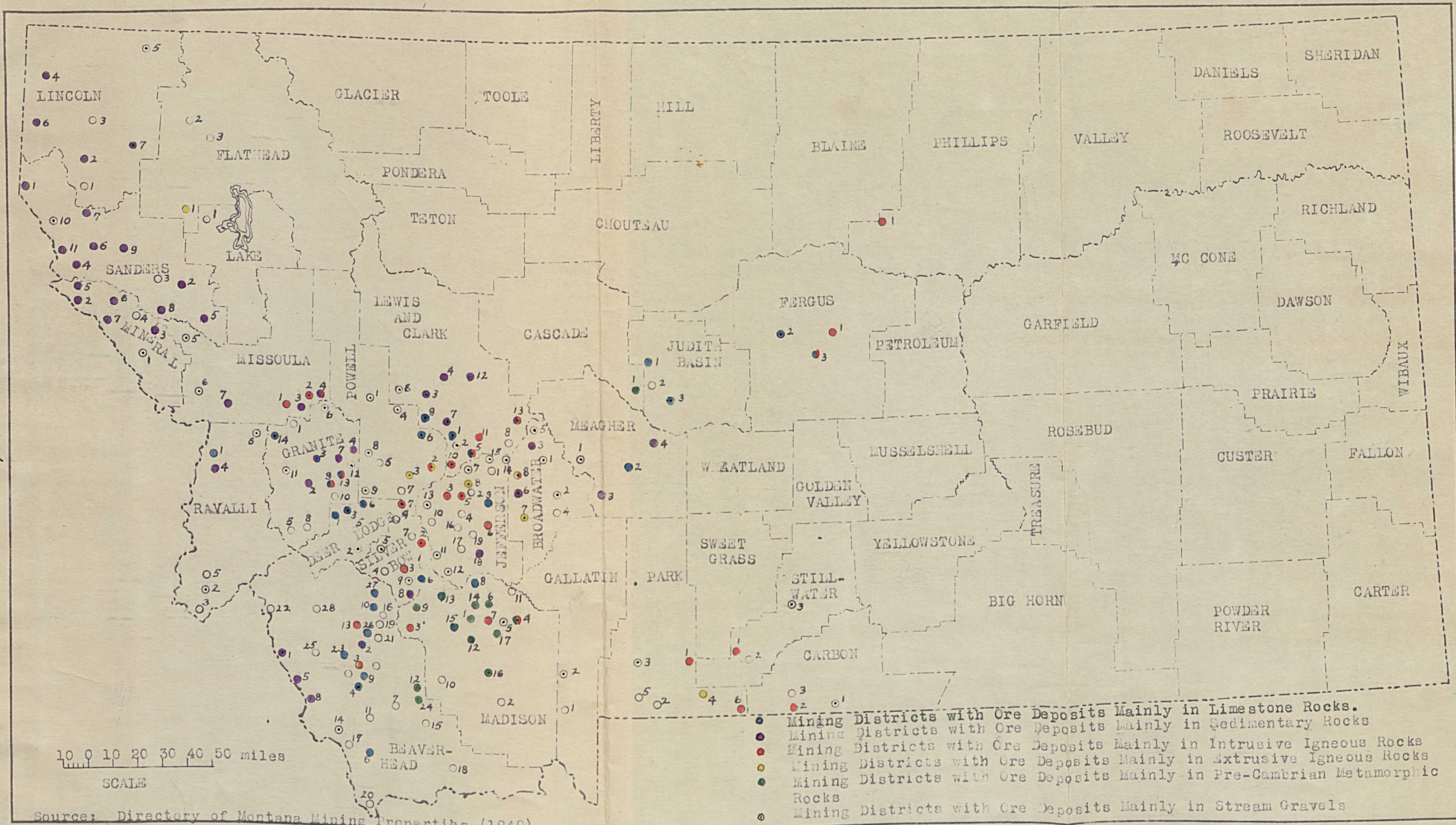
Placer deposits result from the weathering of gold-bearing or other heavy-mineral-bearing rocks. As the metal-bearing rock disintegrates upon weathering, the heavy minerals are freed. Water transports the weathered products and concentrates the heavier minerals in stream gravels. Placer deposits have been very important gold producers in Montana, but also some tungsten and platinum have been recovered from placer deposits.

Creek placers are the commonest and most important type in Montana. The gold is generally concentrated on or near bedrock in the valley alluvium. (32, p. 3)

Bench placers are usually ancient creek or river bars that lie above the present day stream bars. A slight uplift, a decrease of stream load, or an increase of stream volume causes rapid down-cutting by the stream. The former bars are isolated and remain as terraces. (4, p. 237)

River-bar placers are similar to creek placers except that the gold found in river bar is more finely divided. Commonly, the gold is too finely divided to be recovered at a profit.

Some buried placers are found in Montana. The gold was originally deposited in creek bars. Alluvium or slumping of rocks from the banks covered the deposit until the placer was buried at shallow depths. (32, p. 3)



MAP OF MONTANA, SHOWING AREAL DISTRIBUTION OF MINING DISTRICTS

MONTANA MINING DISTRICTS

BEAVERHEAD COUNTY
1. Ajax
2. Argenta
3. Bald Mountain
4. Bannack
5. Beaverhead
   (Dark Horse)
   (Mulchy Creek)
6. Big Muddy
7. Blacktail
8. Bloody Dick
   (Beaverhead
9. Blue Wing
10. Bryant
   (Hecla)
   (Glendale)
11. Chinatown
   (Armstead)
12. Dillon
   (Carter Creek)
13. Elkhorn
   (Coolidge)
   (Wise River)
14. Horse Prairie
15. Jake Creek
16. Lost Creek
   (Brown's Lake)
   (Rock Creek)
17. Medicine Lodge
18. Monida
19. Mount Torrey
20. Niccolia
21. Nogo
   (Apex)
22. Pioneer
23. Polaris
   (Lost Cloud
24. Ruby
25. Saginaw
   (Jackson)
26. Utopia
   (Birch Creek)
27. Vipond
28. Wisdom
   (Big Hole)

BROADWATER COUNTY
1. Confederate Gulch
   (Backer)
   (Canton)
   (Diamond City)
2. Deep Creek
3. Hellgate
4. Lone Mountain
5. Magpie Gulch
6. Park
   (Hassel)
   (Indian Creek)
   (Townsend)
7. Radersburg
   (Cedar Plains)
8. Winston
   (Beaver Creek)

CARBON COUNTY
1. Clark Fork
2. Hellroaring
3. Silver Run

CASCADE COUNTY
1. Neihart

DEER LODGE COUNTY
1. Blue Eyed Nellie
   (Silver Lake)
2. French Gulch
3. Georgetown
   (Southern Cross)
   (Cable)
4. Girard
5. Heber
   (Mill Creek)
6. Lost Creek
   (Dry Gulch)
   (Antelope Creek)
7. Oro Fino
   (Dry Cottonwood)

FERGUS COUNTY
1. Cone Butte
2. North Moccasin
   (Kendall)
3. Warm Springs
   (Gilt Edge)
   (Maiden)

FLATHEAD COUNTY
1. Hog Heaven
   (Flathead)
   (Kila)
2. Star Meadow
3. Whitefish

GALLATIN COUNTY
1. Eldridge
2. West Gallatin
   (Spring Hill)

GRANITE COUNTY
1. Alps
   (Bonita)
2. Antelope Creek
3. Combination
   (Henderson)
   (Black Pine)
4. Dunkleburg
5. Frog Pond Basin
6. Garnet
   (Top-o'Deep)
   (First Chance)
7. Maxville
   (Wyman)
   (Gird Creek)
8. Moose Lake
9. Philipsburg
   (Flint Creek)
   (Granite)
10. Red Lion
   (Cable Mountain)
11. Rock Creek
12. Rose Mountain
   (Gold Creek)
13. South Boulder
   (Princeton)
14. Welcome Creek

JEFFERSON COUNTY
1. Alhambra
   (Hot Springs)
   (Golconda)
2. Amazon
3. Basin
   (Cataract)
   (Comet)
4. Beaver Gulch
5. Boulder
6. Big Foot
   (State Creek)
7. Clancy
   (Lump Gulch)
   (Buffalo Creek)
8. Colorado
   (Corbin)
   (Wickes)
   (Gregory)
9. Elkhorn
10. Elk Park
11. Homestake
12. Little Pipestone
13. Lowland
14. McClellan
   (Mitchell Creek)
15. Montana City
16. Nez Perce
17. Pipestone
18. Whitehall
   (Cardwell)
19. Whitetail

JUDITH BASIN COUNTY
1. Barker
   (Hughesville)
2. Running Wolf
3. Yogo

LAKE COUNTY
1. Elmo
   (Chief Cliff)

MEAGHER COUNTY
1. Beaver
   (Elk Creek)
   (Thompson Creek)
2. Castle Mountains
3. Murray
4. Musselshell
   (Copperopolis)

MINERAL COUNTY
1. Cedar Creek
   (Quartz Creek)
   (Trout Creek)
2. Denemora
3. Iron Mountain
4. Keystone
5. Packer Creek
6. Rock Island
7. St. Regis
   (Deer Creek)
   (Ward)

MISSOULA COUNTY
1. Clinton
2. Coloma
3. Copper Cliff
4. Elk Creek
5. Nine Mile Creek
6. Petty Creek
7. Woodman
   (Lolo)

PARK COUNTY
1. Cowles
2. Crevasse
3. Emigrant
4. Horseshoe
5. Jardine
   (Bear Gulch)
   (Sheepeater)
6. New World

PHILLIPS COUNTY
1. Little Rockies
   (Landusky)
   (Zortman)

POWELL COUNTY
1. Big Blackfoot
   (Helmville)
2. Elliston
   (Ontario)
   (Nigger Hill)
3. Emery
   (Zosell)
4. Finn
   (Washington)
   (Jefferson Gulch)
   (Buffalo Gulch)
5. Garrison
6. Ophir
7. Oro Fino
8. Pioneer
   (Gold Creek)
9. Race Track

RAVALLI COUNTY
1. Curlew
2. Hughes Creek
3. Mineral Point
4. Pleasant View
5. Slate Creek
6. Three Mile

LINCOLN COUNTY
1. Cabinet
2. Libby
3. Rainy Creek
4. Sylvanite
5. Tobacco River
6. Troy
7. Wolf Creek

LEWIS & CLARK COUNTY
1. Austin
2. Blue Cloud
3. Gould-Stemple
   (Fool Hen)
   (Poorman)
4. Heddleston
5. Helena
   (Last Chance)
   (Springhill)
   (Unionville)
   (Owyhee)
6. Lincoln
   (McClellan Gulch)
   (Seven-up Pete)
   (Keep Cool Creek)
   (Liverpool Creek)
   (Stonewall Mount)
7. Marysville
   (Bald Mountain)
   (Ottawa)
8. Missouri River
9. Ophir
10. Rimini
   (Vaughn)
   (Bear Gulch)
11. Scratchgravel Hill
12. Wolf Creek
13. York

MADISON COUNTY
1. Bismark
2. Cherry Creek
3. McCarthy Mountain
4. Norris
5. Norwegian Creek
6. Pony
7. Potosi
8. Renova
   (Bone Basin)
   (Mayflower)
9. Rochester
10. Ruby Mountains
11. Sand Creek
12. Sheridan
   (Mill Creek)
   (Brandon)
   (Indian Creek)
   (Ramshorn)
13. Silver Star
14. South Boulder
15. Tidal Wave
16. Virginia City
17. Washington

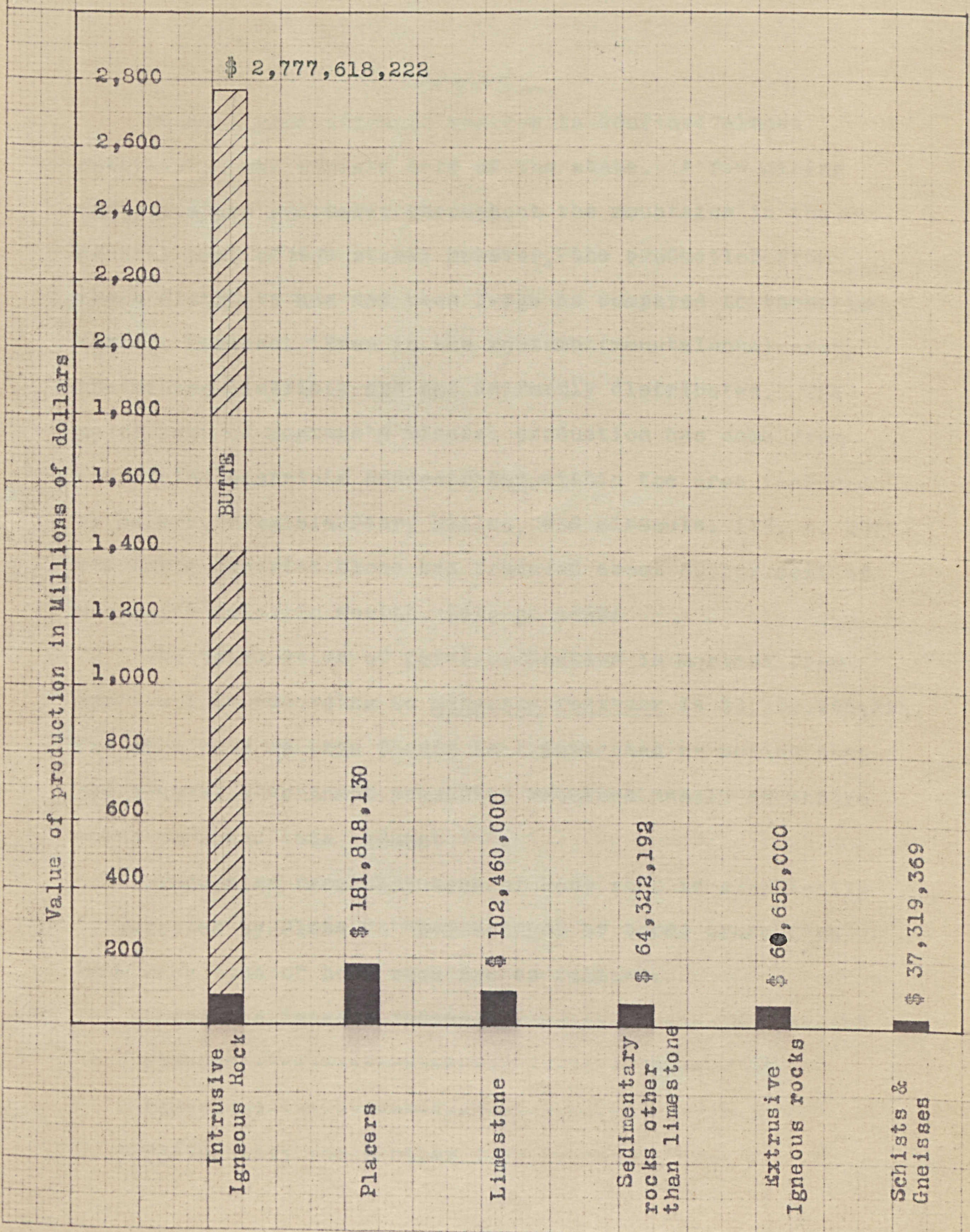
SANDERS COUNTY
1. Blue Creek
2. Camas Prairie
3. Plains
4. Prospect Creek
5. Revais Creek
6. Sleepy Creek
7. Silver Butte
   (Vermillion)
   (Cabinet)
8. Spring Gulch
9. Thompson River
10. Trout Creek
11. White Pine

SILVER BOW COUNTY
1. Basin Creek
2. Butte
   (Summit Valley)
   (Lost Child)
3. Divide Creek
4. Fleecer Mountain
5. German Gulch
6. Highland
7. Independence
8. Melrose
   (Camp Creek)
   (Soap Gulch)
9. Moose Creek

STILLWATER COUNTY
1. Nye
2. Stillwater
3. Yellowstone

PLATE IV

TOTAL VALUE OF THE METAL PRODUCTION IN MONTANA FROM VARIOUS HOST ROCKS



PRODUCTION OF MINERALS FROM VARIOUS HOST ROCKS

General

Mineral production in Montana is confined almost entirely to the western half of the state. A few mining districts are scattered throughout the mountains in the central part of the state; however, the production from these districts has not been large as compared to those in western Montana. Even in the western (mountainous) area, the mining districts are not uniformly distributed. The major part of Montana's mineral production has come from the mining districts concentrated within the area included by Helena, Virginia City, Dillon, and Missoula. (28, p. 26) The Butte district alone has produced about 80 per cent of Montana's metallic wealth. (62, p. 1528)

The total value of metal production in Montana from 1862 to 1948 according to Minerals Yearbook is $3,302,155,224. The magnitude of this figure is illustrated by noting that the Federal government presently requires nearly an entire month to spend this amount.

Production from each type of host rock is graphically illustrated by Plate V. Percentages of total production from each type of host rock are as follows:

Intrusive igneous rocks--------------------84 percent

Placers------------------------------------ 5½ "

Limestone----------------------------------3 "

Sedimentary rocks other than limestone----- 2 "

Extrusive igneous rocks	2 percent
Schists and gneisses	1 "
Unaccounted	$2\frac{1}{2}$ "

The individual production figures for each type of host rock were compiled from many sources. As stated in the introduction, complete and accurate production figures are not available for some districts. This accounts for the disagreement between the total of the individual production figures for each type of host rock and the total production quoted by Minerals Yearbook.

Placer Deposits

Placer deposits have played an important part in Montana's mineral production. The discovery of gold at Bannack and Virginia City attracted thousands of prospectors to the territory, which led to the discovery of rich lode mines and the development of modern civilization in Montana. Placer production was very large in the early mining days. Lyden reports that Alder Gulch produced 30 million dollars worth of gold from 1863 to 1866. (32, pp. 80-81) The total production may have been as much as 100 million.

Placer deposits have been found throughout the western part of Montana. Lewis and Clark county and Madison county produce more than one-half of Montana's placer gold. All of the large placer deposits are in the drainage basins below the lode mining districts, especially those that surround the Boulder batholith.

Table 2 - Placer Gold Production by Montana Mining Districts

DISTRICT	PRODUCTION	DISTRICT	PRODUCTION
BEAVERHEAD COUNTY		LEWIS & CLARK COUNTY	
Bannack	$ 8,000,000	Austin	$ 1,200,000
		Helena	17,079,000
BROADWATER COUNTY		Missouri River	2,000,000
Confederate Gulch	17,500,000	Rimini	200,000
Radersburg	500,000	Ophir	3,500,000
Magpie Gulch	280,000	Gould-Stemple	600,000
Winston	1,990,000	Lincoln	14,095,000
Park	3,000,000	York	3,500,000
Total	23,270,000	Marysville	3,200,000
		Total	45,374,000
CARBON COUNTY			
Clark Fork	1,130	MADISON COUNTY	
		Alder Gulch	50,612,000
DEER LODGE COUNTY		Norwegian Creek	150,000
Cable	250,000	Norris	300,000
French Gulch	5,000,000	Total	51,062,000
Georgetown	40,000		
Oro Fino	80,000	MEAGHER COUNTY	
Total	5,370,000	Thompson Creek	50,000
		Thomas Creek	60,000
FERGUS COUNTY		Total	110,000
North Moccasin	25,000		
		MINERAL COUNTY	
GRANITE COUNTY		Cedar Creek	2,000,000
Garnet	8,500,000	Trout Creek	150,000
Henderson Creek	1,650,000	Quartz Creek	100,000
Rock Creek	30,000	Total	2,250,000
Welcome Creek	30,000		
Gold Creek	35,000	MISSOULA COUNTY	
Total	10,245,000	Nine Mile Creek	4,000,000
		Coloma	5,000,000
JEFFERSON COUNTY		Total	9,000,000
Prickly Pear	2,000,000		
Clancy	113,000	PARK COUNTY	
Boulder	48,000	Emigrant Gulch	400,000
Colorado	25,000		
Mitchell Creek	500,000	PHILIPS COUNTY	
Lowland Creek	300,000	Alder Gulch	25,000
Total	2,986,000		
		POWELL COUNTY	
JUDITH BASIN COUNTY		Pioneer Creek	7,000,000
Yogo Gulch	5,000	Snowshoe Creek	200,000
		Ophir	5,000,000
SILVER BOW COUNTY		Elliston	20,000
German Gulch	5,000,000	Emery	75,000
Silver Bow Creek	1,000,000	Helmville	1,500,000
Summit Valley	1,500,000	Total	13,795,000
Moose Creek	200,000		
Total	7,700,000	RAVALLI COUNTY	
		Hughes Creek	200,000

TOTAL PRODUCTION FROM PLACER DEPOSITS IN MONTANA -------------$181,818,130

Table 3 - Mining Districts Whose Ore Deposits Are Found Predominately in Intrusive Igneous Rocks

DISTRICT	PRODUCTION	METAL	TYPES OF DEPOSIT
BEAVERHEAD COUNTY			
Bald Mountain	$ 60,000	Ag	Fissure Veins
Elkhorn	375,000	Ag, Cu, Pb, Au	Fissure Veins
Total	435,000		
BROADWATER COUNTY			
Winston	160,000	Au, Ag, Pb	Fissure Veins
DEER LODGE COUNTY			
Oro Fino (champion)	350,000	Ag	Fissure Veins
FERGUS COUNTY			
Warm Springs	7,000,000	Au	Fissure Veins
GRANITE COUNTY			
Garnet	3,000,000	Au, Ag	Fissure Veins
Philipsburg	32,181,000	Ag, Mn	Fissure Veins
South Boulder	1,085,000	Au, Ag	Fissure Veins
Top o'Deep	3,000,000	Ag, Mn	Fissure Veins
Total	39,266,000		
JEFFERSON COUNTY			
Boulder & Basin	8,276,000	Au, Ag, Pb,	Fissure Veins
Clancy	3,387,000	Au, Ag, Pb	Fissure Veins
Colorado	13,000,000	Ag, Au, Pb, Zn	Fissure Veins
Whitetail	64,000	Au, Ag, Pb	Fissure Veins
Total	24,727,000		
LEWIS & CLARK COUNTY			
Helena	6,110,000	Au	Fissure Veins
Rimini	7,000,000	Au, Pb, Ag	Fissure Veins
Scratchgravel Hills	1,200,000	Au, Pb, Ag	Fissure Veins
York	350,000	Au, Ag	Ladder Veins
Total	14,660,000		
MADISON COUNTY			
Norris	2,000,000	Au, Ag	Fissure Veins
McCarthy Mountains	82,000	Au	Fissure Veins
Total	2,082,000		
MISSOULA COUNTY			
Clinton	25,000	Au, Ag, Cu	Fissure Veins
Coloma	250,000	Au	Fissure Veins
Elk Creek	25,000	Au	Fissure Veins
Total	300,000		
PARK COUNTY			
New World	1,000,000	Pb, Zn, Ag	Fissure Veins
PHILIPS COUNTY			
Little Rockies	3,000,000	Au, Ag	Breccia filling & veins
POWELL COUNTY			
Elliston	160,000	Pb, Cu, Ag	Fissure Veins
SILVER BOW COUNTY			
Butte	2,684,358,222	Cu, Zn, Ag, Mn	Fissure Veins
SWEET GRASS COUNTY			
Independent	120,000	Au, Ag, Cu, Pb	Fissure Veins
TOTAL PRODUCTION	2,777,618,222		

Placers account for approximately one-half of the gold produced in Montana. Five and one-half per cent of the total mineral wealth produced in the state ($181,818,130) came from placer deposits.

Deposits in Intrusive Igneous Rocks

The deposits in intrusive igneous rocks have accounted for 84 per cent of Montana's mineral production, valued at $2,777,618,222. Copper has been the most important metal produced from igneous rocks; its value exceeds that of all other metals produced in Montana.

Ninety-seven per cent of the mineral production from intrusive igneous rocks has come from the Butte district alone. In addition to copper, large amounts of silver, zinc, gold, and manganese are produced here. The Philipsburg district is second in importance to Butte in metal production from this type of host rock. Silver and manganese are the principal metals found here. The Colorado and the Boulder and Basin districts in Jefferson county, the Helena and Rimini districts in Lewis and Clark county, and the Warm Springs district in Fergus county are the other important mining districts whose deposits are in intrusive igneous rocks. Except for the Warm Springs district, all of these deposits are situated in the Boulder batholith or in its outlying cupolas. Although production has not been important, the Stillwater Igneous Complex contains enormous reserves of chromite.

Most of the production in intrusive igneous rocks comes from fissure veins. Replacement of the wall-rock has been important in some places, especially in the Butte district. The Stillwater chromite deposit is believed to be a late magmatic segregation. (45, p. 19)

Deposits in Limestone

The limestone host rocks have produced $102,460,000 in mineral wealth in Montana or roughly three per cent of the state's total.

Beaverhead county leads all other counties in production from limestone rocks with Granite and Fergus counties following in close succession. The Philipsburg and Bryant (Hecla) districts are the most important; however, many districts of this type scattered throughout southwestern Montana have contributed substantially to the state's mineral wealth. Unlike the other host rocks, the limestone does not have a single outstanding district. Instead, it contains a number of moderately important districts.

The ore deposits in the limestone rocks are either contact metasomatic deposits or replacement deposits. Of the various host rocks, limestone is the most susceptible to replacement.

Deposits in Sedimentary Rocks Other Than Limestone

Sedimentary rocks other than limestone have produced $64,322,192 in mineral wealth in Montana or approximately

Table 4 - Mining Districts Whose Ore Deposits are Found Predominately in Limestone Rocks

DISTRICT	PRODUCTION	METAL	FORMATION	TYPE OF DEPOSIT
BEAVERHEAD COUNTY				
Bannack	$4,000,000	Au, Ag	Madison (Miss)	Contact & Replace
Argenta	2,000,000	Au, Ag, Pb	Paleozoic ls.	Contact & Fissure
Blue Wing*	2,000,000	Ag	Madison (Miss)	Replacement
Bryant	16,000,000	Ag, Au, Pb	Jefferson Dolomite (Dev)	Contact metasomatic
Polaris	60,000	Ag	Paleozoic ls.	Contact metasomatic
Utopia	300,000	Cu, Au, Ag	Paleozoic ls.	Contact metasomatic
Vipond	1,000,000	Au, Ag, Cu Pb	Pilgrim (Cambrian) Jefferson (Dev.)	Bedding Vein
Total	25,360,000			
DEER LODGE COUNTY				
Blue Eyed Nellie	1,060,000	Ag, Pb	Hasmark (Cambrian)	Replacement Vein
Georgetown	11,000,000	Au, Cu	Hasmark (Cambrian)	Replacement Vein
Lost Creek	60,000	Au	Hasmark (Cambrian)	Replacement Vein
Total	12,120,000			
FERGUS COUNTY				
Warm Springs	10,000,000	Au, Ag, Cu Zn, Pb	Madison(Mississippian)	Replacement
North Moccasin	9,000,000	Au,	Madison (Mississippian)	Replacement
Total	19,000,000			
GRANITE COUNTY				
Combination	140,000	Au	Newland ls. (Beltian)	Replacement Veins
South Boulder	150,000	Au, Ag, Cu Zn, Pb	?	Replacement Veins
Philipsburg	19,622,000	Au, Ag, Cu Mn, Pb	Hasmark, Red Lion (Camb) Jefferson (Devonian)	Replacement Veins & Bedding Veins
Welcome Creek	5,000	Au	Jefferson (Devonian)	Replacement Veins
Red Lion	900,000	Au, Ag	Hasmark (Camb)	Replacement
Total	20,817,000			
JEFFERSON COUNTY				
Elkhorn	14,000,000	Ag, Pb, Au Zn	Pilgrim (Cambrian)	Replacement Contact Metasomatic
Whitehall	10,000	Pb, Ag	Paleozoic ls.	Replacement Veins
Total	14,010,000			

Table - 4 - Cont'd

JUDITH BASIN COUNTY				
Barker	350,000	Ag, Pb, Zn	Madison (Mississippian)	Contact Metasomatic
Yogo	30,000	Au, Cu	Paleozoic ls.	Contact Metasomatic
Total	380,000			
LEWIS & CLARK COUNTY				
Austin	325,000	Ag, Cu, Pb	Belt ls. some Paleozoic ls.	Contact Metasomatic
Helena	1,500,000	Au	Madison ls.	Contact Metasomatic
Ophir	225,000	Au, Ag, Cu	Paleozoic ls.	Contact Metasomatic
Total	2,050,000			
MADISON COUNTY				
Silver Star	225,000	Au, Ag	Pre-Cambrian ls.	Contact Metasomatic
Renova	3,900,000	Au, Ag, Pb	Meagher ls.	Fault Vein
Tidal Wave	168,000	Au, Ag, Pb, Cu	Paleozoic ls.	Contact Metasomatic
Total	4,293,000			
MEAGHER COUNTY				
Castle Mountain	1,000,000?	Ag, Pb	Madison (Mississippian)	Replacement
POWELL COUNTY				
Ophir	225,000	Au, Ag, Cu	Paleozoic ls.	Replacement
RAVALLI COUNTY				
Curlew	1,000,000	Ag, Pb	Belt ls.	Replacement
SILVER BOW COUNTY				
Highland	2,205,000	Au	Meagher (Cambrian)	Replacement Veins
TOTAL PRODUCTION FROM LIMESTONE ROCKS	$102,460,000			

2 per cent of the total.

Mineral deposits in the sedimentary rocks are confined chiefly to the Belt series. The only important deposit in sedimentary rocks not found in the Belt series is the veins at Dunkleberg in the Ellis and Kootenai formations. The Marysville district has produced nearly one-half of the wealth obtained from the Belt series. Although the Belt series contains a large number of districts, most of them are rather unimportant individually.

Deposits in Extrusive Igneous Rocks

Production from extrusive igneous rocks is $60,655,000 or approximately 2 per cent of the total mineral production in Montana.

More than three-quarters of the production from this type of host rock has come from the Colorado district in Jefferson county. In the order of descending importance, the only other districts whose production has been significant are Radersburg, Little Rockies, Elliston, Winston, and Hog Heaven.

All of the districts except those in Flathead county are associated with younger igneous intrusives that have intruded the older extrusive rocks, mostly andesites.

Deposits in Schists and Gneisses

In compiling Table 7, the author included only the districts whose host rocks were of the Pony series or Cherry

Table 5 - Mining Districts Whose Ore Deposits are Found Predominately in Sedimentary Rocks Other than Limestone.

DISTRICT	PRODUCTION	METAL	FORMATION	AGE	TYPE OF DEPOSIT
BEAVERHEAD COUNTY					
Argenta	$ 200,000	Pb, Au, Ag	Spokane sh	Beltian	Fissure Vein
BROADWATER COUNTY					
Hellgate	500,000	Cu	Belt Series	Beltian	Fissure Vein
Park	2,400,000	Au	Sediments	All	Fissure Veins
Total	2,900,000				
GRANITE COUNTY					
Combination	1,496,826	Ag, Au	Belt Series	Beltian	Fissure Veins
Dunkleburg	2,190,000	Zn, Pb, Ag Cu, Au	Ellis & Kootenai	Jurassic & Cretaceous	Replacement
Maxville	75,000	Cu, Ag, Au Pb	Flathead Qtz.	L. Cambrian	Fissure Veins
Total	3,761,826				
JEFFERSON COUNTY					
Whitehall	1,700,000	Au, Cu, Mn Pb, Zn	Belt ss & sh	Beltian	Fissure Veins
LEWIS & CLARK COUNTY					
Marysville	31,000,000	Au, Pb, Ag	Belt hornstone	Beltian	Fissure Veins
Gould-Stemple	3,420,000	Au	Belt arg. & Qtz	Beltian	Fissure Veins
Heddleston	6,975,565	Pb, Ag, Au	Belt Argillites	Beltian	Filled Breccia
Wolf Creek	75,500	Cu, Ag	Belt & Flathead	Belt.& Camb	?
York	701,000	Cu, Ag	Belt sh & arg.	Beltian	Fissure Veins
Total	42,172,065				
LINCOLN COUNTY					
Sylvanite	1,806	Au, Ag, Pb	Belt Series	Beltian	Fissure Veins
Troy	1,000,000	Pb, Cu, Zn Au, Ag	Belt Series	Beltian	Veins & Contact Metamorphic
Cabinet	100,000	Au, Ag, W, Pb	Belt Series	Beltian	Fissure Veins
Libby	4,000,000	Au, Ag, Pb Zn, Cu	Belt Series	Beltian	Fissure Veins
Total	5,101,806				

Table 5 - Cont'd

MADISON COUNTY					
McCarthy Mountains	82,000	Au, Ag, Pb	?	Mesozoic	Fissure Veins
Renova	105,000	Au, Ag, Cu	Belt ss.	Beltian	Fissure Veins
Total	187,000				
MINERAL COUNTY					
Iron Mountain	1,000,000	Ag, Pb	Belt sh.	Beltian	Fissure Veins
Packer Creek	200,000	Ag, Pb, Cu	Belt series	Beltian	Fissure Veins
St. Regis	490,000	Cu, Au, Ag Pb	Belt series	Beltian	Fissure Veins
Total	1,690,000				
MISSOULA COUNTY					
Copper Cliff	50,000	Cu	Belt series	Beltian	Fissure Veins
Elk Creek	25,000	Au	?	?	Replacement Vein
Total	75,000				
SANDERS COUNTY					
Revias Creek	275,000	Cu, Au, Pt Ag	Belt quartzite	Beltian	Contact Metamorphic
Thompson River	575,000	Zn, Ag, Pb	Belt series	Beltian	Fissure Veins
White Pine	5,484,495	Pb	Belt series	Beltian	Fissure Veins
Total	6,334,495				
SILVER BOW COUNTY					
Melrose	200,000	Ag	Belt series	Beltian	Fissure Veins
TOTAL PRODUCTION FROM SEDIMENTARY ROCKS OTHER THAN LIMESTONE	64,322,192				

Table 6 - Mining districts Whose Ore Deposits are Found Predominately in Extrusive Igneous Rocks.

DISTRICT	PRODUCTION	TYPE OF DEPOSIT	METAL
BEAVERHEAD			
Bald Mountain	$ 150,000	Bedding Vein	Au,Pb,Ag
BROADWATER			
Radersburg	6,130,000	Fissure Veins	Au,Pb,Ag
Winston	1,600,000	Fissure Veins	Pb,Ag,Zn Au
	7,730,000		
FLATHEAD			
Hog Heaven	1,000,000	Fissure Veins	Pb,Ag
JEFFERSON			
Boulder	100,000	Fissure Veins	Au,Ag
Colorado (Wickes-Corbin)	48,400,000	Fissure Veins	Pb,Ag,Au,Zn
	48,500,000		
POWELL			
Elliston	2,600,000	Fissure Veins	Ag,Pb
Emery	675,000	Bedding Veins	Ag,Au,Pb
	3,275,000		
TOTAL PRODUCTION FROM EXTRUSIVE IGNEOUS ROCKS	60,655,000		

Creek series of metamorphic rocks. Even though the surrounding rocks had been metamorphosed by the Boulder batholith or its cupolas, the host rocks were not considered metamorphic for the purpose of this paper. In a few instances the references did not distinguish between the Belt series and the older pre-Cambrian rocks, but where ever the Belt series could be differentiated, it was classified with the sedimentary rocks.

The schists and gneisses have been the least productive of the various host rocks. Only $37,319,369 or roughly one per cent of the total mineral wealth produced in Montana has come from these rocks.

The Neihart district in Cascade county has been the most important district in the schists and gneisses, although many minor districts are found in Madison county. The Jardine district in Park county has also been an important producer from these host rocks. These districts account for almost the entire production from the pre-Cambrian metamorphic host rocks.

Table 7 - Mining Districts Whose Ore Deposits Are Found Predominately in Schists and Gneisses.

DISTRICTS	PRODUCTION	TYPE OF DEPOSIT	METAL
BEAVERHEAD			
Ruby	$ 500,000	?	Graphite
CASCADE			
Neihart (part in igneous)	16,000,000	Fissure Veins	Ag
MADISON			
Norris	1,600,000	Fissure Veins	Au, Ag, Pb
Rochester	2,500,000	Fissure Veins	Au, Ag, Pb
Pony	2,860,000	Fissure Veins	Au, Ag
Sheridan	567,413	Fissure Veins	Au, Ag, Pb
Silver Star	1,137,000	Fissure Veins	Au, Ag
South Boulder	2,012,000	?	Au, Ag
Virginia City	3,684,000	Fissure Veins	Au, Cu, Pb, Ag
Tidal Wave	450,000	Veins	Au, Pb, Ag
Washington	950,000	Fissure Veins	Au, Ag
Bismark	50,000	?	Cu
Total	15,810,413		
PARK			
Jardine	4,855,593	Fissure Veins	Au, As, W
Crevasse	153,363	Fissure Veins	Au, As, W
Total	5,008,956		
Total Value of Minerals Produced	37,319,369		

Table 8 - Mining Districts Whose Production has been Small or Production Figures are Unavailable.

DISTRICT	METAL	ROCKS
BEAVERHEAD COUNTY		
Ajax	Pb,Cu,Au	Belt Sl.
Beaverhead	Au,Ag,Pb	Belt
Big Muddy	?	Up. Pale.
Black Tail	Au,Cu	?
Bloody Dick	Cu	Belt ss sh
Chinatown	Pb, Au	
Dillon	Cu, Au	Schist
Horse Prairie	Au	Placer
Jake Creek	Pb, Ag	?
Medicine Lodge	?	?
Monida	Au	Placer
Mount Torrey	?	?
Niccolia	?	?
Nogo	Pb, Ag	?
Pioneer	?	?
Saginaw	Cu, Au	?
Wisdom	?	?
BLAINE COUNTY		
Bearpaw	Au,Ag,Pb	Trachyte
BROADWATER COUNTY		
Deep Creek	Au	Placer
Lone Mountain	Au,Ag,Cu	?
CARBON COUNTY		
Clark Fork	Au	Placer
Hellroaring	Cr	Ultra-basic igneous rock
Silver run	?	?
DEER LODGE COUNTY		
Girard	?	?
Heber	Au,Pb,Ag	?
FERGUS COUNTY		
Cone Butte	Au	Granite & Porphyry

DISTRICT	METAL	ROCKS
FLATHEAD COUNTY		
Star Meadow	Cu	?
Whitefish	Cu	?
GALLATIN COUNTY		
Eldridge	?	?
West Gallatin	Au	Placer
GRANITE COUNTY		
Alps	Au,Mn	?
Antelope Creek	?	Belt
Frog Pond Basin	Pb,Zn,Au	?
Moose Lake	?	?
JEFFERSON COUNTY		
Amazon (incl. with Basin)		
Beaver Gulch	?	?
Big Foot	Au	Granite
Elk Park	Ag	?
Homestake	Au,W	Placer
Little Pipestone	Au,W	Placer
Montana City	Au	Rich Placer
Nez Perce	?	?
JUDITH BASIN COUNTY		
Running Wolf	Ag,Cu,Pb	?
LAKE COUNTY		
Elmo	?	?
LEWIS & CLARK COUNTY		
Blue Cloud	?	?

Table 8 - Cont'd

LINCOLN COUNTY		
Rainy Creek	Vermiculite	
Tobacco River	Au	Placer
Wolf Creek	Au	Placer
MADISON COUNTY		
Cherry Creek (Type Sect for Cherry Cr.)		?
Potosi	Ag, W	Granite
Ruby Mountain	?	?
Sand Creek	Au	?
MEAGHER COUNTY		
Murray	Cu	Belt
Musselshell	Cu	Belt sh.
MINERAL COUNTY		
Denemora	Cu	Belt
Keystone	?	?
Rock Island	Au,Ag,Cu,Pb	Belt
MISSOULA COUNTY		
Petty Creek	Au	Placer
Woodman	Au,Cu	Belt
PARK COUNTY		
Cowles	Au,Ag	Gabbro
Horseshoe	Au,Cu	Andesite
POWELL COUNTY		
Finn	Au	Placer
Garrison	P	?
Racetrack	Au	Placer
RAVALLI COUNTY		
Mineral Point	Cu,Ag,Pb	Placer
Pleasant View	Cu,Ag	Belt
Slate Creek	Cu,Ag	?
Three Mile	Au	Placer
SANDERS COUNTY		
Blue Creek	Pb,Zn	Belt
Camas Prairie	Cu,Pb,Ag,Au	Belt
Plains	?	?
Prospect Creek	Sb,Pb	Belt
Silver Butte	Pb,Ag	Belt
Sleepy Creek	Cu	Belt
Spring Gulch	Cu,Au,Ag,Pb	Belt
Trout Creek	Au	Placer
SILVER BOW COUNTY		
Basin Creek	?	?
Divide Creek	?	Granite
Fleecer Mountain	?	?
STILLWATER COUNTY		
Nye	Cr	Ultra-basic rocks
Stillwater	Cu	?
Yellowstone	Au	Placer
SWEETGRASS COUNTY		
Big Timber Canyon	Pb,Ag	?
Natural Bridge	?	?

CONCLUSIONS

The most impressive characteristic of the mining districts in Montana is their location with respect to the intrusive igneous rocks. Almost every deposit can be traced genetically to some igneous body. Although rocks other than igneous intrusives have produced an important part of Montana's mineral wealth, these rocks contain valuable deposits only when they are adjacent to an igneous body.

The author offers the following hypotheses to explain the low mineral productivity of the extrusive igneous rocks and of the schists and gneisses:

Because the extrusive rocks are near the top of the sedimentary series, the mineralizing solutions from an igneous intrusive must travel a great distance to reach them. If the intrusive stopes through the entire sedimentary series to reach the extrusive rocks, uplift occurs; and the uppermost extrusive rocks due to elevation are subjected to rapid erosion. Therefore, wherever favorable mineral-containing intrusive roof pendants are present, erosion of extrusive rocks is greatest. Where erosion is less predominate, conditions are not usually favorable to mineral deposition in the extrusive rocks. Furthermore, many of the extrusive rocks in Montana are younger than the mineralizing intrusive.

Two conditions are probably responsible for the low productivity from the schists and gneisses. Because the pre-Cambrian basement rocks are the first rocks in the geologic column, the high points of an intrusive rock, which usually contain the mineralizing solutions, intrude beyond the old pre-Cambrian rocks and inject the solutions into younger formations. Also, the schists and gneisses are not as receptive to replacement.

In view of the above hypotheses, the most favorable locations for mineral deposits are adjacent to an igneous intrusive body or above the high points of an intrusive mass especially if erosion has not been extensive. The production figures tabulated according to the various host rocks and the locations of the mining districts in Montana as compiled in this thesis support the above conclusions.

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