

There were many other engineers engaged on this work who rendered faithful and efficient service, to all of whom the writer feels deeply grateful.

APPENDIX 1

THE MINERAL RESOURCES OF THE COLUMBIA RIVER BASIN IN EASTERN WASHINGTON AND PARTS OF NORTHERN IDAHO

By HENRY LANDES, *Geologist*, together with reports on the Coeur d'Alene, Idaho, and Butte, Mont., mining districts, by FRANK H. DICKEY, *Assistant Geologist*, Seattle, Wash., March 27, 1931

TABLE OF CONTENTS

PART A		Page
The nonmetallic resources:		
Clay.....	-----	1068
Limestone.....	-----	1077
Marble.....	-----	1080
Dolomite.....	-----	1081
Magnesite.....	-----	1083
Cement materials.....	-----	1088
Granite.....	-----	1090
Basalt.....	-----	1092
Slate.....	-----	1093
Mica (Latah County, Idaho).....	-----	1094
Sand and gravel.....	-----	1095
Silica.....	-----	1096
Coal.....	-----	1097
Natural gas.....	-----	1099
The metallic resources:		
General statement.....	-----	1100
Gold.....	-----	1100
Copper.....	-----	1101
Lead.....	-----	1102
Zinc.....	-----	1102
Iron.....	-----	1102
Tungsten.....	-----	1103
PART B		
Report on the Coeur d'Alene, Idaho, mining district.....	-----	1103
PART C		
Report on the Butte, Mont., mining district.....	-----	1108

THE NONMETALLIC RESOURCES

CLAY—GENERAL DISTRIBUTION

(See pl. no. 148² for map references)

1. The raw clays of the Columbia Basin have a very irregular distribution. As a rule there is very little clay in the high mountainous areas, and the deposits are mainly limited to the plains and plateaus, the foothills, the terraces, and flats along the streams and to the former lake basins that have been partially or entirely filled by sedimentation.

2. Probably the best-known occurrences of clay are those in the territory along the Washington-Idaho line, from the southern limits of Spokane to points beyond Moscow. The clay lies in a belt but a few miles wide, between the rising Rockies to the east and the margins

² Not printed.

of the basalt flows on the west. In many places the beds of clay have been well exposed in the railway and highway cuts, and they have also been found in digging wells. Natural outcrops are not uncommon and the clay is easily recognized by the white color it gives to the soil. The clays of this general area have been derived mainly from granite, gneiss, and pegmatite of an age probably pre-Cambrian.

3. Another well-known locality for the production of clay is that in the general vicinity of Clayton, about 32 miles north of Spokane. Over an area of several square miles a number of pits of clay have been opened up and the materials utilized. The topography is that of a plain surrounded by low granite hills. The lowland was once the location of a large lake which was eventually filled by sediment derived from the neighboring uplands.

4. A third center for the mining of clay is in Douglas County, on the Columbia River, near East Wenatchee. This clay occurs in thick beds and outcrops along the margin of a large terrace which covers several square miles. The beds of clay or shale belong to a sedimentary series of rocks that were laid down in an Eocene lake which once occupied a large area in central Washington. Underlying the clay beds there is a series of old crystalline rocks composed mainly of granite, gneiss, and schist. Formations of this character formed the shore line of the Eocene lake and the ancient rocks now outcrop to the north of the clay mine and along both sides of the Columbia River. The sediments carried into the lake were largely derived from an extensive area of the crystalline rocks just described.

5. The clays noted above are those of high quality and usable in making the higher grades of wares. Ordinary clays, suitable for common brick or similar products, are much more widely distributed. It will be realized by every one that but little of the large area involved has been prospected for clay deposits of the better grades, and this will not be done until there is a much larger demand for clay products.

VARIETIES ACCORDING TO ORIGIN

KAOLIN

6. Kaolin is a white clay, usually residual in character, that is composed almost entirely of the mineral kaolinite. The latter has a composition of Al_2O_3 , 39.8 percent; SiO_2 , 46.3 percent; H_2O , 13.9. Kaolinite is always a secondary mineral and is usually derived from the decomposition of feldspar, although it may result from the thorough weathering of any aluminous mineral.

7. Kaolin is a white burning clay which occurs in both a plastic and a nonplastic condition. It is regarded as a very high grade of clay and is used largely in the manufacture of china, porcelain, and various kinds of whiteware. It is also used in making paper, pottery, tile, and sanitary ware.

RESIDUAL CLAY

8. The best deposits of residual clay are derived from the decomposition of such rocks as granite, gneiss, schist, and pegmatite or other formations which contain a fair percentage of one of the feldspars, preferably orthoclase. Such clays arise from the softening of the rock in place and with the removal by percolating water of some

of the more soluble ingredients. Clays of this character are usually found on gentle slopes where the weathering has been deep and the rate of erosion has been slow.

9. The quality and character of residual clays vary with the kind of original rock concerned. In pegmatites, where masses of pure feldspar, usually orthoclase, are involved the resultant product of decomposition may be kaolin or even kaolinite. In granite and related rocks where minerals other than feldspar also occur the residual material will usually contain varying amounts of free silica, iron, and other ingredients as well as kaolin. Usually the percentage of residual kaolin declines as the amount of feldspathic material in the original rock decreases in quantity.

10. Residual clays with a high kaolin content occur very commonly in the belt of country along the Washington-Idaho boundary line from near Spokane to Moscow. The dominant country rocks are granite, gneiss, and schist, with many pegmatite dikes. The deposits of clay are at their best along the margin of the basalt and in many cases have been exposed to the surface by the erosion of thin lava beds which once covered them. By care in mining it is often possible to secure almost pure kaolin, but it may also be obtained by a process of removing the impurities, such as sand, by washing the mass as it comes from the pit.

SEDIMENTARY CLAY

11. A clay of this type is one that came into existence as a residual clay, but has been carried away from its original position and deposited in water. The transporting agent is usually a stream, large or small, but may be simply the wash of the rain down a gentle slope. The final disposition of the residual clay is in a lake or a pond where the materials are carefully sorted, giving rise to a banded or stratified condition. The size of such a deposit of sedimentary clay will depend largely upon the depth and area of the original lake and upon the amount of subsequent erosion of the clay since the lake disappeared.

12. In sedimentary beds of clay the sorting of the materials is usually very complete. There may be some layers of very pure kaolin, alternating with clays less pure and with beds of sand.

13. The sedimentary beds often contain leaves and other remains of the plants that grew around the margins of the lakes. At the present time the lake beds may lie under a covering of wind-blown soil, glacial debris, or they may have no overburden upon them.

14. In the clay belt from Spokane to Moscow there are several localities where the presence of former lakes is easily recognized. The original basins came into existence where the westward flowing streams were dammed by the flows of lava which were gradually raising the general elevation of the basalt plateau. The lakes no doubt were very variable as to size and none were so large but what they were very soon filled by the streams which carried the residual soil from the foot-hills of crystalline rock that lay to the east.

SILTS AND SILTY CLAYS

15. Along the upper Columbia River in Washington, as well as the Spokane, Colville and other streams, the broader valleys are often lined with benches or terraces of silt. The latter is a rock meal and was made by the action of glaciers in their scouring or abrasion of

granites and related rocks. The silt or rock meal owes its distribution to the great floods of water that were produced by the melting ice. The silt occurs in layers, indicating that the sorting power of water was used, whether the deposits are alluvial or were laid down in standing water.

16. The silt was made on such a large scale that at the conclusion of its production it filled some of the valley to heights of 400 to 500 feet above the former river level. Subsequent erosion, since the ice period, has removed the major portion of the silt. That which remains today is easily recognized by its white color as it occurs in bluffs or the margins of the terraces along the larger valleys.

17. The silt represents the mechanical breaking up of the rock, with very little decomposition or chemical change. It is plastic to only a small degree and that is due to the very fine grain to which it has been ground. The silt and silty clay beds may sometimes be utilized in ceramic work but they are now so remote from manufacturing plants that these very extensive deposits belong to the future as far as their development is concerned.

DEVELOPED AREAS

CLAYTON, WASH.

18. Clayton is a town on the Great Northern Railway, about 32 miles northwest of Spokane. It is located on a broad plain which is underlaid by extensive beds of clay of lacustrine origin. The clay has been derived from the decomposition of the granites which form the low hills over broad areas around the margins of the plain. After thorough weathering the granitic soil was carried into the lake by the streams and there the material was well sorted and deposited in beds of varying thickness. After the filling up of the lake the surface of the lacustrine plain was covered to a smaller extent by wind-blown material and to a somewhat greater degree by glacial sand and gravel.

19. The largest clay pit has been opened up at Clayton. It covers several acres and has a depth which varies from 20 to 30 feet. The amount of overburden is very small and the clays readily obtained. Several varieties of clays are mined, the principal one being a plastic fire clay with a very fine grain. Other beds of clay carry varying amounts of sand, with more or less iron. The clay in color is usually white, but some layers are yellow and others vary from light to dark gray (no. 36 on map).

20. The Abbot pit is located about 6 miles north of Clayton, and the clay hauled to the latter place for use. Other banks have been opened up, mainly to the north and east of Clayton, such as the Connor and Nefus pits (no. 35 on map). It is safe to say that over an area of many square miles of the neighboring country there occur extensive deposits of clay, such as those well exposed in the pits at Clayton and elsewhere. The depth of the clay no doubt is variable. The conclusion is certain that the reserves of clay in this vicinity are enormous and sufficient to last for hundreds of years.

CHESTER, WASH.

21. Chester is a town on the line of the Oregon-Washington Railroad & Navigation Co., 11 miles southeast of Spokane. About 2½

miles east of Chester a pit was opened many years ago from which a large tonnage of high-grade clays has been obtained. The pit covers several acres and the working face has a height of about 15 feet. The clays are sedimentary in origin and were laid down in a lake of unknown extent. From the topography of the country about the pit it appears likely that the clay beds underlie several hundred acres. The overburden of soil at the pit is thin enough to be easily removed by scrapers. Elsewhere the glacial debris above the clay is fairly deep and prevents an estimate of the tonnage of the beds without uncovering them by sinking wells or drilling holes (no. 42 on map).

22. The clays in the Chester pit have been derived from the granite rocks that outcrop nearby. As fast as formed by the decomposition of the rock the soil was washed down into the lake basins. The materials were carefully sorted, and today range from beds of rather pure kaolin to layers of sand. Fossil leaves are commonly found, and these indicate a Miocene age to the deposits, in common with those nearby and at Clayton.

23. The clay from the Chester pit is now utilized largely in the manufacture of terra cotta. At one time it was made into sewer pipe and different varieties of brick. It has a wide variety of uses and is of marked economic value.

MICA, WASH.

24. About 16 miles southeast of Spokane, at the town of Mica, on the line of the Oregon-Washington Railroad & Navigation Co., there is a large clay pit owned by Gladding, McBean & Co. This pit is more than a half mile long and varies from 100 to 350 feet in width. The working face ranges from 15 to 30 feet in height (no. 43 on map).

25. The clay from the basal part of the Mica pit appears to be residual. The original rock was a granite which has so thoroughly decomposed that the resultant mass is a compact white material that shows no bedding. The presence of irregular masses of kaolin indicates that pegmatite dikes were of common occurrence in the granite. The topmost portions of the Mica deposit display a stratification of the materials, proving a distribution by streams and in small local ponds of water. The bedded deposits vary from thin sheets of kaolin to layers of sandy clay and gravel. The small pebbles are themselves rather soft and have mostly been derived from a deeply weathered granite.

26. The pit at Mica was opened about 1895 and ever since has been a steady producer of various types of clays. The overburden of wind-blown soil covers the clays to such a thickness in this vicinity that the area of deposits of economic value is unknown, but cannot fail to mount to less than several hundred acres.

FREEMAN, WASH.

27. Freeman is a town on the line of the Oregon-Washington Railroad and Navigation Co., 19 miles southeast of Spokane. Near the depot, and by the side of the track, a clay pit has been operated for nearly 30 years. At the present time the pit has a face about 300 feet long and 30 feet high. The overburden consists of 4 feet of glacial drift capped by 10 feet of wind-blown soil (no. 44 on map).

28. The clay has been derived from the rather complete weathering of granite and its intrusive dikes of pegmatite. The mass of rock has completely softened in place and is wholly residual in character. The clay varies in quality from a pure kaolin to a mixture of kaolin, silica, and mica. In mining it is not practical to separate the kaolin very readily, but that is easily accomplished by washing the whole mass of clay.

29. In the face of the pit the clay varies in color from white to gray. It is mostly shipped as mined, and used by the Washington Brick, Lime & Sewer Pipe Co. in their plant at Clayton for siliceous fire-clay brick.

MOSCOW, IDAHO

30. Within the area around Moscow there occur several known deposits of white clay, and a number of pits have been opened up and the clay utilized. The deposits are of both residual and sedimentary types. The clay is manufactured into various wares at two manufacturing plants, one at Moscow and a second near Nora.

31. Three miles east of Moscow, near the Northern Pacific Railway and on the Rogers Ranch, there is a pit operated by the Moscow Fire Brick & Clay Products Co. The deposit is sedimentary in origin and contains a white clay of excellent quality. At the top there is a covering of gravel derived from granite. The thickness of clay is unknown, but a bore hole proves that it extends at least 20 feet below the floor of the pit. Other bore holes, outside of the pit, indicate that this clay deposit covers an area in excess of 80 acres (no. 47 on map).

32. The Moscow Fire Brick & Clay Products Co. operates a pit immediately east of Moscow that is known as the Canfield pit. The clay is adapted for pottery and face brick and could no doubt be used for chinaware. The clay is also used as a mix in fire brick and hollow tile and is used as a flux (no. 46 on map).

JOEL, IDAHO

33. Six miles east of Moscow and 1 mile from the Northern Pacific station of Joel is a clay deposit owned and operated by the Moscow Fire Brick & Clay Products Co. The deposit is very large and is located near the contact of the basalt and the older crystalline rocks. The clay is largely residual but there has been a partial sorting of the materials that have been derived from the granite, pegmatite, and mica schist (no. 48 on map).

34. The pit in the Joel deposit has been opened on a hillside at an elevation of 50 or 60 feet above the highway. It covers an area about 350 feet long and 175 feet wide and has a face which varies from 30 to 40 feet in height. The overburden ranges from 2 to 3 feet and the clay has been proven to a depth of 100 feet and no doubt extends below that level. The material from the pit is first handled by a mechanical drag excavator with an aerial ropeway for transport. The pit produces a plastic clay of high grade.

NORA, IDAHO

35. About 14 miles east of Moscow and 1 mile north of Nora there is a deposit of residual clay belonging to the Idaho Fire Brick Co. The deposit lies at the head of a narrow valley and is capped by a

sheet of basalt. Below the basalt there is a face of clay exposed which is at least 400 feet long and 50 feet thick (no. 49 on map).

36. The clay has been produced by the weathering of a granite, which was traversed by a network of pegmatite dikes. The structure of the original rock is well preserved, but the feldspars in particular have been thoroughly decomposed and yield a clay of excellent quality.

TROY, IDAHO

37. About 5 miles northeast of Troy occurs the Johansen pit. There is here a face of clay about 15 feet high which shows a clean kaolin with a little coarse quartz. The clay is hauled by truck to the plant of the Idaho Fire Brick Co., where it is used in the making of fire brick (no. 50 on map).

EAST WENATCHEE, WASH.

38. Near East Wenatchee there is a large clay mine owned by Gladding, McBean & Co. The material is shipped to Renton, near Seattle, where it is made into fire brick. The clay is light burning, turning to a very light buff or cream color (no. 5 on map).

39. The clay or shale beds are lacustrine in origin and hence occur in well defined layers. They are interstratified with sandstones and conglomerates. The beds all have a gentle dip to the southeast at angles that vary from 1 to 11 degrees. The principal stratum of clay that is mined has a thickness at the outcrop of 24 feet. It is entered by three working tunnels, the longest of which is about 500 feet. The tunnels are connected by several crosscuts and in this way there are many faces of the clay available for mining. At the outcrop the clay has an overburden ranging from 10 to 20 feet. Some mining is done in open pits.

MANUFACTURING PLANTS

CLAYTON, WASH.

40. The manufacture of clay wares was begun at Clayton in 1888. Prior to that date the extensive clay deposits of that vicinity had been discovered and partially prospected and railway transportation provided. The industry grew slowly because of the sparse population in the Northwest, but as the markets have expanded the factory at Clayton has become a very important producer of clay goods. The operating concern is the Washington Brick, Lime & Sewer Pipe Co., with its principal offices in Spokane.

41. At Clayton two principal kinds of wares are made. In one plant the chief products are face, fire, and common brick, with a total daily consumption of approximately 160 tons of clay. In the second plant the wares that are made are mostly architectural terra cotta, glazed and art wall tile and pottery, requiring about 15 tons of clay daily.

42. In the brick plant both the periodic down-draft and scove kilns are used. In both instances the flames and gases come in direct contact with the ware. In the terra-cotta kilns the firing is done much the same as for brick, except that neither the flames nor the gases come in contact with the ware in the kiln, but are enclosed by a muffle wall back of which the flames must travel. The fuels used in burning

are from the woods around Clayton and coal from the Roslyn and Crows Nest districts.

43. The Clayton power plant supplies both the brick and the terracotta departments; it has 3 boilers, a Corliss engine, a Terry steam turbine, and a generator to make the electricity for use in lighting and for operating different machines throughout the factory. About 325 horsepower is needed daily at the Clayton plant.

DISHMAN, WASH.

44. At this place, 7 miles east of Spokane, there is a large factory for clay wares, owned by the Washington Brick, Lime & Sewer Pipe Co. The products made are of the hollow-ware varieties, consisting of sewer pipe, hollow building tile, hollow partition tile, sanitary ware, structural hollow tile, flue lining, chimney pipe, quarry tile, wall coping, and a patented flat clay shingle. In all, about 75 tons of clay are consumed daily, which is obtained from the pits at Freeman, Mica, and Clayton.

45. The plant at Dishman began operations in 1911. Its requirements now amount to about 300 horsepower, partly obtained from a Corliss engine served by two boilers, and also from electricity purchased of the Washington Water Power Co.

MICA, WASH.

46. In 1900 a factory was built at Mica to utilize the clay from the local deposits. The plant is now operated by Gladding, McBean & Co., and the principal products are sewer pipe, fire brick (including special shapes), face brick, common brick, and hollow tile. Some of the raw fire clay is shipped to Renton to use there as a blend with local clays.

47. At the Mica plant there are in use 9 round down-draft kilns and 1 scove or up-draft kiln. Coal is used exclusively in the burning of the clay wares. As a maximum for operation, 325 horsepower is required, all derived from steam.

FREEMAN, WASH.

48. At Freeman, near the pit earlier described, a washing plant is operated by the Washington Brick, Lime & Sewer Pipe Co. The raw clay, which contains from 50 to 75 percent free silica, is put through crushing rolls from which it goes into a blunger where it is thoroughly mixed with water. The heavy silica content is removed from this very liquid solution in elevator slats, and the liquid is pumped from a vat into long troughs set on a very slow grade. After traveling several hundred feet in the troughs the kaolin, which is in suspension, is returned to a pump and is again repumped to more settling troughs for the final separation. As the fluid passes to a last settling basin, an acid is added which helps to flocculate the kaolin. After the kaolin has sufficiently flocculated and settled the water from the top is siphoned off and the creamy kaolin is pumped into its final drying basin. By this method a very pure kaolin is produced and then shipped to various plants for use in making clay wares.

MOSCOW, IDAHO

49. At this place the Moscow Fire Brick & Clay Products Co. operate a plant consisting of 5 kilns, 3 round down-draft, and 2 rectangular ones, with a total capacity of 250,000 bricks. For fuel coal is used on all high-heat brick, such as fire brick, and on all light colored face brick. Slab or cord wood is used in burning all red wares. The factory is a building 60 feet by 40 feet in size. The steam dryers are 220 feet long and 130 feet wide, with a capacity when full of 180,000 bricks. All products are made by the stiff mud process, with the exception of special shapes that are made by hand. The wares usually made are fire, face, and common bricks, hollow tile, and special shapes. When the plant is run at full capacity about 150 tons of clay are used daily. From 3,000 to 6,000 kilowatt-hours of electric power is consumed per month to operate the plant at full capacity.

FUTURE POSSIBILITIES OF THE CLAY INDUSTRY

50. The clay plants above described are engaged mostly in the manufacture of common, face, and fire bricks, sewer pipe and tile, hollow building block, and terra cotta. The amount of clay available is so great that it belongs in the class of raw materials that may be considered inexhaustible. The quality of the higher clays is such that almost any ware known to the industry may be made from the local deposits. As the market demands grow, due to an increase of population and in its purchasing power, the variety of wares manufactured will certainly increase. Some of the products that may be expected in time will be the clay kitchen wares, pottery wares of the ornamental variety, the enameled metal wares, and the bath, laundry, and sanitary wares.

51. The following are the chemical analyses of typical clays selected from 7 localities of the regions:

	Plastic clay, Freeman	Fine-grained clay, Mica	Light gray clay, Chester	Sandy clay, Freeman	Washed clay, Freeman	Canfield pit, Moscow, Idaho	Dark flint clay, Wenatchee
SiO ₂	53.20	54.80	52.32	77.00	47.50	53.78	46.67
Al ₂ O ₃	30.72	31.10	30.68	13.80	36.05	28.57	35.84
Fe ₂ O ₃	2.40	1.68	1.70	1.70	1.60	4.39	3.61
CaO.....	.83	Trace	.80	.93	.92	.56	.62
MgO.....	.52	Trace	.46	.54	.55	Trace	Trace
Na ₂ O.....	-----	-----	Trace	1.42	1.78	.88	-----
K ₂ O.....	3.00	.21	1.50	.28	.04	.53	-----
TiO ₂	-----	.23	.52	.50	.25	-----	-----
Moisture.....	-----	2.70	1.76	-----	-----	-----	-----
Volatile.....	9.00	9.40	10.08	4.40	12.30	11.70	13.25
Total.....	99.67	100.12	99.82	100.57	100.99	100.41	99.99

REFERENCES

- Henry Landes. The Clay Deposits of Washington. United States Geological Survey, Bulletin 260, 1905, pp. 550-558.
- S. Shedd. The Clays and Clay Industry of Washington. State College of Washington, 1910.
- Hewitt Wilson. The Clays and Shales of Washington; Their Technology and Uses. University of Washington Engineering Experiment Station, Bulletin No. 18, 1923.

LIMESTONE

GENERAL STATEMENT

52. Limestone is a rock composed almost wholly of calcium carbonate. Usually it contains a very small percentage of such common substances as silica, alumina, and iron. The composition is further varied when magnesium carbonate occurs along with the calcium carbonate. The magnesium carbonate may range in quantity from nothing to practically all of the rock. When the calcium carbonate content amounts to 54.2 percent and the magnesium carbonate to 45.8 percent the rock is known as dolomite. When the amount of calcium carbonate declines to zero and the rock is composed essentially of magnesium carbonate it is known as magnesite.

AREAL DISTRIBUTION

53. In the four counties along the International boundary, in north-eastern Washington, deposits of limestone occur in very many localities. Some of them are very small and consist merely of erosion remnants, while others cover many square miles. Some of the limestone is a very pure calcium carbonate, but much of it contains magnesium carbonate in varying quantities. When the percentage of magnesium carbonate is not large the rock is usually called a dolomitic limestone.

54. The beds of limestone in this area are usually associated with shales and sandstones. The sedimentary series is Paleozoic in age and one that represents a thickness of many thousands of feet. The strata have been heavily folded and often faulted and otherwise involved in extensive mountain building processes. The result has been a very thorough alteration of the original beds and the shales have been changed to slates or argillites, the sandstones to quartzites, and the limestones largely to a condition of marble. The limestone is therefore crystalline in character, and its color ranges usually from white to gray, but it is occasionally much darker. The original shells of which it was made have been almost invariably altered to the point where individual fossils cannot be recognized.

55. In Pend Oreille County a well-known limestone area extends along both sides of Clark Fork from the vicinity of Ione to the international boundary, a distance of over 20 miles. The rocks associated with the limestones are mainly dolomites and argillites. This sedimentary series has been thoroughly folded and the outcropping beds have a constant north and south strike. Intrusions of igneous rocks are very rare, but in some localities the beds of limestone contain workable deposits of lead and zinc.

56. The limestones of Pend Oreille County, lying as they do along the broad valley of Clark Fork, are readily accessible. They outcrop in bold cliffs along the valley sides, with a scant overburden, and the stone is readily obtained by the usual quarrying methods. A branch of the Chicago, Milwaukee, St. Paul & Pacific Railway extends from Spokane to Metaline Falls and affords the necessary transportation facilities.

57. In Stevens County, in the Colville Valley, there are many places where economic deposits of limestone occur. They are usually found

in the foothills or higher mountains adjacent to the broad valley but in general are fairly accessible. They are more or less associated with dolomites so that careful preliminary testing must be made when pure limestone is desired.

58. Along the upper Columbia River, from the international boundary almost to the mouth of Kettle River, deposits of limestone occur in areas of varying size. The limestone is invariably crystalline in character and is usually white in color. The outcrops make up high cliffs and bald hills which border the valley, principally along the river from Northport to Bossburg. Some of the deposits are of great size and contain reserves of good limestone that will suffice for all demands for an unlimited time. The limestones of this vicinity have transportation today afforded by the Great Northern Railway, and later by the Columbia if it is made available for navigation.

59. In Ferry County there are deposits of limestone at many places, usually of a comparatively small size. Some of the bodies are too isolated to be of immediate use. The largest masses are those near the summit of the mountain range immediately west of Orient. This limestone is of good quality but rather inaccessible at the present time. Other occurrences of limestone have been described from the vicinity of Republic and in the territory east of Inchelium, on the Columbia River.

60. Limestones occur at a number of places in Okanogan County. The largest deposits are located northwest of Riverside, on the Okanogan River, where they cover at least 20 square miles. They form mountain masses which rise from 1,000 to 2,000 feet above the valley of the nearby river. Most of the limestones are light in color and rather compact in texture. They are covered sparingly by an overburden and are very accessible for quarrying or utilization in any way.

61. In the general vicinity of Chesaw, in Okanogan County, not far from the British Columbia line, there are several occurrences of limestone. The deposits vary in area from a few acres to several hundred acres, and are of economic importance. The quality of the stone is excellent, and with a light overburden the operation of quarries would not be a difficult matter. The chief obstacle to the development of these deposits is their remote situation.

62. In Chelan County deposits of limestone have been located and partially developed on both shores of Lake Chelan, and on the west bank of the Columbia, about 5 miles above Wenatchee.

QUARRIES AND PLANTS

63. In the past 30 years many quarries have been opened in the limestones of northeastern Washington. A few of the quarries have been operated continuously, but a number have become inoperative for the time at least. Some quarries were discontinued because the magnesia content in the stone became too high for the present use of the product. In some instances the shifting of industries made it desirable to secure limestone elsewhere. The closing of the smelter at Northport caused a great decline in the quarrying of limestone in that vicinity.

64. For many years quarries have been in more or less continuous operation along the Columbia River between Bossburg and North-

port. The limestone occurs in high bluffs and with almost no overburden. Shipping facilities are provided by the Great Northern Railway which skirts the foot of the cliffs. The rock is a rather pure limestone and cheaply quarried.

65. The largest quarry now operating is the one owned by the International Portland Cement Co., and located 4 miles above Marcus. From 70,000 to 100,000 tons of limestone are quarried each year and shipped to the cement plant at Irvin, near Spokane (no. 17 on map).

66. Another active quarry is the one at Evans (post office, Bossburg), which is owned and operated by the Idaho Lime Co. This company has six kilns in operation, with a daily capacity of about 875 barrels. Wood is used for calcining the stone. The lime has a wide use in building construction, as a flux, in the bleaching industry, for paper mills, and as a water softener (no. 16 on map).

67. The Janni quarry is located 2 miles south of Northport, and produces from 5,000 to 10,000 tons of limestone yearly. The rock is entirely crystalline and very white in color. It is ground at the quarry and sold for such purposes as terrazzo and chicken grit. Some of the stone is broken to the proper size and sold to the paper mills (no. 12 on map).

68. For a number of years the Washington Brick, Lime & Manufacturing Co. operated large quarries and lime kilns at Springdale, in southeastern Stevens County. Eventually the percentage of magnesium carbonate became too great in the stone to make the best quality of lime, and operations were discontinued (no. 33 on map).

USES

69. In the country at large the amount of limestone sold annually exceeds 100 millions of dollars, or more than all other varieties of stone combined. Because limestone has so many varied uses in the industries the demand for it grows rapidly with the years. About one half of the limestone produced in the United States, in value, is sold as crushed stone, for use in concrete and as a road metal. The next principal utilization is as a building stone, followed in order by such uses as fluxing material, in agriculture, for riprap, for chemical purposes, etc.

70. The amount of lime, made from calcined limestone, that is sold annually in the United States, amounts to between 30 millions and 40 millions of dollars. From one half to one third of the lime, in value, is used in the building industry. The next largest consumers are the metallurgical plants, the paper mills, and the agriculturists. In the leading chemical industries lime is used in a great variety of ways. It is employed in water purification, salt refining, sand-lime brick, and a host of other ways.

71. In northeastern Washington the limestone deposits have been drawn upon for cement-making more than for any other purpose. For many years quarries have been operated by the cement manufacturers in the vicinity of Metaline Falls, and more recently on the Columbia River, above Marcus. The next largest use, at least as far as bulk is concerned, has been in the production of stone for use as a flux in the smelters. The burning of lime has been persistently continued for many years. Some of the smaller or local kilns have not operated continuously, and the number of active plants is there-

fore a variable one. Newer uses of the limestone may be seen in the making today of such products as terrazzo stone, and in supplying the rock in proper size and purity for making wood pulp.

72. The following are the chemical analyses of limestones from five selected localities of northeastern Washington:

[From bulletin no. 4, Washington Geological Survey]

	Quarry of Inland Portland Cement Co. at Metaline Falls	Quarry of Idaho Lime Co. at Evans	Quarry lo- cated 2 miles south- west of Northport	Light gray limestone from Buck- horn Moun- tain, near Chesaw	1½ miles west of Riverside
Silica (SiO ₂)	1.32	0.96	1.98	0.86	2.24
Alumina and iron (Al ₂ O ₃ , Fe ₂ O ₃)	.72	.20	.40	.72	4.00
Lime (CaO)	54.86	55.10	52.25	54.10	49.05
Magnesia (MgO)	.70	.36	2.92	.35	2.28
Loss on ignition	42.84	43.28	42.87	42.50	41.32

REFERENCES

Shedd, S. Cement Materials and Industry in the State of Washington. Bulletin No. 4, Washington Geological Survey, 1913.

Weaver, Charles E. The Mineral Resources of Stevens County. Bulletin No. 20, Washington Geological Survey, 1920.

MARBLE

GENERAL STATEMENT

73. In origin marble usually has its starting point in beds of sedimentary rock. The rock may have been a limestone or a dolomite, or any gradation in composition between these two. Due to metamorphic action, usually caused by the folding of the strata, the original beds have become altered until they are crystalline in character. The degree of metamorphism may be all the way from that which is incipient to that which is complete. The effect upon the constituents of the rock is to alter them to a partial or to a complete crystallization. The terms crystalline limestone or crystalline dolomite are scientific expressions descriptive of these altered rocks.

74. The word "marble" is rather a commercial one and refers to crystalline limestones or dolomites that are pleasing in color and that will take a fine polish so that the stone may be used for decorative or monumental purposes. It is also a requisite that the stone be but little broken as it occurs in place so that it may be quarried in large blocks. It should be free from cracks in order that a block of it may be sawed into large slabs.

DISTRIBUTION

75. In northeastern Washington none of the limestones or dolomites occur which are not partly or wholly crystalline. These rocks belong to a very thick sedimentary series that has been quite thoroughly altered throughout. While the limestones and dolomites as a result are now regarded as crystalline in character, it does not follow that they may produce marble of a high quality.

76. In the years preceding 1900 a great deal of prospecting was done for marble throughout northeastern Washington. It was this search which brought to notice the extensive limestone and dolomite

areas of this part of the State. During 1900, and for a few years thereafter, many companies were organized to develop the marble locations that had been secured. Naturally the places chosen for work were those not too far removed from a railway, because of the necessity of convenient transportation.

77. Nearly all the attempts to open and operate marble quarries were made in Stevens County. Several were located a few miles north and west of Valley, on Greenway (Huckleberry) Mountain. Some of these quarries were well supplied with machinery, with mills for cutting, turning, and polishing the stone. Various colored marbles were quarried and prepared for the market, as well as some very beautiful serpentine. Other quarries were situated nearer the town of Valley and toward the east.

78. Chewelah was also a center of marble activity, with several quarries located from 3 to 5 miles away on the west, and others in the nearby foothills to the east. These quarries were under development for several years and had the advantage of nearness to the railroad.

79. About 16 miles northeast of Colville some large marble quarries were opened and operated. Even though they could be reached only by mountain roads they were unusually well equipped with machinery. The motive power was steam, and so was operated the drills, derricks, channelers, gang saws, rubbing saws, etc. Other quarries were located both to the southeast and to the southwest of Colville.

80. Farther north in Stevens County there were quarries located on the low mountains of marble around Bossburg and Ryan (near Williams). Outside of this county there was some activity among the marble deposits of the lower Clark Fork, especially around Box Canyon, about 2 miles above Metaline Falls.

81. For the last several years there has been but little activity among the marble quarries in Stevens County or neighboring localities. In some instances it was found that a heavy overburden of broken stone must first be removed, or otherwise the marble could not be taken out in blocks of suitable sizes. In other instances the quarries were too far from a railroad and so the total transportation costs were high. Even under the best of circumstances the markets were not very good because of the comparatively small population of the Northwest. With improvements in transportation, which will bring a lowering cost, and a population of ample size to offer desirable markets, there is no doubt that the marble industry will eventually reach a place of much importance in northeastern Washington.

REFERENCE

Shedd, S. Building and Ornamental Stones of Washington, volume 2, Washington Geological Survey, 1903.

DOLOMITE

DISTRIBUTION

82. Dolomite occurs in more or less close association with limestones in many localities in northeastern Washington. There are extensive areas where the limestones are quite free of magnesia and hence are pure limes. In other areas the magnesia and lime content so balance each other that the resultant rock throughout is a dolomite. In yet

other places the limestone and dolomite masses are so intermixed that it is often impossible to mine one product to the exclusion of the other.

83. In its pure condition dolomite is a little harder and more resistant than limestone, and its specific gravity or relative weight is somewhat greater. It does not dissolve so readily and caves and caverns are not commonly produced in it as in limestone. The color of dolomite varies greatly, usually white to gray, but it may be almost any color. The rock is commonly coarsely crystalline in appearance with a pearly or sometimes a vitreous luster.

84. Chemical analyses, rather than the physical appearance of the rock, must be depended upon ordinarily to distinguish a true dolomite or even a dolomitic limestone. The dolomites in north-eastern Washington that have so far been discovered have been made known in the prospecting for high-grade limestones. It is likely that bulk for bulk the deposits of dolomite exceed those of limestone. The exact limitations and relative purity of the dolomite areas will probably never be known because of the limited uses of this stone.

85. In the region under discussion the best known areas where dolomites or limestones with considerable magnesia occur are in the Colville Valley. In his report on the mineral resources of Stevens County, Weaver has mapped one area which he calls the Stensgar dolomite. It outcrops as a narrow belt about 21 miles long, extending from northeast to southwest, in the Huckleberry Mountains, southwest of Colville. No development work has been done on this belt for the dolomite content, but rather for the magnesite deposits which occur locally within it.

86. As described by Weaver the character of the Stensgar dolomite varies greatly from place to place. The extremes in composition are represented by the magnesite which is a relatively pure magnesian carbonate and the occasional occurrence of a pure limestone. In between these maxima may be found all possible variations of calcium magnesium, but with the latter predominating. The dolomitic rock is crystalline and usually fine of grain. It varies much in color—gray, bluish, or pinkish—depending upon the impurities. Intrusions of igneous rock are common and these have always modified the dolomite.

87. In the lower Clark Fork Valley, in Pend Oreille County, dolomites and dolomitic limestones frequently occur. These facts have been brought out in the various examinations that have been made for portland cement materials, wherein a very low magnesian percentage is necessary. Much of the rock commonly regarded as limestone will be found to be partly magnesian in character, when chemical analyses are made.

88. Analyses published in Bulletin No. 4, Washington Geological Survey, indicate a high percentage of magnesium carbonate in some of the limestones that outcrop in the hills west of Orient on the Kettle River. Similarly among the analyses given for the limestone deposits north and west of Riverside, on the Okanogan River, one finds that some magnesia is usually present. In fact, it is evident that some of the material approaches a true dolomite in composition.

QUARRY DEVELOPMENTS

89. The only quarry opened for the production of dolomite is one located about 5 miles east of Colville, in Stevens County. This

quarry began operations in 1917 and was a steady producer for several years but is now inactive. It was owned by the Tulare Mining Co. The stone was calcined in two large rectangular kilns and shipped to the paper mills near Portland. The quarry has been developed in what Weaver mapped and described as the Old Dominion limestone. Evidently this limestone contains local deposits of true dolomite that are of commercial importance. (No. 20 on map.)

UTILIZATION

90. In those instances where the chemical composition is not of primary importance, it is clear that dolomite might be used in many ways in lieu of limestone. When the rock is used in the walls of buildings, or for foundations, or as crushed material, limestone has no advantage over dolomite. It therefore happens that much dolomite, or dolomitic limestone is prepared and used when the name limestone is applied to the product.

91. There are several uses for dolomite in which limestone cannot be used as a substitute. While in its natural state dolomite is not very refractory, it can be made so by dead-burning or calcining at a high heat. When it is heated to temperatures ranging from 2,700 to 3,100° F. the moisture and nearly all the carbon dioxide are expelled. The product is regarded as dead-burned and possesses a high refractory value.

92. It is not probable that the dolomites of Washington will ever be used to any extent in the making of refractory wares. The latter will come from the magnesite deposits that are large in size and from which superior products may be made. The dolomite rock will be used in the future where it is needed for buildings, for crushed stone, as a flux, in terrazzo, and in many other ways.

REFERENCES

- Shedd, S. The Cement Materials of Washington, Bulletin No. 4, Washington Geological Survey, 1913.
Weaver, C. E. The Mineral Resources of Stevens County, Bulletin No. 20, Washington Geological Survey, 1920.
Whitwell, G. E. and Patty, E. N. The Magnesite Deposits of Washington, Bulletin No. 25, Washington Geological Survey, 1921.

MAGNESITE

GENERAL STATEMENT

93. Magnesite is a carbonate of magnesium, in which magnesium oxide comprises 47.6 percent and carbon dioxide 52.4. The magnesium content is commonly replaced to some degree by calcium and iron. Magnesite as a mineral is often associated with dolomite and calcite. As a rock it often contains silica and alumina as well as calcium carbonate.

94. Magnesite occurs in two forms, usually known as massive and crystalline. When massive, magnesite is ordinarily found in veins or deposits in serpentine. It is an alteration product, due in large measure to the action of carbonated waters upon the magnesium silicate of the serpentine. The crystalline magnesite is primarily associated with crystalline limestones or dolomites, and occurs in more or less bedded deposits.

DISTRIBUTION

95. The only magnesite deposits thus far found in the Columbia Basin are located in Stevens County, about 60 miles north of Spokane. They occur in a belt about one fourth of a mile wide but more than 25 miles long. The belt begins at a point about 5 miles south and west of Chewelah, in the Colville Valley, and extends in a south-westerly direction, diagonally across Huckleberry Mountain. The southern end of the magnesite belt is at a point about 6 miles from the Columbia and about the same distance from the Spokane River.

96. The northern part of the magnesite area is on the flank of the mountains and fairly accessible. Shipments are made from the towns of Chewelah and Valley on the Great Northern Railway. The southern magnesite deposits are within Huckleberry Mountain and at localities where transportation is rather difficult. The principal area of activity is now at the northern end of the belt, at the nearest point to Chewelah.

GEOLOGY OF THE MAGNESITE AREA

97. The magnesite of Stevens County occurs in a belt of rocks described by Weaver as the Stensgar dolomite. The latter is a well-defined sedimentary layer interstratified with the Deer Trail argillite beds. They are all a part of a very thick group of sedimentary formations that have been compressed and folded to such an extent that they are essentially metamorphic in character. The Stensgar dolomite and associated beds have a characteristic dip of about 35 degrees to the northwest, but locally they may vary from nearly flat to almost vertical. In the Stensgar dolomite the magnesite occurs in pockets, lenses, and large masses where the calcium carbonate has been carried out by solutions and the resultant rock left as a rather pure magnesium carbonate. The solutions have probably originated in the basic dikes that commonly occur within and about the dolomite. From the dikes the percolating water has carried magnesium carbonate into the dolomite where the exchange of magnesium for calcium has taken place. The solutions have followed bedding planes, joints, fissures, and faults, and thereby brought about an irregular displacement of the dolomite by masses of magnesite. In many places the replacement is but partially complete, and it is possible to find every gradation from a rather pure limestone through dolomites of variable compositions to a true magnesite.

98. Magnesite occurs in a variety of colors, ranging usually from white to gray, but sometimes red or black. It is crystalline, and in texture may be very dense and compact. More often it is coarse in grain, with the cleavage planes well developed. It has a hardness of about 4, and a specific gravity of 3, or thereabouts.

DESCRIPTION OF THE DEPOSITS

99. The Stensgar dolomite first attracted prospectors in the years following 1900, when several marble claims were located upon it. Very little was done with the marble, but in one of the abandoned quarries, in 1915, the presence of magnesite of commercial value was first demonstrated. Immediately thereafter several quarries were developed, due to the extreme demand for domestic magnesite because of the conditions imposed by the war.

100. One of the early marble locations was at a point on the Stensgar dolomite belt, about 15 miles west of the town of Valley. It was called the Red Marble quarry because the rock has a distinctive reddish-brown color. When it was found that the great mass of rock was really magnesite and not marble a large quarry was opened upon the deposit. The rock was first hauled to Valley in trucks, but an aerial tramway was constructed to carry the material to a railway spur at the foot of the mountain. But little magnesite was eventually shipped from this quarry because other and more accessible deposits were soon developed.

101. The Red Marble is the deposit of magnesite located farthest south on the Stensgar dolomite, that has yet been found. From all indications it is by far the largest mass of magnesite so far found in this locality. It outcrops over a considerable area and has been prospected by diamond drilling. It is rather difficult in advance of actual quarrying, to give its exact dimensions. The latest estimate of the quantity of commercial magnesite in reserve in the Red Marble deposit is 17,000,000 tons (no. 23 on map).

102. The Double Eagle deposit is located about $1\frac{1}{2}$ miles northeast of the Red Marble, on the eastern face of Huckleberry Mountain. About 1917, operations were begun on this property and actively carried on for several years. The ore was treated in upright kilns and the calcined magnesite hauled by truck to Valley. The ore in reserve in this deposit is estimated at 100,000 tons (no. 24 on map).

103. About $1\frac{1}{2}$ miles north of the Double Eagle is a deposit of magnesite known as the Keystone. From 1898 to 1903 this property was operated as a marble quarry, and was well equipped with machinery to handle a large tonnage. The prepared stone was hauled by truck to Valley, about 10 miles away. The first shipments of magnesite from Stevens County were made from this point. The material is coarsely crystalline, and varies in color from dark blue to bluish black. The deposit is a large one, and according to Whitwell and Patty it is known to be about 600 feet long, 225 feet wide, and 200 feet thick (no. 25 on map.)

104. Not far from the Keystone is the Midnight magnesite deposit which, so far, has not been opened for production. Careful estimates which have been made place the amount in reserve at 100,000 tons.

105. About 3 miles northeast of the Keystone is the Woodbury deposit of magnesite. It was opened up in 1916 and operations were continued for about 2 years. A quarry was developed with a face about 150 feet long and 25 feet high. Two vertical cylindrical kilns were placed in use, with a combined average output of 30 tons of calcined magnesite per day. This deposit is not large and will probably not be reopened again (no. 26 on map).

106. Near the northeast end of the Stensgar dolomite belt occur the Moss and Allen deposits. The quarries located upon them are only 100 yards apart, with the Moss farthest south. They are really on opposite ends of the same body of magnesite. The latter is about 1,000 feet long, from 250 to 300 feet wide, and with an average thickness of 200 feet. Not all of the rock is of commercial quality, and careful sorting must be practiced (no. 27 on map).

107. In 1917 a standard-gage railway was built from the Moss and Allen quarries to the Great Northern at Valley, 6 miles away. At the

Allen quarry four vertical kilns were constructed to calcine the magnesite. The demand for prepared magnesite increased to such an extent that, during 1918, a large amount of rock was shipped to Irvin, near Spokane, where it was calcined at the plant of the Inland Portland Cement Co. A little later all of the shipments of magnesite from these quarries were diverted for treatment to the calcining plant at Chewelah, described below.

108. The Finch is the most northern of the magnesite deposits, and is located but a short distance from the Allen, near the end of the Stensgar dolomite belt. From the Finch and the Allen quarries has come the entire production of magnesite from Stevens County in recent years. In the two quarries about 100 men are employed and the daily output of magnesite rock is 300 tons (1930 figures).

109. In the Finch quarry, which is now quite large, a number of working faces have been developed. This makes it possible to mix the rock from various places in order to maintain the necessary percentage of magnesium carbonate and reduce the impurities. The latter consist essentially of dolomite, silica, and limestone. The Finch deposit has been carefully prospected by shafts, tunnels, and many diamond-drill holes. The reserves in commercial magnesite are now placed at 500,000 tons.

110. At the quarry the magnesite is first fed through a jaw crusher where it is broken to a size of about 5 inches. It is then passed through gyratory crushers and reduced to a final size of 2 inches. It is also washed to remove the talc and the fine material which is always higher in silica than is the coarser rock. From a storage bin of 300 tons capacity the rock is carried in tram buckets for a distance of 5 miles to the treatment plant at Chewelah (no. 28 on map).

PREPARATION OF MAGNESITE FOR USE

111. The only reduction plant now operating on magnesite in Stevens County is the one at Chewelah that is owned by the Northwest Magnesite Co. This plant was erected in 1917 and now has a capacity of 10,000 tons per month of calcined magnesite. The employees number 75 men, and for all operations 1,000 horsepower is required (no. 29 on map).

112. When the rock is received at the reduction plant via the aerial tramway it is crushed in rolls to an 8-mesh size. Since the magnesite as received from the quarry is quite free from iron, this element, in the condition of magnesite, in a pulverized form, is now added. Enough magnesite is added to bring the final magnesite product to about 6½ percent in iron.

113. The dead burning is done in six rotary cement kilns of a size 7½ by 125 feet. Powdered coal is used as a fuel, and a temperature of about 2,900° F. is attained. The clinker is crushed through a ½-inch screen, or to other sizes, if desired, and then shipped in bulk. It goes to the steel companies where it is used mainly for open-hearth furnace bottoms. Its final destination is mostly in the Pittsburgh and Chicago districts. A part of the calcined magnesite goes directly east by rail, while the remainder is shipped via Seattle and the Panama Canal.

114. In 1930 the Northwest Magnesite Co. established at their Chewelah plant a factory for the making of Thermax, which is the

same as a product manufactured in Europe and sold under the name of "Heraklith." At Chewelah the materials employed are the flue dust from the magnesite reduction plant and excelsior made from fir and tamarack logs. Thermax is used as a fireproof plaster-base sheathing, or in solid partitions for its high insulating value and acoustical properties.

115. The fir and tamarack logs that are used have little value for lumber. They are cut up and run through ordinary excelsior machines, producing a rather coarse excelsior. This is mixed with a grout of sord cement, using magnesium sulphate in place of the chloride. The material is then formed into boards of 1-, 2-, or 3-inch thickness, and 20 inches in width, by being passed between steel conveyor belts traveling through a steel tube, which holds the product to exact size until set. The tube is enclosed in an insulated stove, through which hot gases from the burning of waste wood are passed and which hastens the setting reaction. After coming out of the stove the boards pass through a dryer in which the remaining moisture is removed by hot gases. The board comes out in a continuous ribbon which is cut automatically into desired lengths and is then ready for storage and shipment. In the Thermax plant 30 men are employed; the output amounts to 85,000 board feet per day; and 600 horsepower is required to operate the machinery.

UTILIZATION OF MAGNESITE

116. The Northwest Magnesite Co. is a producer of crude, calcined, and dead-burned magnesite. In late years practically no crude has been sold and but very little that is calcined only. Nearly all the product is a dead-burned magnesite, used as a refractory.

117. In the country as a whole it is believed that in ordinary times from 75 to 82 percent of the magnesite consumed goes into refractories; from 15 to 20 percent is used as caustic magnesite in the plastic trade; and the final 3 to 5 percent finds a use in making epsom salts, in the chemical industries, and in other ways.

118. In 1929 the domestic dead-burned magnesite consumed in the United States amounted to 78,700 short tons; for the same year the sales of caustic calcined magnesite were 11,390 short tons. By far the bulk of the dead-burned magnesite was produced in Washington, while nearly all of the caustic calcined product came from California. During 1929 the usual quotations for dead-burned Washington magnesite were from \$22 to \$24 per short ton, f.o.b. Chewelah.

THE WORLD SUPPLY OF MAGNESITE

119. Magnesite is an important but not an uncommon mineral and it is produced commercially in more than a dozen countries. Its use is primarily as a refractory, and so those countries that make iron and steel and their products are the largest users of magnesite. On an average about 5 pounds of dead-burned magnesite are used in making 1 ton of steel. The chief competitors of magnesite as a refractory are dolomite, chromite, fire clay, and silica brick.

120. Prior to the World War, Austria-Hungary was the largest producer of magnesite, followed by Greece. When foreign shipments were suspended during the war, domestic production was greatly stimulated and Washington and California supplied the

magnesite required. In 1929 the imports amounted to 53,182 short tons, as follows: Dead-burned, 50,379 tons; caustic calcined, 6,500 tons; and crude, 300 tons. About three fifths of the importations came from Austria, and more than one half of the remainder from Czechoslovakia. The supplies coming from Greece are now limited to a few hundred of tons annually.

121. In the world production for 1928 the leading country was Austria with 310,100 metric tons. The United States marketed 115,393 tons; Greece, 104,421 tons; Czechoslovakia, 87,396 tons; Canada, 25,137 tons; British India, 24,798 tons; and a small output from several other countries.

122. In the magnesite reserves of the world the greatest tonnage by far is located in Austria. The United States comes second, followed by Greece and Canada. Important deposits are also known in Czechoslovakia, Venezuela, British India, Russia, Italy, Australia, and elsewhere.

123. The following are the chemical analyses of typical magnesites selected from five localities:

[Bulletin No. 25, Washington Geological Survey]

	Finch quarry, Stevens County, Wash.	Allen quarry, Stevens County, Wash.	Red Marble quarry, Stevens County, Wash.	California magnesite, Porterville, Tulare County	Grenville district, Quebec, In- ternational Magnesite Co.
MgO.....	45.20	44.50	45.02	45.17	39.25
CO ₂	49.70	47.91	49.51	50.74	49.72
CaO.....	1.74	1.02	1.07	1.35	7.89
SiO ₂	1.85	2.07	4.27	2.28	1.60
FeO.....	.88	1.03	.78		
Fe ₂ O ₃29	1.81

REFERENCES

- Weaver, Charles E. The Mineral Resources of Stevens County, Bulletin No. 20, Washington Geological Survey, Olympia, 1920.
Whitwell, G. E., and Patty, E. N. The Magnesite Deposits of Washington, Bulletin No. 25, Washington Geological Survey, Olympia, 1921.

CEMENT MATERIALS

GENERAL STATEMENT

124. The raw materials used in the making of cement usually consist of limestone, clay, and gypsum. Normally the mix is composed of about 75 percent limestone, 22½ percent clay, and 2½ percent gypsum. When the limestone and clay occur together in one bed, in the proper proportions, the cement made from this combination is known as a natural cement. The term "portland cement" is used when the limestone and clay occur separately in nature and are artificially combined in the process of manufacture. In either case gypsum must be added, its primary purpose being that of a retarder. Since magnesium carbonate usually accompanies calcium carbonate, in a varying degree, in all limestones, the amount of it must always be carefully determined by analysis. The maximum limit of magnesium carbonate is about 5 or 6 percent in portland cement, but may run much higher in natural cement.

RAW MATERIALS

125. Under the heading of "Limestone" in this report the occurrences of this rock in northeastern Washington have been described. While limestone outcrops over large areas, especially in Stevens and Pend Oreille Counties, it usually contains magnesium carbonate as an ingredient, often to the extent of rendering it unfit for portland cement. Since the percentage of magnesium carbonate may quickly change in a quarry, making the rock immediately ahead of no value, it requires a careful preliminary drilling and prospecting to find a limestone that may be depended upon. In spite of this condition there are very large deposits of limestone of dependable purity which can supply many cement plants far into the future.

126. When it comes to the clay requirements for cement it is known that this ingredient occurs in even greater abundance than the limestone. Clay is found as a surface deposit over much of the general area north of the basalt plateau. It has been developed in many pits from Spokane southward along the Washington-Idaho line. It may be obtained from the extensive beds of shale, slate, and argillite that comprise much of the bedrock of the countries between the lava country on the south and the Canadian line.

DEVELOPMENT

127. For many years the cement resources of northeastern Washington have received much attention. In a sparsely settled country the markets have grown but slowly, and it has been the lack of people rather than the lack of desirable raw materials that has delayed development.

128. About 1901 the first plans were made to manufacture cement in this part of the State. A site was chosen at a point on Clark Fork, in Pend Oreille County, about 40 miles north of Newport. The place was called "Cement", and the only means of transportation was either on the river or along a wagon road. After some prospecting a deposit of natural cement rock was found, with some near-by beds of both clay and limestone of good quality. A small plant was erected which ran for a time in the early part of 1904, but was soon discontinued (no. 19 on map).

129. At Metaline Falls, on Clark Fork, about 72 miles north of Newport, a cement plant was constructed in the years 1910-11. It was first operated under the name of the Inland Portland Cement Co. but after some years the title was changed to that of the Lehigh Portland Cement Co. The limestone that is used is trammed from a large quarry that has been opened on the face of a mountain about one half mile east of the plant. The rock occurs in massive strata and varies from a light gray to black. It varies in its composition from bed to bed, but there is a great quantity of it of very high grade (no. 15 on map).

130. The Lehigh Portland Cement Co., at their Metaline Falls plant, have two rotary kilns installed, one being in continuous use. The capacity per kiln is about 1,000 barrels of clinker per day. Powdered coal is used as a fuel in burning the cement, and the dry process is followed. The power requirements amount to about 1,540 horsepower to operate the mill and 260 horsepower for the quarries. The

power is secured from a hydroelectric plant on Sullivan Creek, a mountain tributary which enters Clark Fork at Metaline Falls.

131. The International Portland Cement Co. began operations in 1912 at its plant located at Irvin, about 9 miles east of Spokane. In its first years of production the necessary limestone and shale were brought from quarries located on the east side of Pend Oreille Lake in northern Idaho. The raw materials were first carried across the lake in barges, a distance of 6 miles, to Bayview and then shipped by rail for 50 miles to the factory at Irvin. A few years ago these quarries were abandoned and new ones opened up at a point about 4 miles north of Marcus on the Columbia River. Both limestone and clay are obtained here and shipped over the Great Northern Railway to the plant (no. 40 on map).

132. At Irvin two rotary kilns are in use, and the capacity of the factory is about 1,500 barrels daily. The dry process is used, and powdered coal is the fuel. It requires about 1,200 horsepower to operate the plant.

REFERENCE

Shedd, S. The Cement Materials of Washington. Washington Geological Survey, Bulletin No. 4, Olympia, 1913.

GRANITE

GENERAL DISTRIBUTION

133. Granite is found in many localities in northeastern Washington. In age it belongs to Jurassic time. It occurs as batholiths, some of them of very large size. The usual associates of the granitic rocks are the gneisses, schists, and pegmatites.

134. In Spokane County granite occurs abundantly over the country to the east and north of Spokane, and in a limited way to the west also. It is the most common rock along the Washington-Idaho line, and some of the great mountain masses, such as Mount Spokane, are principally made up of this formation. Granite outcrops almost continuously in the bluffs along Little Spokane River, from Newport to the mouth of that stream. It makes up the high hills around Medical Lake, where the granite knobs rise above the surrounding basalt plateau.

135. In Stevens County a broad belt of granite extends from its southern border, along the eastern side, to a point several miles north and east of Colville. This granite area occurs along the boundary line between Stevens and Pend Oreille Counties and makes up the wide and high divide between the Clark Fork and Colville Valleys. This was named by Weaver the Loon Lake granite because of its typical occurrence around that body of water. Similar granite also outcrops over a large area in northern Stevens County, southeast of Northport. Along the lower Spokane Valley granite is a common rock, and there are many isolated areas of it in the mountains of the southwestern section of the county.

136. A great mass of granite constitutes the broad divide between the Columbia-Kettle River Valleys on the east and the great valley in which Republic is located in northeastern Ferry County. This formation and associated rocks also occur commonly along the international boundary in this county extending as far south as Curlew.

137. Granite is the dominant rock in the northeastern part of Okanogan County, especially in the region around Mount Bonaparte. Along the Okanogan River, and over many areas to the westward, granitic rocks are of abundant occurrence. In Chelan County, along both walls of the Columbia, granite and related rocks are found as far south as the mouth of Wenatchee River. Substantially all the way from Spokane to Wenatchee the canyon walls of the Spokane and Columbia Rivers are largely made up of granitoid rocks. The principal exceptions are the basalt cliffs which sometimes form the upper rim rock of the canyons and the great terraces of gravel, sand, and silt.

LOCATION OF QUARRIES

138. Nearly all the quarries for obtaining granite have been opened up in the general vicinity of Spokane. This is not surprising, because in that vicinity the best markets are to be had and also the transportation problem was not difficult to solve.

139. Some of the earliest granite quarries were developed in the vicinity of Medical Lake, about 16 miles southwest of Spokane. A broad area of granite outcrops near Medical Lake, very convenient for the location of quarries. The rock is covered but slightly by any soil and fresh granite may be secured without much stripping.

140. The granite occurs on hillsides where the opening of quarries is not a difficult matter. The stone works well, may be readily split as desired, and may be obtained in blocks of any size. The principal workings have been known as the "Alfred Giles quarry", "J. W. Morris quarry", and the "Washington Monumental & Cut Stone Co. quarry". Mineralogically the granite is composed of orthoclase feldspar, quartz, hornblende, and both muscovite and biotite micas (no. 39 on map).

141. Another area in Spokane County for the quarrying of granite is located near the mouth of Little Spokane River, about 9 miles north of Spokane. Several quarries have been developed along a side hill where the stone may be taken out with the most convenience. The granite may be quarried into blocks of varying sizes, and is not marred by seams or any discoloration. Its composition is that of a true granite, except that plagioclase feldspar is rather common. The quarried stone is taken to Spokane where it may be cut and polished and made ready for use. The quarries and the plant in Spokane are owned and operated by the Washington Monumental & Cut Stone Co. (no. 38 on map).

142. East of Spokane some granite quarries have been in operation more or less continually for many years. The principal one has been operated by Culver & Merwin, and is located about 4 miles from the city limits (no. 41 on map).

143. At several places in northeastern Washington, among the many granite outcrops, small quarries have been opened in order to secure stone for purely local uses. It is evident that the granite resources of this general area are very great and ample to supply all possible demands that may be made upon them.

USES OF GRANITE

144. The quarries of granite around Spokane have placed upon the market a limited variety of products. Much of the material has been

secured for structural purposes, and has been used in buildings, bridges, and heavy foundations. Some of the stone has been cut and polished and used for monumental purposes. Other uses have been for curbs and gutters in city streets.

145. In some localities, where the granite has become somewhat decomposed, it is quarried and crushed and used in the construction of highways. A portion of the Sunset Highway, in Lincoln County, was surfaced from a granite outcrop which occurs near Creston.

REFERENCES

- Patty, E. N., and Glover, S. L. The Mineral Resources of Washington. Bulletin No. 21, Washington Geological Survey, 1921.
 Shedd, S. The Building and Ornamental Stones of Washington, Volume 2, Washington Geological Survey, 1902.
 Shedd, S. The Mineral Resources of Washington. Bulletin No. 30, Washington Geological Survey, 1924.

BASALT

DISTRIBUTION

146. The bedrock over the country between the Snake River on the south and the Spokane-Columbia Valleys on the north is very largely basalt. Granite and related rocks occur along the lower rims of Spokane River and also along the south wall of the Columbia as far downstream as Wenatchee. These formations also occur along the margin of the basalt in the general vicinity of Spokane and along the Washington-Idaho boundary to the southward of that city.

147. North of the Spokane River basalt outcrops over several areas in Stevens County as far as the town of Valley. In the southern part of Ferry County there are many small masses of basalt that are erosion remnants from an original and more extensive area of this rock. The same conditions hold for the adjoining section of Okanogan County as far west as the river of that name.

148. The basalt of the Columbia Basin varies greatly in character and quality within very short distances. It is made up of flows of lava, commonly lying flat or nearly so, and of very variable thickness. In the usual bed or sheet of lava, in a vertical section, the upper and lower portions are very porous or honeycombed. The central part is ordinarily massive, very hard, and quite free from steam holes or cavities. The true color is black, but locally it may be greenish-black, red, or brown. At its best basalt is compact, tough, comparatively heavy, and resistant to weathering.

USES

149. Partly because of its abundance, and also due to its good qualities, basalt is much used as a road metal. The ordinary practice is to open up a quarry and install the necessary machinery for crushing and grading the rock at the outcrop of basalt nearest the point on the highway that is being surfaced. It usually costs less to move the quarry equipment than to haul the prepared stone very far, and so several temporary quarries may be drawn upon along any highway of considerable length. For the usual highway use it is not necessary to select the hardest and most compact basalt, but that which is porous to a certain degree is often preferred.

150. Another use for basalt is as crushed stone in the making of concrete. This applies not only to the permanent surfacing of highways but to many building operations. For concrete work a grade of basalt is selected that is tough, hard, and compact. Usually quarries for the production of crushed rock are essentially permanent and are operated more or less continually.

151. To a limited extent basalt is quarried as a foundation stone and also for the walls of buildings. The keen competition of other materials, such as cement, brick, and terra cotta, has depressed the basalt demand almost to zero. For small jobs there will always be a local use of basalt in building operations.

152. When basalt is used in building roads, or in other public works, the quarries are frequently owned and operated by counties, towns, or the contractors who have the work in hand. For other purposes, when the quarries are well located as far as the markets are concerned, and are essentially permanent in character, they are owned by individuals and companies as a continuing business. The amount of basalt is so great that wherever it is accessible it will continue to be used for all time to come for certain purposes to which it is peculiarly adapted.

SLATE

153. Slate is a rock, composed originally of clay, that has been compacted and hardened by extensive metamorphic action. The significant thing about slate is its remarkable cleavage in one direction, whereby it may be broken into thin, smooth slabs, and which may be trimmed to any desired size. To be of commercial quality slate must have a constant and durable color, and have a toughness which prevents breakage except under very unusual strain. The rock must be free from cracks or joints, so that slabs of large size may be secured.

154. In its origin slate is a part of a very extensive series of sedimentary beds of rock that have been involved in mountain building on a large scale. In this way the metamorphosing agencies of heat and pressure have been derived and slate developed as a final product of a long thermodynamic process. Through the long action of erosion the deep-seated beds of slate are finally exposed at the surface where the material may be quarried if it is of economic value.

155. In northeastern Washington the only good prospecting ground for slate is in Stevens County. The very thick group of metamorphic rocks therein found is made up of great beds of quartzite, marble, and argillite. In the argillite areas it may be possible to find beds of slate which would have a commercial value.

156. The only quarry thus far opened up is located in an air line about 11 miles west of Valley, on the eastern front of Huckleberry Mountain. The slate is found in what Weaver has named the Deer Trail argillite. This is a formation, in central Stevens County, which occurs as a belt about 20 miles long and with an average width of 3 miles. The strike of the beds in this belt is to the northeast, with a variable dip or pitch to the northwest. The Deer Trail argillite is underlain on the east by the Stensgar dolomite which carries the magnesite deposits of Stevens County. (No. 22 on map.)

157. The quarry of slate noted above has been operated intermittently, and its total output has not been large. It is located on the

side of a valley, with sharp walls, and where the amount of overburden is small. At the present time the width of the quarry is less than 150 feet, but it has a face with a height of about 75 feet. While the strata dip to the northwest at an angle of 30 degrees, the cleavage of the slate is practically in a vertical direction.

158. The slate may be taken out in large plates or sheets and will cleave to a desirable thickness. In color it varies from dark blue to black. It is rather soft and easily broken, but no doubt will improve in quality when a greater advance into the mountain is made by the quarry face. The quarry is not very accessible as far as cheap transportation is concerned, and that appears to be a rather serious obstacle to further development.

REFERENCE

Shedd, S. The Mineral Resources of Washington. Department of Conservation and Development, Bulletin No. 30, Olympia, 1924.

THE MICA DEPOSITS OF LATAH COUNTY, IDAHO

159. For many years white mica or muscovite has been prospected for and mined in a belt of country a few miles north of Avon, Latah County, Idaho. In this general area the formations are mostly gneiss and mica schist of pre-Cambrian age. These rocks are cut by masses of pegmatite, which occur in various patterns. Sometimes the pegmatite is in the form of a thin sheet, and at other times it is lenticular, chimneylike, or cylindrical in outline.

160. The bodies of pegmatite contain a number of minerals, all coarsely crystallized. The most common ones are feldspar and quartz, with which the white mica is usually associated. Accessory minerals are garnet, tourmaline, and beryl, often in large crystals.

161. In an area 2 miles wide and several miles long, at an elevation of about 4,000 feet, a number of claims have been staked on the pegmatite outcrops. Much development work has been done, mainly by open cuts, tunnels, drifts, and shafts. At the present time the Muscovite Mine is the only one that is active. In years past other properties, principally the Levi Anderson, Luella, and Maybe, have been producers of mica.

162. The mica occurs in irregular masses in the pegmatite, and in the mining of it it must be carefully separated from the other minerals. Often the mica is found in rather narrow streaks or in small lenses, and in order to secure it a large amount of adjacent rock must be taken out and wasted. The commercial mica occurs in masses known as books. Each book may be split into thin leaves or sheets of the thickness desired. The economic value of a deposit depends largely upon the number and sizes of books that are found. In the Muscovite Mine the books vary from 1 to 4 inches across the face, which is usually rectangular in outline.

163. In general about 85 percent of the mica annually used in the United States is for electric insulation. Minor uses are for stove fronts, phonograph discs, and as a filler or lubricant. The price largely depends upon the size of the sheets that may be secured and upon the quality.

REFERENCE

Mica Deposits of the United States. Bulletins 530 and 740. United States Geological Survey, Washington, D.C.

SAND AND GRAVEL

ORIGIN AND DISTRIBUTION

164. During the glacial period a large part of northeastern Washington was covered by the ice. Two distinct glacial invasions are definitely known, with a strong probability that there were earlier ones whose records have been almost wholly destroyed. The terminal moraine which marks the southern limit of the ice, when followed from the east, enters the State almost opposite Spokane. It extends for 12 miles or so south of the city in the form of a pronounced arc. It then sweeps northwest, with its location about 15 miles west of Spokane. When it approaches within 4 or 5 miles of Spokane River it turns westward and approximately parallels that stream until the Columbia is reached.

165. To the west of the confluence of the Spokane and Columbia Rivers the terminal moraine makes a bend of many miles to the north, in the southern end of Ferry County. It crosses the Columbia again at the head of Grand Coulee, and after making a broad sweep to the south, returns to the Columbia a little below the mouth of Chelan River. To the westward of the Columbia trench the terminal moraine has not been mapped.

166. By its abrasion of the rock it passed over, the ice produced a tremendous quantity of sand and gravel. South of the terminal moraine this material extends for many miles along the channels which were the drainage lines from the melting ice. Over the plains the beds of sand and gravel often extend in broad sheets, but when confined to the valleys the deposits usually occur in terraces. The result of the glacial episode has been a very general distribution of sand and gravel in a network of old stream channels that cover the country south of the Spokane and Columbia Valleys as far as Snake River. There is hardly a locality that is more than a few miles distant from a coulee or old channel that is lined with terraces of sand and gravel.

167. North of the terminal moraine there is a more widespread distribution of sand and gravel than to the south of it. In its recession the ice produced by melting great streams which widely disseminated the glacial debris. Over the level or gently rolling country the material was broadly spread, and in the valleys was concentrated more in ribbonlike patterns. All of the valleys that extend from north to south are conspicuous for the enormous fills of sand and gravel that yet remain within them. That is notably true of the Okanogan Valley and its continuation in the Columbia Valley as far south as the mouth of Crab Creek. It holds also for the valleys of the Spokane and upper Columbia as well. Both the Clark Fork and Colville Valley margins are lined with deposits of sand and gravel that were the products of the waning of the great glaciers that came out of the north.

QUALITY

168. A great variety of rocks were abraded by the ice in the production of the sand and gravel deposits above described. The softer stone was usually ground up fine and its debris carried by the streams far toward the sea. The more resistant rock was the material out of which the present sand and gravel beds were usually made. In an

examination of the ordinary pit one finds that granite, gneiss, and schist are very common ingredients. In some cases quartzite and other related metamorphic rocks may be found. Basalt does not occur in the pits except where the ice moved over a considerable area of this formation. In general the usual sand and gravel has the appearance of rock freshly broken and rounded and displays but little evidence of weathering. Both the grains of sand and the pebbles of varying size are compact, hard, and durable. Having been distributed wholly by water the deposits are washed clean and usually lie in well assorted layers or beds.

USES

169. The foremost use of sand and gravel has been in the building and surfacing of roads. The very common occurrence of these materials has greatly assisted in the creation of a general system of roads that cover the large area under consideration. Both sand and gravel have been extensively used in the making of concrete for many purposes. The gravel has been used by the railways for ballast and for fills. The sand has a wide use in masonry and otherwise. The principal competitor of sand and gravel has been crushed rock, usually basalt.

REFERENCE

Leighton, Morris M. The Road Building Sands and Gravels of Washington. Washington Geological Survey, Bulletin No. 22, Olympia, 1919.

SILICA

KINDS OF MATERIALS INCLUDED

170. In this report, under the above heading, there will be included two varieties of silica of economic value. The first is quartz, in massive form, and in such a state of purity that it is readily mined and is of commercial importance. The second is diatomaceous earth, or what is sometimes called diatomite. This is a soft, white, very fine-grained, earthy material that is found at many places in the eastern half of Washington.

QUARTZ

171. An important deposit of free silica, or quartz, occurs about 15 miles north of Spokane, near Denison. The quartz is quite pure, accompanied to a very slight degree by feldspar and muscovite. It outcrops as a prominent hill, about 700 feet in diameter, and with a maximum of over 200 feet. The mass, above the general level of the surrounding plain, must contain many hundreds of thousands of tons. The overburden of soil is but slight and quarry operations may be carried on at a low cost. The material has been employed to some extent in the manufacture of silica brick. It may have an important future use in the making of ferrosilicon in electric furnaces (no. 37 on map).

DIATOMACEOUS EARTH

172. This material is often mined and sold, under other names, such as diatomite, infusorial earth, silica, and kieselguhr. In origin it represents the remains of microscopic 1-celled plants that originally

lived in ponds and lakes. Sometimes the entire basin of water became filled with the earthy material derived from these plants, and the lake was thereby destroyed. The deposit so made varies with the area and depth of the initial lake. It often happens that the diatomaceous earth is now exposed at the surface, with little or no overburden, but sometimes the deposits are found only under sheets of lava or other rocks.

173. There are several localities where diatomaceous earth in large quantities occurs in central Washington. The best known deposits are on Squaw Creek, about 20 miles southeast of Ellensburg, in Kittitas County. In this locality diatomaceous earth has been found over an area of several square miles. The principal bed has a thickness of about 10 feet, with an overburden which is from 8 to 14 feet deep (no. 7 on map). Similar deposits occur not far away from Roza, a station on the Northern Pacific Railway, about 14 miles south of Ellensburg. At Roza a bed several acres in extent has been mined intermittently, and prepared for use in the drying and pulverizing plant near the railway (no. 6 on map).

174. Over an area of several hundred acres, located about 15 miles south of Quincy, in Grant County, diatomaceous earth has been found in a number of places. Some of it was encountered between the beds of basalt in the farmers' wells. That which has been quarried and utilized occurs on the surface, usually appearing along the sides of the shallow valleys of coulees. One bed that has been extensively worked has an average thickness of 12 feet, but with a length and a breadth that are unknown (no. 8 on map).

USES

175. The primary uses of silica, occurring as a massive quartz, are for abrasive purposes, because of its superior hardness. Its uses in sandpaper, in polishing stone, and in tube mills are well known. Silica is also valuable for refractory purposes and in metallurgy and the chemical industries. When at its best it may be used in glass-making, or even in the making of optical apparatus.

176. The value of diatomaceous earth depends more upon its physical than its chemical properties. It is not commonly marketed in its crude state but undergoes some treatment before being shipped. Among its many uses the more conspicuous may be noted: In heat and sound insulation; as an absorbent for many liquids; as a filtering medium in the sugar industry, and in oils, syrups, etc.; as a filler in rubber, cement, plaster, etc.; as an abrasive in cleansing and polishing; and for a large variety of applications in chemistry.

REFERENCES

- Patty, Ernest N. and Glover, Sheldon L. The Mineral Resources of Washington. Washington Geological Survey, Bulletin No. 21, Olympia, 1931.
Shedd, Solon. The Mineral Resources of Washington. Department of Conservation and Development. Bulletin No. 30, Olympia, 1924.
Wilson, Hewitt. The Clays and Shales of Washington. University of Washington Engineering Experiment Station. Bulletin No. 18, Seattle, 1923.

COAL

177. Coal fields of variable sizes have been known for many years in the Columbia Basin of Washington. The only one that has had continuous operation and a large production is the Roslyn field in

Kittitas County. Some shipments of coal have been made from the Manastash area, a few miles south of Roslyn. Nearby is the Taneum field where some prospecting for coal has been done.

178. There is a small area of coal measures about 12 miles west of Valley, in Stevens County, which contains one or more beds of coal. A mine was operated there for several years but has recently been discontinued. A small mine near Wenatchee operates each winter, and supplies fuel for the local trade.

ROSLYN FIELD

179. This coal area is located in the eastern part of Kittitas County and near the geographical center of the State. The belt of workable coal, thus far proven, is about 7 miles long and 3 miles wide and runs from northwest to southeast. The coal measures lie partly under the valleys of the Yakima and Cle Elum Rivers and partly on the southwest slope of the ridge separating these valleys from that of the Teanaway River. The field is on the main lines of two railways, the Northern Pacific and the Chicago, Milwaukee, St. Paul & Pacific (no. 3 on map).

180. The beds of coal occur in what is known as the Roslyn formation, Eocene in age, which is made up of lacustrine beds of sandstone and shale, with very little conglomerate. The average thickness of the formation is about 3,500 feet. Ten seams of coal are included, with an aggregate thickness amounting to 47 feet. The coal beds were formed in basins of irregular outline. But little sediment was carried into the lake basin during the accumulation of the coal, for the latter is quite free from inorganic matter.

181. The Roslyn sediments, with the coal seams, were laid down in a horizontal position but they have been disturbed until they now form a synclinal or troughlike fold. The beds on the south side of the axis pitch at high angles, but those on the north side, where the principal mining is carried on, have dips of about 2 degrees. In the mines but few faults have been found. There are thin places in the seams due to rolls or to movements at the time of the folding of the rocks. In the general mining area the surface of the ground parallels the dip of the strata so that much of the coal lies at no great depth. The coal is bituminous in rank.

182. The greater part of the coal mined in this field has come from the Roslyn seam. The latter has a thickness of from 4 to 5 feet, has been mined along a distance of 7 miles, and involves an area of at least 10,000 acres.

183. The bed known as the "Big Dirty" has a thickness ranging from 15 to 19 feet, but contains only from 5 to 6 of workable coal. Its position in the series is about 200 feet above the Roslyn bed, and hence much of it has been eroded away. It underlies about 4,000 acres of ground. Coal from this seam runs higher in ash than is true of the Roslyn bed.

184. About 400 feet below the Roslyn is the Wright bed, which is about 4 feet thick. Its exact area is unknown, but, if it is identical with the seam worked in the Lakedale mine, it should underlie a larger area than is true of the other coals. It runs higher in ash than does the Roslyn bed.

185. Coal was discovered in the Roslyn area about 1871. A mine was opened on the Big Dirty vein in 1882 and the coal hauled to

Ellensburg. Following the completion of the Northern Pacific Railway several mines were placed in operation around Cle Elum and Roslyn, and shipments began on a large scale. In time the production from Kittitas County came to exceed that from any other county in the State, and that lead is still maintained. The annual output of the Roslyn field is usually in excess of 1,000,000 tons. About three fourths of the coal is used by the Northern Pacific Railway in its locomotives and its shops. The remainder enters the commercial field and is sold in practically all of the markets in the State.

186. The following are chemical analyses of six coal samples from the Roslyn field:

[Bulletin 474, U.S. Geological Survey]

	Roslyn bed at Beekman mine, Beekman	Roslyn bed at Patrick-McKay mine 2½ miles northwest of Roslyn	Roslyn bed at Roslyn no. 3 mine, Ronald	Roslyn bed at Roslyn no. 4 mine, Roslyn	Roslyn bed at Roslyn no. 7 mine, Cle Elum	Roslyn bed at Summit mine, Cle Elum
Moisture.....	4.4	3.1	3.1	3.7	5.0	7.6
Volatile matter.....	33.2	35.6	35.6	34.3	36.1	35.2
Fixed carbon.....	49.5	50.0	49.9	48.6	46.8	45.2
Ash.....	12.94	11.27	11.37	13.40	12.15	12.01
Sulphur.....	.35	.41	.40	.36	.36	.44
B.t.u.....	12,520	12,850	12,860	12,250	11,900	11,580

REFERENCES

- Saunders, Edward J. The Coal Fields of Kittitas County, Washington. Geological Survey, Bulletin No. 9, 1914.
 Smith, George Otis. Description of the Mount Stuart Quadrangle. U.S. Geological Survey, Folio No. 106, 1904.

NATURAL GAS

187. In 1912 a well was drilled, in the hope of finding water, on a section of land located about 12 miles north of Benton City, in Benton County. The well was located in the arid country at the eastern base of Rattlesnake Hills, where the general elevation above sea is around 1,200 feet. The log of the well indicates that several layers of basalt were drilled through, but at a depth of 610 feet the bit entered a bed of clay. This stratum proved to be 90 feet deep, or a total depth for the well of 700 feet. As soon as the rock was reached beneath the clay a flow of natural gas began which amounted to about 300,000 cubic feet per day. For some months the gas was allowed to flow freely and then the well was capped (no. 9 on map).

188. Following the discovery well other drilling was done on the neighboring sections of ground. The stratum of clay, 90 feet thick, was penetrated in all of them. Gas was secured in varying quantities from most of the wells, but some were failures. A diamond drill hole about 2,200 feet deep failed to find other important reservoirs below the one at the base of the 90-foot clay. Analyses showed the gas to be dry, and not connected with petroleum.

189. The only operator at the present time in what is commonly known as the "Benton County gas field" is the North Western Natural Gas Co. The central office of this company is at Wichita, Kans., and

the local office at Grandview, Wash. The company has bought or drilled 12 wells in this field, 10 of which are now producing. The individual wells vary in their daily output from 100,000 cubic feet to 1,000,000 cubic feet. Pipe lines have been laid to Prosser, Grandview, Sunnyside, and Mabton, a main-line total of about 40 miles. About 41 miles of additional pipe have been laid for the service distribution of the gas. The daily sales at the present time amount to 500,000 cubic feet.

REFERENCE

Culver, Harold E. Abstract of the Report on the Geology and Resources of the Pasco and Prosser Quadrangles. Reports of Investigations No. 1, Department of Conservation and Development, Olympia, 1926.

THE METAL RESOURCES

GENERAL STATEMENT

190. There are many mines and prospects in northeastern and north-central Washington where various metallic minerals are found. They occur in the areas, to the north and west of the basalt plateau, where the rocks are usually crystalline or metamorphic in character. The metallic minerals are usually associated with igneous intrusions, and the ores are commonly found near the contacts of the dikes, sills, or batholiths with the adjacent rocks. In the instance of gold some of it is found in the form of placer deposits.

191. The metal occurrences in Washington are not of the bonanza type, nor does the State have any unusually large deposits of low-grade ores. As a rule the metallic minerals occur in veins of moderate size and of medium value. In the history of metal mining in the State, involving more than 60 years, the center of activity has rather frequently changed. In some instances a property is closed because the ore is exhausted or with depth the values decline. The fluctuations in the prices of the metals have brought about alternating periods of activity and dormancy. Improvements in the methods of milling and metallurgy have sometimes given an economic value to an ore body that was formerly regarded as of no consequence. Too much optimism and speculation have occasionally brought to a close a mining venture that should never have been attempted.

192. The number of metallic minerals found in the different districts is wide and varied. In noting their occurrences below, only those will be described that are in some localities at least of economic value.

GOLD

193. The first gold mining in Washington was done in the placer deposits along Swauk Creek, near Liberty, in north-central Kittitas County. The gravels here were worked more or less continually for at least 30 years, with a total yield estimated at more than \$3,000,000. Soon after placering became of importance on the Swauk, lode mining was begun at Blewett, on the upper Peshastin River, in south-central Chelan County. For many years this district was a steady producer of free gold, which occurred chiefly in serpentine (no. 4 on map).

194. One of the most important gold camps in eastern Washington has been around Republic, in northwestern Ferry County. Active production began about 1900 and several mines have been in more or

less continual operation since that date. The veins vary from a thin streak to a maximum of 15 feet, with 5 to 6 feet as the average thickness. They are made up of milky quartz interbanded with a cherty or porcelainlike quartz of exceedingly fine grain. The gold in the quartz is essentially free, but occurs in very minute particles, not visible to the eye. It is very unequally distributed through the quartz, thus adding to the risks of mining. The Republic ores are all sent to smelters for reduction, since no other method of separating the gold seems to be feasible (no. 10 on map).

195. The most important gold property in Stevens County has been the First Thought mine, located about 3 miles northeast of Orient. The mine is connected with the railroad by an aerial tram 13,000 feet long. The development work consists of three adit tunnels and a winze from the lowest level. The ore averages in value about \$15 per ton. (No. 11 on map.)

196. The Oroville-Nighthawk district covers an area of about 150 square miles, in north-central Okanogan County, along the international boundary. Mining activity has prevailed in this region for over 40 years and many mines are now found in varying stages of development. The first attention was given to gold properties, but deposits of silver, lead, and copper are now mined as well.

COPPER

197. The production of copper has fluctuated greatly with the changing prices of the metal through the years. A maximum value brings many mines into activity that will close when the market reaches the bottom. At the present time, despite the low selling price of copper, large development enterprises are under way at two places in eastern Washington. The first of these is on the upper Chiwawa River, in northwestern Chelan County, about 40 miles from Leavenworth. At this locality the Royal Development Co. has been engaged for several years in opening up a large body of low-grade copper, and has recently installed a mill for concentrating the ore (no. 1 on map).

198. A second scene of activity is at the Holden mine, located about 10 miles west of Lake Chelan, on the south side of Railroad Creek. In this area the principal country rock is schist, and the ore minerals are copper and zinc, with a little gold and silver. The property is being developed by several thousand feet of tunnels, raises, and winzes, as well as by an extensive series of diamond drill holes. The mineralized zone is very large in size, and the deposit is of an intermediate grade in value (no. 2 on map).

199. The United Silver-Copper mine, 5 miles northeast of Chewelah, Stevens County, has been the most important producer of copper in eastern Washington. The country rocks are schists, argillites, and quartzites, with occasional lenses of limestone. The vein of ore has been well explored as to both length and depth, and has an average width of 6 feet. The values are mainly in copper, with considerable silver, all in a gouge of milky quartz. The mine is well equipped with machinery, including both a concentrating plant and a flotation unit (no. 30 on map).

200. Other producers of copper in the past have been the Copper World Extension mine, about 10 miles west of Loomis, and several mines near Loon Lake, Stevens County.

LEAD

201. Eastern Washington became a producer of lead about the year 1883. Since that time the output has come almost exclusively from Stevens County, with very minor amounts from Pend Oreille, Ferry, and Okanogan Counties. The most important mining center has been on Gladstone Mountain, in Stevens County, 8 miles south of the Canadian line and a few miles west of the boundary with Pend Oreille County. The chief mine has been the Electric Point, which shipped about \$1,000,000 worth of ore between 1916 and 1920. At this mine the ore occurs in the form of columns or "chimneys" which contain the lead minerals, mostly galena, cerussite, and anglesite. The Gladstone mine adjoins the Electric Point, and the two are almost identical in general characteristics (no. 14 on map).

202. One of the best known mines in eastern Washington has been the Old Dominion, located about $7\frac{1}{2}$ miles east of Colville. It has been operated intermittently since 1883, when high-grade silver-lead ore was found at a little way below the surface. The ore body is located in limestone, near the contact of the latter with granite. At depth the valuable minerals are chiefly galena and sphalerite, with sulphides of silver. The highest grade ore was that found in the weathered zone near the surface (no. 21 on map).

203. Other mines that have been producers of lead are the Santa Rita mine, located 18 miles west of Springdale; the Bonanza, 5 miles east of Bossburg; and the Young America at Bossburg.

ZINC

204. The production of this metal in eastern Washington has been limited almost wholly to Stevens and Pend Oreille Counties. But rarely do the zinc minerals occur alone in deposits of commercial value. More often they are found along with other minerals, such as those of lead and copper, and hence the output of zinc is often a byproduct in the mining of other metals.

205. In Pend Oreille County the principal prospects and mines containing zinc are found on both sides of Clark Fork, between Metaline Falls and the Canadian line. The zinc minerals usually accompany those of lead, and all occur as replacements in beds of limestone and dolomite. The ore does not commonly occur in veins but rather in bunches and pockets more or less scattered.

206. In the vicinity of Northport in Stevens County zinc is a product of several mines. The Black Rock mine, 6 miles northeast of Northport, is essentially a zinc property. The ore, down to a depth of about 180 feet, is the carbonate of zinc, with the sulphide, or sphalerite, occurring below that level. A similar mine is the Gorien, located 6 miles east of Northport. In this instance the ore body is not large but of high grade (no. 13 on map).

IRON

207. Ores of iron are very generally lacking in northeastern Washington. About the only producing property has been the Kulzer mine, located about 3 miles east of Valley, in Stevens County. The iron minerals are limonite and hematite, which give the ore a varying color from brown to red. The metallic iron content ranges from

50 to 68 percent, with the phosphorous and silica rather high. Some of the ore has been shipped to the Tacoma smelter for use as a flux, and a considerable quantity has been utilized by the Northwest Magnesite Co. at Chewelah (no. 31 on map).

208. About 9 miles west of Valley there is an iron property known as the Iron Jack, upon which much prospecting work has been done. The minerals that make up the ore are hematite, magnetite, and martite. The values run as high as 68 percent in metallic iron, with but little phosphorous.

209. Twelve miles north of Colville, on Clugston Creek, in Stevens County, deposits of limonite have been partially developed. The ore runs from 50 to 56 percent in metallic iron. Other iron ore deposits in Stevens County have been discovered and prospected in the Deep Lake district, 10 miles southeast of Northport, and in the Deer Trail district, west of Springdale.

TUNGSTEN

210. While tungsten occurs at a number of places in northeastern Washington, it has been mined and marketed only from Stevens County. The best known mine is the New Germania, which before the World War was owned and operated by some Germans who concentrated the ore and shipped it to industrial plants in Germany. This property is located about 17 miles west of Springdale, in the Deer Trail district. The tungsten minerals found are wolframite, ferritungstite, and scheelite. The ores are usually contained in pegmatite veins which belong to the Loon Lake granite (no. 32 on map).

211. Some 5 or 6 miles northeast of Loon Lake, in Stevens County, some tungsten claims have been partly developed and small shipments made of the ore. The tungsten minerals occur in quartz veins, which in turn are found in granite, quartzite, and schist (no. 34 on map).

REFERENCES

- Jenkins, Olaf P. Lead Deposits of Pend Oreille and Stevens Counties. Department of Conservation and Development, Bulletin No. 31, Olympia, 1924.
Patty, Ernest W. The Metal Mines of Washington. Washington Geological Survey. Bulletin No. 23, Olympia, 1921.
Weaver, Charles E. The Mineral Resources of Stevens County. Washington Geological Survey. Bulletin No. 20, Olympia, 1920.

REPORT ON THE COEUR D'ALENE, IDAHO, MINING DISTRICT

By FRANK H. DICKEY, *Assistant Geologist*

GENERAL STATEMENT

1. This report is on the economic phases of the mineral resources of the Coeur d'Alene mining district, the most productive region in Idaho and one of the great silver-lead areas of the world. The developed portion of the district covers an area of 404 square miles and is entirely in Shoshone County, due east of Spokane, near the Idaho-Montana line, as is shown on the map.

2. In 1842 a Jesuit Mission was established at the head of Coeur d'Alene Lake. Twelve years later Lieut. John Mullan started an exploration to locate a feasible route for a road across the Coeur d'Alene Mountains, to connect Fort Benton with Fort Walla Walla, which road was completed in 1863 at an expenditure of \$230,000.

3. The first quartz mine was staked in 1878, and 6 years later the gold rush started to the placer diggings on the North Fork of the Coeur d'Alene River, near the present site of the town of Murray. At the same time some placer was washed in Canyon Creek, which resulted in the staking of the Tiger and Poorman mines. A couple of years later the ore bodies in the neighborhood of Wardner were discovered and by 1889, 17,500 short tons of lead and 1,000,000 ounces of silver were annually mined. Since that time the production of the area has steadily increased, until in the last report of the United States Mineral Resources, which is for 1927, the total given for the annual value of the minerals produced in the Coeur d'Alene district is \$26,091,273.

GENERAL GEOLOGY OF THE DISTRICT

4. Both sedimentary and igneous rocks are present in the Coeur d'Alenes. The sedimentary rocks are called the Belt series and are of the Algonkian period. These rocks are mostly composed of slates, quartzites, and calcareous shales. The formations making up the Belt series are:

(a) The Prichard, which is the lowest of the Belt series, has a thickness of 8,000 feet without its base being exposed and is composed of blue shale and slate, with subordinate amounts of interbedded gray sandstone and quartzite.

(b) The Burke, overlaying the Prichard formation, is noted for its pale-tinted siliceous shale and sericitized flagy quartzite. It has a maximum thickness of 3,500 feet.

(c) The Revett quartzite which is a massive rock ranging in thickness up to 2,300 feet.

(d) The St. Regis, made up of quartzite, sandstone, and shale. It is 1,000 feet thick and in the center is characterized by peculiar purple and green colors.

(e) The Wallace, which is 4,000 to 6,000 feet thick, is composed of calcareous sandstone and shales and impure limestone.

(f) The Striped Peak, found only in a few places and composed of 1,000 feet of lilac-colored quartzite.

IGNEOUS ROCKS

5. The igneous rocks in the Coeur d'Alenes are represented by three types of intrusive rocks, namely, monzonites, lamprophyres, and diabases. The monzonites are considered to be offshoots of the Idaho batholith whose age is placed as Mesozoic. The diabases occur as dikes and sills, while the lamprophyres are found only as dikes.

6. Anorthosite and basalt occur in small amounts. Granodiorite, porphyritic monzonite, and pegmatite are other igneous rocks that have been reported as being in this region. All of these rocks are found in small amounts and do not seem to have any bearing on the genesis of the ore; therefore, their occurrence and distribution will not be taken up in this report.

STRUCTURE

7. The structure of the Coeur d'Alenes is complex. The region has been subjected to folding and possibly some early faulting, and at a later period was faulted on a large scale. Of these faults the Osburn fault is the most conspicuous as it can be traced for over 300 miles. It has a horizontal displacement of 10 to 15 miles and a vertical

displacement of about 1,000 feet. This fault does not run in a perfectly straight line but its general direction is west-northwest.

GEOLOGY OF ORE DEPOSITS

8. It is generally conceded by most authorities that in this district there is a genetic relationship between the monzonite intrusions and the ore bodies. Strong evidence supporting this view is the fact that it has been proved that the period of mineralization occurred after the monzonite intrusion and before the intrusions of the lamprophyre dikes. As the lamprophyre dikes are considered to be a differentiation production of the monzonite magma, it follows that the period of mineralization occurred at a period when hot emanations were given off by the monzonite magma which is very significant.

9. The ore in this region in most cases occurs in the sedimentary rocks and in many instances is found some distance from any known intrusions of monzonite. This is accounted for by the belief that the monzonite is of much larger extent at depth than it is on the surface. In this manner an ore body may be a long distance horizontally from any monzonite but only a short distance vertically.

10. The ore occurs in fissures or shear zones but not in any of the major faults such as the Osburn fault. Here it occurs partly as a filling in the fissures, but mostly as a replacement of the shattered rock that is found in the composite veins and shear zones. The wall rock in some places has been replaced by ore, and when this occurs it almost invariably has been shattered before replacement took place.

11. These fissures are nearly vertical, and the ore in some of the mines has a vertical range as great as 4,600 feet (in the Morning mine), while other mines, such as the Tiger mine, have been bottomed at a very moderate depth. This is thought to be due to a change in the formation rather than to its being below the vertical range of mineralization. In a general way the Prichard slates are not considered as being favorable for the deposition of ore.

12. The most valuable metal in this district is lead, with silver coming second, followed by zinc. Copper, gold, tungsten, and antimony are also found, but are of lesser importance. The bulk of the ore ranges in tenor from 3 to 14 percent lead and from 2½ to 6 ounces of silver to the ton, which is concentrated to a product containing over 50 percent lead. Where silver values run high usually tetrahedrite is found. The values in zinc vary greatly as is illustrated by the following: The Hecla mine contains practically no zinc while the Interstate-Callahan mine contains four or five times as much zinc as lead. The amount of zinc seems to increase with depth but not much data has been collected on this phase. At the present time galena is the only important lead mineral, but in the earlier days of the camp the oxides were of some economic importance. Zinc occurs here as sphalerite, and silver values either accompany the galena or the tetrahedrite.

13. The outcroppings of ore are not prominent in this region because the ore occurs in shattered zones and naturally the shattered rock is subject to faster erosion than the unshattered rock on either side. Even the sulphide ores are subject to faster decomposition than the slates and quartzites; consequently the ore bodies mostly occur in de-

pressions, and, because the district is well watered and covered with vegetation, many of the ore bodies were not discovered for a long time and new ore will surely be discovered in the future.

MINING METHODS

14. The ore deposits in the Coeur d'Alenes are tabular in shape and stand nearly vertical, but the ground in most places stands so poorly that the shrinkage slope method of mining cannot be used. Timbering and filling has to be resorted to and this makes mining costly, in many cases being as high as \$7 or \$8 per ton. Most of the mines are at the present time working at a considerable depth which increases the hoisting and pumping charges and consumes a great deal of power.

TREATMENT OF ORE

15. In this region the first silver-lead ore mined was hand-sorted and shipped in a crude form to the smelters. Later, however, lower grade ores were profitably mined and concentrated prior to shipment to the smelters; the process being graded crushing, followed by gravity concentration, using jiggs and tables. This method of treatment was successful when the ores were not so complex as to require fine grinding.

16. In the complex lead and zinc ores which require very fine grinding in order to liberate the minerals, a separation could not be effected. As the smelters place heavy penalties on any zinc in lead ores these complex deposits were not commercially profitable prior to the advent of the flotation method of concentration.

17. Many of the ores in the Coeur d'Alenes are very complex lead-zinc combinations and in plants treating this class of ore all the rock is finely ground and the entire separation is made by the flotation process. An example of this type of mill is the plant of the Federal Mining & Smelting Co. at Mullen, Idaho.

18. Mills which are treating simple lead and silver ores are still using gravity concentration, but in most cases a few flotation cells have been added to recover the slimes. The Bunker Hill & Sullivan Mining Co. is operating a lead smelter and an electrolytic zinc plant at Kellogg, Idaho.

PRESENT POWER CONSUMPTION IN THE REGION

19. No exact figures are available for the power consumed in Shoshone County. The greater part of this is supplied by the Washington Water Power Co. This company reports that 172,135,000 kilowatt-hours were used in 1929, and 137,312,000 kilowatt-hours were used in 1930, or an average consumption for these years, of 26,700 and 21,342 horsepower, respectively. The power reported from other sources was 6,379 horsepower, which makes the total reported power in this region 27,721 horsepower during 1930.

20. A small amount of power was used that has not been reported, this however would not be large, the total average consumption being in 1930 probably less than 30,000 horsepower. The Washington Water Power Co. reports a peak load of 37,520 horsepower which

would make the total peak load about 50,000 horsepower. The smaller consumption of power in 1930 was caused by the closing of a number of the smaller mines due to the low market. The three largest producers used more power in 1930 than in 1929.

21. The Bunker Hill & Sullivan Mining Co. is the largest consumer of power in the district with a total average consumption of 13,846 horsepower which is used in the various operations as follows: Consumption in underground workings 1,050 horsepower; on the surface, including mills (concentrators), 4,257 horsepower; smelter, 1,986 horsepower; and the electrolytic zinc plant, 6,553 horsepower.

22. The Morning mine, operated by the Federal Mining & Smelting Co., used an average of 4,746 horsepower in 1930, of which 1,957 horsepower was used underground; 2,648 horsepower was used in the mill, and 141 horsepower general surface. The Page mine, owned by the same company, used an average of 813 horsepower during the year.

23. The Hecla mine used 2,918 horsepower during 1930, divided as follows: 1,935 horsepower underground, and 983 horsepower on the surface. The Hercules Mining Co. reported using an average of 820 horsepower during the same period.

PRESENT CONDITIONS OF MINING INDUSTRY IN THE DISTRICT

24. The production for Shoshone County in 1927 was 1,919,309 tons of ore including old tailings treated. This is the latest figure available, but the production for 1930 should be about the same. The Bunker Hill & Sullivan mine mined 455,475 tons of ore in 1930, and the Federal Mining & Smelting Co. mined 458,819 tons of ore in the same year, which is over 100,000 tons more ore mined by these two companies than was mined in 1927. This is partly offset by the closing down of some of the smaller mines due to an unfavorable market.

25. Production has probably reached its peak in the Coeur d'Alenes, although it may hold its present rate for some time to come and continue producing for many years. It is true that some of the active mines seem to be on the wane, but one large ore body has been discovered within the last 2 years in one of the first areas prospected. It may be assumed that other ore bodies will be found in the future.

26. The tendency in the mining industry in the last 20 years is to use more power per ton of ore mined in both milling and mining operations. Also, as mines get deeper, the consumption of power is greater both in pumping and hoisting. Hence it is reasonable to expect that there may be a small increase in power consumption in the future in this district.

BIBLIOGRAPHY

- Umpleby, Joseph B., and Jones, E. L. Geology and Ore Deposits of Shoshone County, Idaho, U.S. Geological Survey Bulletin 732.
Ransome, F. L., and Calkins, F. C. The Geology and Ore Deposits of the Coeur d'Alene District, Idaho, Professional Paper 62.
Lindgren, Waldemar. Mineral Deposits, page 646.
Gerry, C. N. Gold, Silver, Copper, Lead, and Zinc in Idaho, Mineral Resources of the United States for 1927.

REPORT ON THE BUTTE, MONT., MINING DISTRICT

By FRANK H. DICKEY, *Assistant Geologist*

GENERAL STATEMENT

LOCATION

1. This is a brief summary of the mining operations of the Butte mining district, Montana. The points emphasized are the economic phases of the power consumption and the future of the district.

2. The city of Butte is situated in the heart of the Butte mining district, which covers 25 square miles in the northeastern corner of Silver Bow County. In a small area of only 6 square miles beneath the city lies one of the world's greatest copper-producing districts.

HISTORY

3. The discovery of rich placer at Bannock, Alder Gulch, and Last Chance Gulch, in 1863, attracted large numbers of prospectors into Montana. In 1864, placer was located on the site of the present city of Butte from which it is estimated that a total of \$1,500,000 was realized.

4. As the lodes were much in evidence, W. L. Farlin staked the Travona mine in the summer of 1864. The following year, a rich strike of silver was made at this mine which encouraged the erection of a 10-stamp mill the next summer. This enterprise turned out a failure. In 1875 Mr. Farlin erected a 10-stamp mill and a furnace for the purpose of treating silver ores. The treatment charges were from \$25 to \$30 per ton. Production of silver reached its peak from 1887 to 1892, since which time it has declined.

5. Some of the copper veins were staked as early as October 1864. Active development was not undertaken until 1872 when W. A. Clark turned his attention to copper. He tried to ship the ore, but the freight charges were so high that the venture was unprofitable and in 1879 he arranged to have the Colorado smelter built at Butte. Four years later the Anaconda Copper Co. built a reduction plant at Anaconda to treat Butte ores. From this time on copper played a leading role until Butte has ranked as one of the most productive copper camps in the world.

GENERAL GEOLOGY OF THE REGION

6. "A central mass of granitic rock, now exposed for about 64 miles in length and 12 to 16 miles in width, is surrounded by upturned and folded sedimentary rocks whose edges are abruptly cut by the granite. Remnants of a former capping of dark-colored and baked andesites occur as patches over the northern part of the region, and extensive areas of the same rocks form mountain masses flanking the granite on the east, north, and west, concealing the sedimentary contacts in these areas. These andesitic rocks are partly intrusive, but mainly extrusive lavas or volcanic debris.

7. "The granite itself contains numerous patches and dikes of white alaskite that are regarded as a later silicious phase of the granite itself. All these earlier rocks, including the sedimentary limestone, etc., are cut by rhyolitic dikes and capped by extensive

accumulations of fragmental rhyolitic rocks and lava flows. Mineral-vein formation preceded this later volcanic period and is still in progress in some parts of the district. Over the northeastern part of the granite region quartz veins, usually barren, are extremely common and of unusual size, forming the crest of long high ridges and dominating the local topography. The deeper and older valleys of the district are filled by alluvial deposits and lake beds largely composed of rhyolitic volcanic dust and material washed down the slopes when the rhyolitic eruptions occurred.

8. "From studies elsewhere it is known that over a large part of the State igneous activity began on a grand scale at the close of the Cretaceous period. The region between Helena and Butte yields no positive evidence of the age at which the andesitic rocks were formed further than that it was post-Cretaceous and earlier than the deposition of the Neocene lake beds.

9. "Since the close of the volcanic epoch represented by the rhyolite no great changes have occurred in the geologic features of the district. The Miocene lakes have been drained by streams flowing northward. During later glacial time the higher summits were covered by local ice sheets, which formed the moraines now conspicuous in the mountains east of Elk Park and at other localities, though not near Butte. The grander features of topography are the same today as at the close of Miocene time, having been modified only by canyon cutting and valley filling, which changed only the scenic details."⁹⁴

THE GEOLOGY OF THE BUTTE DISTRICT

10. At Butte the granitic rock is slightly more basic than the rest of the granite. Here we also find the alaskite. This is more acidic than the main mass of the Boulder batholith and it is thought that at depth a differentiation in the magma occurred. The main mass of the Butte quartz monzonite separated from the magma and, solidifying first, left behind a residue of the more acidic elements still in the liquid form. Later this acidic residue (alaskite) was squeezed into the cracks in the solidified Butte quartz monzonite, thus forming dikes and sheets of irregular shapes composed of alaskite.

11. A rhyolite porphyry occurs in wedge-shaped masses and in dikes which cut both the Butte quartz monzonite and the alaskite but not the veins. Thus its age is definitely established as younger than these rocks but older than the veins. This rhyolite only occurs in the copper region. The latest rocks are a series of rhyolitic flows which came as intrusions in the form of dikes and fillings in volcanic necks, and extrusive which occur as lava flows or surface breccias. Dikes of rhyolite cut the veins and all other rocks, thus placing it as the youngest series in the district.

GEOLOGY OF ORE BODIES

12. "The ores occur in a fissure system of great complexity. The principal veins strike east and west. A second system, known as the blue or northwesterly veins, intersect and fault with moderate

⁹⁴ Weed, Walter Harvey, *Geology and Ore Deposits of the Butte District, Montana*. U.S. Geological Survey, Prof. Paper 74.

throw the east-west veins, which are called the Anaconda system. The dips are to the south at high angles. These two series of veins are cut by northeasterly trending faults which have caused a dislocation of the older veins amounting to 200 or 300 feet. The fault veins sometimes carry ore as 'drag' but do not contain large bodies of ore.

13. "The ore shoots are irregular; while some continue to the greatest depth attained at the present time (3,000 to 4,000 feet), others have been bottomed in a much shorter distance.

14. "The stope width is from 6 to 30 feet. And, while the east-west veins are wider and more productive, there is not a great deal of difference in mineralization between the two systems. Even when the veins are sharply defined, much of the ore has resulted from the replacement of the country rock. In the central part of the copper area there is wide-spread replacement by ore and the outlines of the ore bodies are indefinite."⁹⁵

15. The veins in the district are classed as being either copper or silver, according to the predominant mineral values. The copper veins average about 2.5 ounces silver per ton while the silver veins carry a little copper. The copper lodes are restricted to an area of 6 square miles, in which no silver veins occur.

16. The copper ore is a "heavy, coarse-grained sulphide aggregate in which pyrite predominates, the quartz gangue is not prominent."⁹⁵ Chalcocite is the principal copper mineral and it is of the massive variety. Other minerals found in the copper ore bodies are pyrite, sphalerite, enargite, tennantite, bornite, and chalcopyrite.

17. The copper is leached from the outcrops leaving a barren zone of honeycombed quartz veins, ranging in thickness from 10 to 400 feet. "In the central copper area, where the granite is greatly altered, the upper limit of the sulphides is practically a plane in spite of surface inequalities of nearly 300 feet. There is a slight enrichment of silver in the leached zone, the material carrying as much as 30 ounces of silver per ton, in contrast to 2.5 ounces per ton in the sulphide ore."⁹⁵ No secondary enrichment of gold is apparent.

18. "A sharp line of demarcation separates the two zones, the change in many places occurring within 2 or 3 feet vertically. At this level the ores contained much chalcocite and averaged about 8 percent or more of copper. Solid masses of glance ore, 15 feet in thickness, were found. Covellite is less abundant and secondary chalcopyrite is rare. In depth the enriched ore gradually decreases in value, but secondary chalcocite persists in places to depths of 3,000 feet or more."⁹⁵

19. "The silver-lead-zinc mineralization is apparently later and the sulphides consist of pyrite, sphalerite, galena, and some chalcopyrite."⁹⁵ These minerals are usually shattered and brecciated by a quartz manganeseiferous invasion. In general the values in the silver veins do not go below 1,500 feet.

MINING METHODS

20. The badly shattered Butte formation does not stand well and in most places requires timbering. At the present time about 95 percent of the stopes are "square set"; or, in other words, the walls

⁹⁵ Lindgren, Waldemar, Mineral Deposits, pp. 697-700.

are supported by timbers as soon as possible after the ore has been removed. This makes mining costly which is offset by the high tenor of the ore which averages over 3.5 percent copper.

21. Another factor increasing the cost of operations is that mining is now being carried on at a depth of 4,000 feet. This necessarily adds to the pumping and hoisting charges. A third reason for higher costs is the high temperature encountered in the lower levels which greatly reduces the efficiency of labor. This evil is combated by forcing a large volume of cold air through the lower workings.

TREATMENT OF ORE

22. Ninety-five percent of the ore mined in the Butte district is treated by some method of concentration. In most cases this is graded crushing and concentration by gravity, followed by flotation. Some of the new mills in this district are straight-flotation plants in which all the feed is ground fine. When the ore is complex, fine grinding has the advantage of making a much better separation between the different minerals than when gravity concentration is employed.

23. The Anaconda Copper Co. ships its ore 32 miles to Anaconda before it is concentrated. The copper concentrates are then smelted to form blister copper which product, in turn, is treated electrolytically to emerge as copper 99.98+ percent pure. The mine water contains copper which is precipitated by means of scrap iron. Four million five hundred thousand pounds of copper were recovered in this manner during 1927 at Butte.

POWER CONSUMPTION IN THE BUTTE DISTRICT

24. The Butte mines are very deep. They use large amounts of power in hoisting, pumping, and in their ventilating systems. Ventilation alone accounts for 3,000 horsepower. Figures on power consumption in pumping and hoisting operations are not available but the amount must be very great as a single hoist will rate 4,500 horsepower. No figures are obtainable for the power used at Anaconda. The electrolytic refineries at Great Falls require 80,000 horsepower.

25. The Anaconda Copper Co. has increased its holdings in the last few years until at the present time it is the only large operator in the district. This company gets its power from Great Falls, Mont., through the Montana Power Co., one of its subsidiary companies.

PRESENT CONDITIONS OF THE MINING INDUSTRY IN THE BUTTE DISTRICT

26. During 1927, Silver Bow County produced 3,610,699 tons of ore containing the following metals: ⁹⁶

Copper.....	pounds...	205, 774, 687
Zinc.....	do.....	156, 627, 681
Lead.....	do.....	25, 537, 495
Silver.....	ounces...	9, 243, 605
Gold ⁹⁷	\$543, 939

Butte contributed 13.37 percent of the copper mined in this country in 1927. The variations in the amounts of copper produced at Butte

⁹⁶ Old tailing treated included.

⁹⁷ These figures are for Silver Bow County but can be taken for the Butte district as very little ore comes from this county outside of Butte.

from year to year seem to be due to the price of copper and the market conditions, rather than the ability to produce the metal.

27. The size of the ore reserves at Butte are not known, or at least they are not made public. For this reason no definite estimates of the life of the camp can be made. Ore has been found on the lowest levels yet attained. It is true that some of the ore bodies have been bottomed on the upper levels but, as other ore bodies have been encountered that had not reached the surface, there would seem to be as much ore in the deeper workings of the mine as in the upper levels.

28. The depth to which these mines can be worked will depend on how soon the increasing cost of pumping, hoisting, and cooling will prohibit further economical operations. Cheap power will make it possible to mine at great depths, thus adding to the life of the mines. The Montana Power Co. is producing power economically at the hydroelectric plant at Great Falls, Mont. Within the last few years the company has installed a number of hoists capable of hoisting from a depth of 5,000 feet indicating an intention of operating to that depth. The conclusions, drawn from the above, are that the Butte district will continue for years to be an important producer of copper.

BIBLIOGRAPHY

Weed, Walter Harvey. Geology and Ore Deposits of the Butte District. United States Geological Survey, Professional Paper 74.

Rickard, T. A. Applied Geology at Butte. Mining and Scientific Press, vol. 123, p. 427.

Lindgren, Waldemar. Mineral Deposits, p. 696.

Taggart, Arthur F. Handbook of Ore Dressing, p. 82.

APPENDIX 2

WATER-SUPPLY AND STORAGE ANALYSES

Supervised by GLENN L. PARKER, *District Engineer*, U. S. Geological Survey, Tacoma, Wash.

CONTENTS

	Page
General outline of procedure.....	1114
Set no. 1.....	1116
Set no. 2.....	1118
Set no. 3.....	1120
Set no. 4.....	1123
Set no. 5.....	1126
Set no. 6.....	1129
Set no. 7.....	1131
Flathead Lake—Intermediate plan of development.....	1134
Study data:	
Set no. 1 }	
Set no. 2 }	
Set no. 3 }	
Set no. 4 }	facing page 1134
Set no. 5 }	
Set no. 6 }	
Set no. 7 }	
Flathead Lake—Intermediate plan of development.....	1135
Tables of modified flows and lake elevation:	
Explanation.....	1138
Tables.....	1139
Set no. 1: Hungry Horse Reservoir, regulated elevation.....	1139
Set no. 2:	
Kootenai Reservoir, regulated elevation.....	1139
Columbia River at Kettle Falls, modified discharge.....	1140