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GEOLOGY AND ORE DEPOSITS OF THE CRIPPLE CREEK DISTRICT, COLORADO[1]

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U. S. Geological Survey in cooperation with
Colorado State Geological Survey Board and
Colorado Metal Mining Fund.

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ILLUSTRATIONS

ABSTRACT

The study on which this report is based has had two main objectives—(1) to recognize conditions that control the downward continuity of ore zones and the localization of ore shoots in the Cripple Creek district; (2) to determine to what extent geologic conditions may affect the location and driving of a proposed deep drainage tunnel about 1,000 feet below the present one.

The breccia mass in which most of the mines are situated represents a denuded volcano of late Miocene age surrounded by pre-Cambrian granite, gneiss, and schist, which are locally covered by remnants of Paleozoic and Mesozoic sedimentary and early Tertiary volcanic rocks. Pertinent features of the regional geology that have a bearing on the economic geology of the district are reviewed in historical order.

The Cripple Creek volcano is a composite mass formed by dominantly explosive eruptions along a network of master fissures that had resulted from regional compression during the Laramide revolution. The earliest stage of development of the volcano is obscure, but it is known that a basinlike depression was formed in the northeastern part of the volcanic area and was filled largely by water-laid pre-Cambrian debris together with a minor amount of local volcanic debris. Recent work in the Cameron mine has disclosed in this water-laid rock a lenticular bed of carbonaceous shale with fossil leaves that closely resemble those of the late Miocene lake beds at Florissant, northwest of the district. Correlation on the whole, however, though not final, suggests that the fossiliferous beds in the Cripple Creek district were formed during a later epoch of Miocene time than those at Florissant. Remnants of bedded rock have been found elsewhere in the volcano, particularly in its eastern and southeastern parts, but for the most part bedding has been destroyed by the succession of explosive eruptions that determined the complex outline of the volcanic neck or crater and filled it with a mass of breccia.

The composite volcano is believed to taper downward into several roots or subcraters, through which latite-phonolite, syenite, phonolite, and alkaline basaltic rocks were succes-

sively intruded and formed dikes, "flats," and larger irregular masses. Subsequent to the basaltic intrusions a local explosive eruption of basaltic breccia took place in the central part of the district and formed a breccia pipe called the "Cresson blowout." Vein formation followed.

Many of the fissure zones along which intrusions and vein formation occurred coincide essentially in direction with the older fissures along which the volcano was developed. These zones, together with associated minor fissures, may be attributable in minor degree to such local causes as the settling of the breccia within the crater and the upward thrust of intruding lava or of minor explosions; but they are due mainly to intermittent regional compression and shearing in a northerly direction. This regional activity culminated before the intrusion of phonolite and developed master shear zones in granite at the favorably situated corners of the deep subcraters in the southern part of the district. These shear zones contain the principal mines outside of the breccia area. During the declining stages of regional activity the eastern and western parts of the district tended to move northward with respect to the central part, and the principal vein zones accordingly occupied fissures that were subjected to tension during this movement. Most of them trend northward to northwestward in the eastern part of the district and north-northeastward to east-northeastward in the western part. Pre-existing structural features in the northeastern part of the district deflected the force more to the northeast, and the vein zones in part follow that general direction. Local conditions have also influenced the distribution and position of veins and ore shoots throughout the district, as is shown in some of the detailed mine descriptions.

The most persistent vein zones are (1) along the master shear zones in granite, (2) the upward extensions of favorably situated prevolcanic fissures in breccia, and (3) the principal fissure zones that branch from those extensions. The principal disturbance that followed vein deposition was a prevailingly vertical uplift that produced faults of considerable size in the surrounding country and a few relatively small postmineral faults within the district.

The mineral deposits were formed during three general stages. The first stage was characterized mainly by the deposition of jaspery and porous aggregates of quartz and adularia and fine-grained, massive mixtures of fluorspar and quartz accompanied by some coarsely crystalline pyrite. The characteristic minerals of the second stage are quartz, fluorspar, fine-grained pyrite, dolomite or ankerite, celestite, roscoelite, zinc blende, galena, tetrahedrite, tellurides of gold, and in some places tellurides of silver and copper. The association of tellurides with the other minerals is variable, as the tellurides were formed last and in some places after openings had been closed by the deposition of the earlier minerals; indeed, the deposition of gold and other tellurides may be regarded as confined to a substage that followed the second general stage. The third general stage is represented mainly by openings containing clear to smoky quartz, chalcedony, fine-grained and radiating pyrite crystals, calcite, and locally cinnabar. Some of these late minerals, especially cinnabar, are attributable to rising solutions, but others, especially pyrite and chalcedony, may be attributable to descending waters below the oxidized zone.

The deposits occur as veins, irregular bodies, and collapse breccias. Outstanding features of the veins are their steplike arrangement and the occurrence of many ore shoots at or near intersections with other steeply dipping fissures and "flats." The irregular bodies occur in shattered ground, some of it corroded and honeycombed during the first stage of mineralization and all of it closely associated with intersecting fissure zones. A few of them have been found at rather great depth, but more have been found at moderate to shallow depths. The mineralized collapse breccias were formed by excessive corrosion, which reduced shattered ground to rubble early in the first stage, and by the coating of the rubble fragments with minerals of all three stages; but, with the exception of the rich cavern or large vug in the Cresson mine, they have been of too low grade to be mined.

Although the veins form relatively broad, complex systems at shallow depths, they converge downward, toward the roots of the subcraters. Ore has been mined to a maximum depth of 3,000 feet, and its general uniformity in mineral composition from the shallowest unoxidized to the deepest exposures gives no indication of an approach to the ultimate depth at which tellurides could form. Structural conditions, however, restrict the number and distribution of ore shoots with increasing depth and, together with the costs of deep exploration, determine the downward limit of mining. In some places ore-forming solutions traveled long distances and even reached shallow ground before finding structural conditions that favored deposition of ore in commercial quantity.

Detailed descriptions of significant features in the deepest mines are given, together with brief descriptions of several other mines.

Geologic conditions are generally favorable for the driving of the proposed deep drainage tunnel. The ground water, however, tends to become increasingly isolated with depth in basins that correspond to the subcraters, and any tunnel, to effect adequate drainage of the district, should have branches reaching to the different subcraters. A consideration of geologic and ground-water conditions and of the most promising deep ore reserves favors the choice of an adit that would extend from Marigold, about 6 miles south-southwest of the district, to the Granite and Portland mines with a northward extension toward the Cresson mine, which is in the same basin as the Granite mine. A direct extension could be made from the Portland to the Vindicator mine, and a long branch from the Cresson extension could be driven to drain mines in the southwestern part of the district.

INTRODUCTION

The Cripple Creek mining district, in central Colorado, is one of the famous gold camps of the world. It had a total recovered output of 17,235,716.16 ounces of gold and 1,931,651 ounces of silver[1] to the end of 1933. Gold mining began there in 1891 and increased at an accelerating rate, with few interruptions, until 1900, when the maximum annual output of 878,067 ounces of gold, valued at $18,149,645, was attained.[2] Between 1901 and 1911 production fluctuated but on the whole declined to an annual value of $10,563,000. For the next few years it increased, particularly in 1915, when the discovery of an extremely rich shoot in the Cresson mine brought the annual value to $13,683,000.

When the district was only a few years old and the mines were still shallow, ground water became a serious problem. Many mines were pumped, and drainage was also established by tunnels which were driven at lower and lower altitudes as the mines became deeper. The last tunnel to be driven, the Roosevelt drainage tunnel, was started in 1907 and was financed through cooperation of the principal mining companies. Its final extension was completed in 1918. It drained a large part of the district at an average altitude of about 8,100 feet and permitted still deeper mining by pumping from depths of a few hundred to 1,000 feet below the tunnel level. In 1917, when gold camps in general were handicapped by World War conditions, the district's production began to decline rapidly, and this decline was hastened by the exhaustion of several large shoots, while the development of new shoots had to be neglected. High cost of operation discouraged attempts at recovery, and since 1920 the value of annual production has averaged less than $4,000,000. Since 1928 it has gradually declined until in 1932, despite some increase in activity, it was only $2,395,000, nearly half of which was won by the reworking of old dumps.

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[1] Henderson, C. W., Gold, silver, copper, lead, and zinc in Colorado: Mineral Resources, 1908-31; Minerals Yearbook, 1932-33, 1934.

[2] Lindgren, Waldemar, and Ransome, F. L., Geology and ore deposits of the Cripple Creek district, Colo.: U. S. Geol. Survey Prof. Paper 54, p. 135, 1906. Henderson, C. W., History of mining in Colorado: U. S. Geol. Survey Prof. Paper 138, p. 247, 1926.

The recent increase in activity consisted at first mainly of work by individuals, spurred on by the relative increase in the purchasing power of gold during the industrial depression that began in 1929 and was further stimulated by the gradual increase in the price of gold from $20.67 to $35 an ounce from August ,1933, to January, 1934.[3] This stimulation came too late to increase the quantity of gold produced in 1933, which was only 468 ounces greater than that produced in 1932, but the value of the output was greater. According to C. W. Henderson, the output was 127,950 ounces in 1934, compared with 109,185 ounces in 1933.

The district was first studied for the United States Geological Survey by Cross and Penrose in 1894,[4] 3 years after production began, and a complete resurvey of it was made by Lindgren and Ransome[5] in 1904, shortly after it had passed its zenith. The work in 1904 was supported jointly by the State of Colorado and the United States Geological Survey. The prediction by Lindgren and Ransome that the deeper levels would be less productive than the shallower levels was generally confirmed by subsequent operations, but the discovery of a deep rich ore shoot beneath a low-grade interval in the Portland mine, the remarkable downward persistence of ore shoots as a whole in the Cresson mine, and the occurrence of well-defined though not very productive veins at deep levels in several other mines led to a request from the Colorado Mining Association for a new cooperative study in the light of these developments. This study was undertaken by Loughlin[6] in 1924 and 1925, and since then short visits have been made by him at intervals, to take advantage of the reopening of certain mines that might reveal evidence of critical importance regarding the downward persistence of the

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[3] Henderson, C. W., Minerals Yearbook, 1934, pp. 25-43.

[4] Cross, Whitman, Geology of the Cripple Creek gold mining district, Colo.: Colorado Sci. Soc. Proc., vol. 5, pp. 24-29, 1894. Cross, Whitman, and Penrose, R. A. F., Jr., The geology and mining industries of the Cripple Creek district, Colo.: U. S. Geol. Survey 16th Ann. Rept., pt. 2, pp. 1-209, 1895.

[5] Lindgren, Waldemar, and Ransome, F. L., op. cit.

[6] Loughlin, G. F., Ore at deep levels in the Cripple Creek district, Colo.: Am. Inst. Min. Met. Eng. Tech. Paper 13, 32 pp., 1927.

ore deposits. These visits were made under the cooperative topographic and geologic program of the Colorado Metal Mining Fund, the State of Colorado, the State Geological Survey Board, and the United States Geological Survey, which had been in essentially continuous operation since 1922.

In the winter of 1930-31 Koschmann spent 4 months in the district and studied most of the shallower mines that were then active. By that time most of the deepest developments in the district had ceased and the mines had filled with water to the level of the Roosevelt drainage tunnel; but by 1933, owing to changing industrial conditions, the improved outlook for gold renewed interest in deep development and gave rise to a proposal for draining the mines by a tunnel that would be driven as a Public Works project and would be about 1,000 feet deeper than the Roosevelt tunnel. Therefore, under the Colorado topographic and geologic cooperative agreement, we revisited the district from September, 1933, to January, 1934, made further studies with special reference to the proposed tunnel, and submitted a report to the Public Works Administration in May, 1934. The main features of that report are incorporated in the following pages, which present a more comprehensive though not exhaustive report on the district.

Much valuable information has been lost through the abandonment of workings between the resurvey by Lindgren and Ransome and the recent studies. Many small mines, some of which may have been accessible, have not been seen because our attention has been directed to specific rather than to general problems and because of the limited time available for our studies. Among the small mines not visited are the Joe Dandy, where an important discovery has recently been reported, and several others that have recently been reopened. Several months more could be spent advantageously in the district to complete a general resurvey.

During the study of the new tunnel project large-scale detailed topographic and geologic mapping by Koschmann, assisted by Willis G. Hills, was extended southwestward from the Cripple Creek quadrangle to Marigold, where the portal sites of the proposed tunnel are situated. Only cursory attention has been given to the surface geology in the productive part of the district, which was mapped in detail by Ransome and Graton in 1903.[7]

We here acknowledge our indebtedness to the many operators, engineers, and miners who have cooperated so whole-heartedly in the study of their mines and records, and especially those who have voluntarily given of their time and general information in supplying essential data; also to our colleagues who have critically read the manuscript and offered helpful suggestions.

The outstanding conclusions based on the recent study place special emphasis on regional deformation to account for the origin of the fissure systems; the composite character of the Cripple Creek crater or volcanic neck, which has been developed along intersecting fissure systems and is believed to pass downward into several roots or subcraters, each of which became a local deep source of intrusive lavas and ore-forming solutions; the general downward convergence of ore bodies toward these sources; the importance of the steplike arrangement of veins in both horizontal and downward development; the relations of ore shoots to local details of deformation and their significance in further exploration; and the dependence of the downward limit of mining on these structural conditions rather than on the ultimate depth at which the ore minerals could form. Intensive development with due regard to the significance of fissuring and the mineral composition of the veins is likely to lead to new discoveries, both horizontally and downward. Development below present drainage level is to be encouraged in certain places where costs are not prohibitive, but in other places structural features render deeper development very speculative. The ground water shows a tendency to occupy somewhat isolated basins with increasing depth. The physical conditions are generally favorable for driving a new, deep drainage tunnel, which would probably pass from Marigold to the Granite and Portland mines at Victor and thence toward the Cresson.

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[7] Lindgren, Waldemar, and Ransome, F. L., op. cit., pl. 2.

Bibliography

An annotated list of publications on the Cripple Creek district to the end of 1904 was included in Professional Paper 54. A selected list of articles published in 1905-34 is presented below. Several other articles that refer briefly to the district contain little or no original information and add nothing worth while to that in Professional Paper 54 and the articles here cited.

GEOLOGY

Butler, B. S., Potash in certain copper and gold ores: U. S. Geol. Survey Bull. 620, p. 233, 1916. Calls attention to high potash content of Cripple Creek and other tailings, which would become of interest if the extraction of potash from silicate rocks should pass the experimental stage.

Colburn, E. A., Replacement deposits in the Ajax mine [Victor, Colo.]: Eng. and Min. Jour., vol. 95, pp. 739-741, 1913. Sketches geology of the mine and describes the replacement deposits and related veins. States that phonolite dikes are younger than the ore, and therefore differs with Lindgren and Ransome regarding the factors that controlled the deposition of the replacement bodies.

Colburn, E. A., Influence of flat dike on ore formation [Cripple Creek], Colo.: Eng. and Min. Jour., vol. 96, pp. 599-600, 1913. Describes a small ore shoot formed along and below a "flat" basaltic dike, which evidently diverted solutions from the main very-productive vein fissure, which intersects the dike along a fault with a 4-foot throw. The location is not stated.

Emmons, W. H., The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, pp. 345-348, 1917. Agrees with Lindgren and Ransome (Prof. Paper 54) that no appreciable enrichment has taken place below the oxidized zone at Cripple Creek.

Herrick, R. L., The Cresson mine: Mines and Minerals, July 1911, pp. 735-740.

Lindgren, Waldemar, Telluride ores, Cripple Creek: Min. and Sci. Press, vol. 94, p. 472, 1907. Abstract of author's paper on "Metasomatic processes in the gold deposits of Western Australia." Compares telluride deposits of Cripple Creek with those of Kalgoorlie, W. A., and the Mother Lode, Calif., and suggests that diminution in quantity of ore with depth is due to rapid circulation of solutions to higher levels rather than to the instability of tellurides at high temperature and pressure.

Loughlin, G. F., Ore at deep levels in the Cripple Creek district, Colo.: Am. Inst. Min. Met. Eng. Tech. Pub. 13, 1927. Briefly describes the Cresson "blowout", recognizes three general stages of mineral deposition, shows that rich, pyritic ore is caused by minute fracture fillings of calaverite and hessite, and describes low-grade collapse breccia and local sources of ore in the southeastern part of the district.

Loughlin, G. F., Cripple Creek mining district: 16th Internat. Geol. Cong. Guidebook 19, pp. 113-122, 1932. Essentially a condensation of information in Am. Inst. Min. Met. Eng. Tech. Paper 13.

Loughlin, G. F., and Koschmann, A. H., Proposed deep drainage tunnel for Cripple Creek (report made for Public Works Administration), 1934. Not published, but copies in open files of Public Works Administration in Washington, D. C., and Denver, Colo. Most of it is included in the present paper.

Muilenburg, G. A., Manganese deposits of Colorado: Colorado Geol. Survey Bull. 15, pp. 32-33, 1919. Briefly mentions a deposit of manganiferous iron ore poorly exposed in the Homestake or Ironclad mine. Average manganese content of 6 samples was 17 per cent. Van Tuyl (see below) states that the ore streaks are too small and scattered to be of value.

Patton, H. B., and Wolf, H. J., Preliminary report on the Cresson gold strike at Cripple Creek, Colo.: Colorado School of Mines Quart., vol. 9, No. 4, pp. 1-15, 1915; (abstract, Geol. Soc. America Bull., vol. 26, pp. 84-85, 1915). Describes the large "vug" on level 12.

Patton, H. B., The Cresson bonanza at Cripple Creek [Colo.]: Min. and Sci. Press, vol. 115, pp. 381-385, 1917. Repeats description of the "vug" and describes two other occurrences on level 14.

Rickard, T. A., Two famous mines: Min. and Sci. Press, vol. 103, pp. 765-766, 1911. Includes the Independence mine of Cripple Creek.

Sharwood, W. J., Notes on tellurium-bearing gold ores: Econ. Geology, vol. 6, pp. 22-36, 1911. Brief reference to Cripple Creek ores.

Stevens, E .A., Basaltic zones as guides to ore deposits in the Cripple Creek district, Colo.: Am. Inst. Min. Eng. Trans., vol. 33, pp. 686-698, 1903. Reprinted in Emmons, S. F., Ore deposits, pp. 411-423, New York, 1913 (pub. by A.I.M.E.). Original article was cited in Prof. Paper 54. Maintains that there is a genetic relation between the basaltic dikes and ore deposition and that the type of rock is more important than the structure in determining the occurrence of ore.

Van Tuyl, F. M., The Cripple Creek district of Colorado, a resurvey; geology and ore deposits: Colorado School of Mines Quart., vol. 14, No. 3, pp. 5-10, July 1919. A condensed account, reviewing interesting ore discoveries up to 1919. Similar accounts by H. J. Wolf on mining, I. A. Palmer on metallurgy, with historical introduction by J. T. S. Smith and resumé by V. C. Alderson.

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Brunton, David W., and Davis, John A., Safety and efficiency in mine tunneling: U. S. Bur. Mines Bull. 57, pp. 11, 74, 82, 87, 118, 126, 140, 151, 155, 206-8, 1914. Describes cost of driving, dimensions, and other mining features of Roosevelt tunnel.

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OUTLINE OF REGIONAL GEOLOGY

The Cripple Creek district, as first shown by Cross[8] and later by Lindgren and Ransome,[9] consists mainly of a denuded complex or composite volcano formed by explosive eruptions on a gently undulating land surface. The mines of the district are within or close by this volcano. The region surrounding the volcano (fig. 1) consists mainly of granite, which encloses small to large masses of schist and gneiss and is capped in places by sandstone, grit, and conglomerate derived mainly from the granite and by masses of volcanic rock.

The volcanic rocks include rhyolite, andesite, and the alkaline group that constitutes the Cripple Creek volcano and

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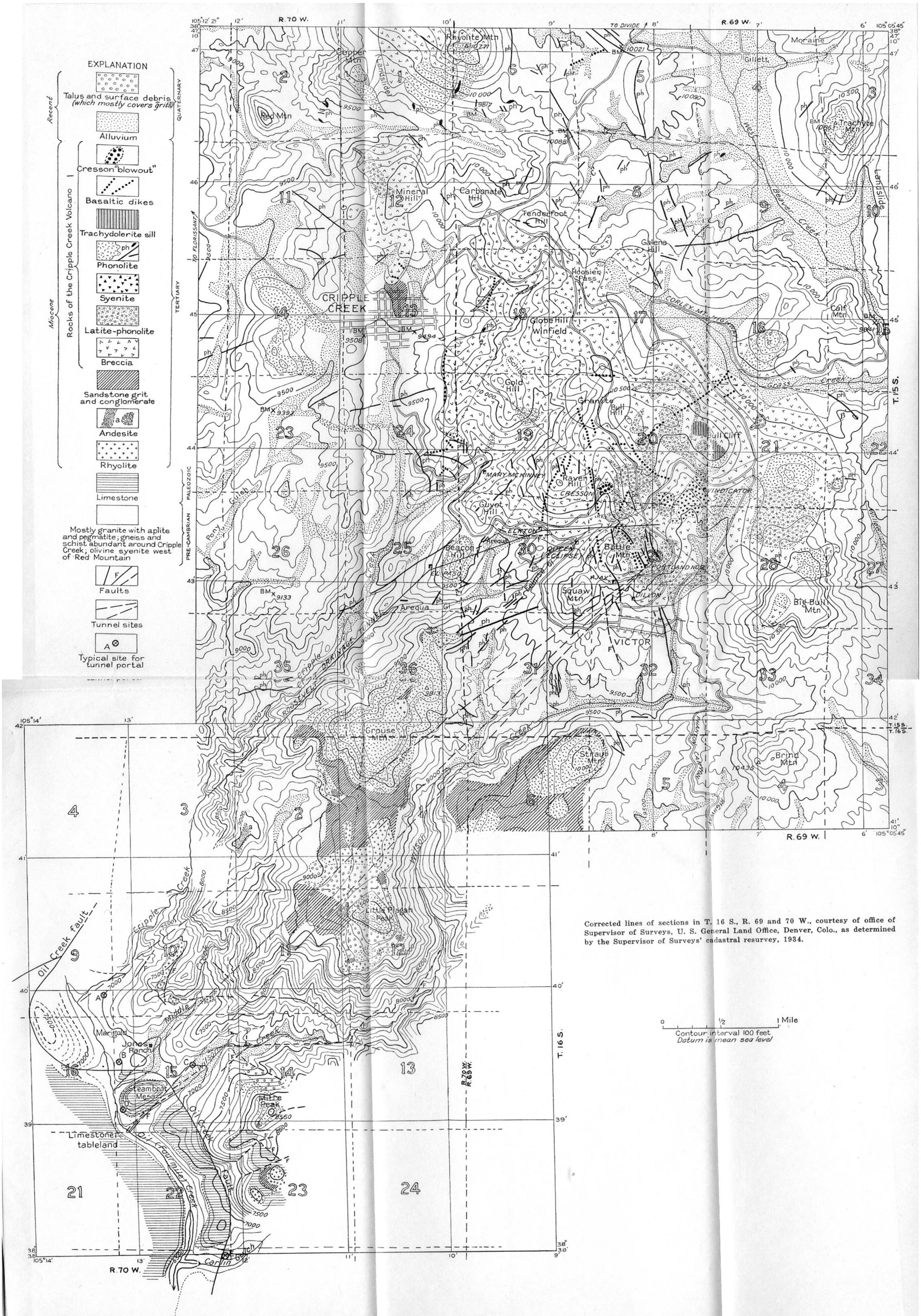
[8] Cross, Whitman, Colorado Sci. Soc. Proc., vol. 5, pp. 24-29, 1894.

[9] Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 18-23.



Corrected lines of sections in T. 16 S., R. 69 and 70 W., courtesy of office of Supervisor of Surveys, U. S. General Land Office, Denver, Colo., as determined by the Supervisor of Surveys' cadastral resurvey, 1934.

Figure 1.—Geologic and topographic map of the Cripple Creek district and area to the south.

its outliers. The rhyolite and andesite are extensive in the region west of the district, but within the area represented by figure 1 they are represented only by small masses in the vicinity of Grouse Mountain and Little Pisgah Peak, southwest of the district. They were formed long before the rocks of the Cripple Creek volcano and are of no direct interest as regards ore deposits, but one or more dikes of rhyolite or rhyolite breccia may be cut by the proposed drainage tunnel.

The Cripple Creek volcano has been reduced by erosion to a group of rounded hills which range from 10,700 feet down to 9,500 feet in altitude and are mostly within the area underlain by its complex steep-walled neck. Fragmental volcanic material (breccia) does not extend beyond the walls of this complex crater except in a few places on its north side. The surrounding area of granite, gneiss, and schist includes Pikes Peak and other high peaks to the north, east, and southeast of the volcano, and the land surface rises irregularly toward them; but to the south and southwest it slopes gradually in a series of ridges for about 3 miles and then drops steeply from an altitude of about 9,000 feet to less than 7,000 feet. The portal sites for the proposed deep drainage tunnel are in this low area, where the southward-flowing creeks of the district converge and join Oil or Fourmile Creek. They are about 6 miles from the principal mines, which are within and just south of the complex crater.

As this erosion surface and the rock formation around the volcano have some bearing on the local problems of mining geology, a summary of the geologic history of the region is inserted here, before the detailed local discussion.

Pre-Cambrian time

Extensive granite intrusions

The principal rock of the region around the Cripple Creek volcano is part of an enormous mass of pre-Cambrian granite that extends throughout much of the Colorado Front Range and is known as the "Pikes Peak granite." It is a very coarse-grained red rock and was intruded into a thick series of sedimentary rocks, now represented largely by mica schist and quartzite. A considerable mass of the schist is present around the town of Cripple Creek, and smaller masses are enclosed in the granite throughout the region. The larger masses in the Cripple Creek district are shown on the colored geologic map accompanying Professional Paper 54, but in figure 1 of the present report, which is largely a simplified copy of that map, in black and white, all the pre-Cambrian rocks are shown as a unit. No large masses of pre-Cambrian quartzite have been found in the district, but some are present at widely separated places in the surrounding region, as shown in the Pikes Peak folio.[10] Near the schist the granite developed an intensely layered or gneissic structure. Farther from the schist a faintly to moderately developed gneissic structure is present in many places. Throughout the area south of the Cripple Creek volcano the gneissic structure trends northeast and dips northwest at moderate to steep angles.

After the newly consolidated Pikes Peak granite had been subjected to fracturing it was invaded by dikes and large masses of finer-grained granite, several varieties of which have been recognized. The most prominent of these in the Cripple Creek district is a medium- to fine-grained red granite, called the "Cripple Creek granite," which is the dominant rock south and west of the town of Cripple Creek. It also forms the granite "island" in the north-central part of the volcano (fig. 1) and is present farther northeast. An isolated mass on the spur midway between Grouse Hill and Straub Mountain is in a nearly horizontal position as if it had spread along a tension fracture about normal to the gneissic structure of the Pikes Peak granite.

Another variety of fine-grained granite, called the "Spring Creek granite," has been mapped in the vicinity of Red Mountain, north-northwest of the town of Cripple Creek. Small to large dikes of very fine grained granite or aplite and extremely coarse grained granite or pegmatite are found

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[10] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Pikes Peak folio (No. 7), 1894.

throughout the region in all the large masses of granite. Those noted in the Pikes Peak granite by us commonly follow the general direction of gneissic structure or fractures with low-angle dips at nearly right angles to it.

Other pre-Cambrian rocks include a large mass of olivine syenite west of Red Mountain and numerous dark-gray to black diabase dikes that cut all the granites, gneiss, and schist. The largest of these dikes, which trend northwest and southwest, are in and northwest of the town of Cripple Creek, and several smaller dikes, which strike nearly north and west, are exposed in prospects south of the volcano. There also they tend to lie parallel and at right angles to the gneissic structure.

Paleozoic and Mesozoic time

Extensive sedimentation

The pre-Cambrian rocks as a whole were deeply eroded and worn to a gently undulating surface before any other noteworthy events took place. This surface during Paleozoic and Mesozoic time slowly subsided, with some oscillations, and was covered by limestone, sandstone, and shale of great aggregate thickness, which are well represented along the valley of Oil Creek south of the area shown in figure 1. These formations as a whole originally extended over nearly all of the Pikes Peak quadrangle, although some of the higher parts of the granite surface probably remained uncovered.[11]

Laramide revolution

Regional folding, faulting, and fissuring

During the Laramide revolution, which ended and followed the Mesozoic era, the entire Rocky Mountain region underwent uplift and horizontal compression. The sedimentary rocks in the Pikes Peak region were rather complexly folded. Those at Woodland Park and near Colorado Springs, northeast and east of Pikes Peak, were turned to a vertical position, while those farther southeast and south, along the present foothills, were thrown into a series of wavelike folds

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[11] Lovering, T. S., Geologic history of the Front Range, Colorado: Colorado Sci. Soc. Proc., vol. 12, No. 4, pp. 75-88, 1929.