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R. D. GEORGE, State Geologist

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GEOLOGY AND ORE DEPOSITS
OF THE
ALMA DISTRICT
PARK COUNTY, COLORADO

BY
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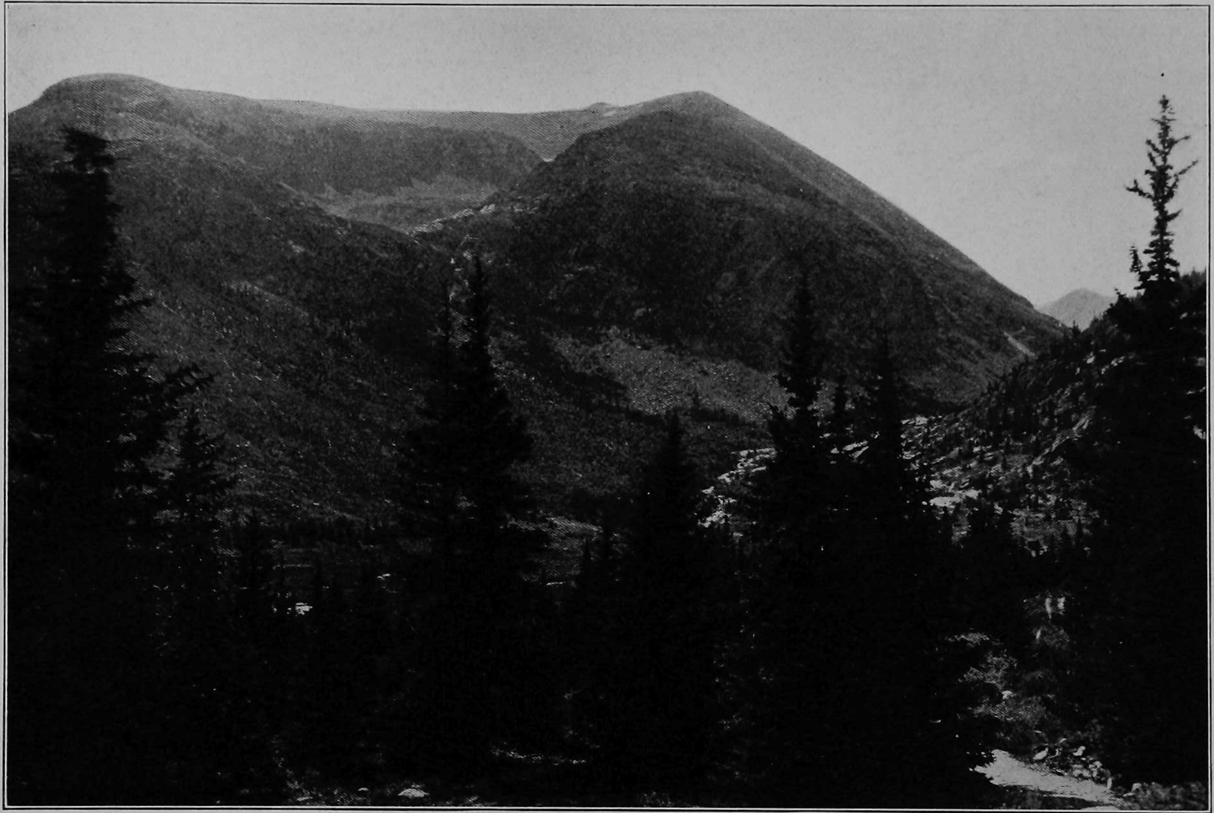
PLATE IV—View of Mount Lincoln as seen from the Hoosier Pass road. The valley on the mountain is Lincoln Amphitheater, with a rock stream showing in the bottom. Montgomery lies at the foot of the mountain. The peak is barely visible against the skyline in the center. (See pp. 62 and 141.)

C. M. Bauer



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LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, December 1, 1912.

Governor John F. Shafroth, Chairman, and Members of the Advisory Board of the State Geological Survey.

Gentlemen:—I have the honor to transmit herewith Bulletin 3 of the Colorado Geological Survey.

Very respectfully,

R. D. GEORGE,
State Geologist.

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CHAPTER I

INTRODUCTION

PRELIMINARY STATEMENT

Interest in the Alma mining district, which lies on the east side of the Mosquito Range, nearly opposite Leadville, dates from before the discovery of valuable gold deposits in the Leadville district. In fact, as will appear elsewhere, the discovery of placer gold deposits on the east side of the Mosquito Range slightly antedates the discovery of the same precious metal on the west side of that range. Active mining operations, therefore, in the region under consideration, have been going on from a comparatively early date. These mining operations have undergone numerous fluctuations, and, whereas the result has on the whole been disappointing, in the great majority of cases, very considerable values in the precious metals have actually been produced. Furthermore, there is abundant evidence pointing to the presence of large and valuable ore deposits still unworked, which, under modern economic methods of mining and of ore treatment, may well become available.

With a view to facilitating and encouraging a more active development of this old, but still promising, mining district, the State Geological Survey has undertaken a resurvey of the district.

In connection with the preparation of his monograph of the Leadville mining district, with the accompanying geologic atlas, Emmons extended his investigations over most of the Mosquito Range. The time available for the study and mapping of the range was admittedly short, so that the work could not be so accurate as might be wished. Furthermore, the continued prosecuting of prospecting and mining operations, since Emmons' field work was completed in 1880, has afforded a better opportunity for detailed study of the geology than was at the time possible. While these and other reasons abundantly justified the undertaking of a more careful survey of this part of the Mosquito Range, it was hoped that the topographic survey on which Emmons based his geologic mapping would prove serviceable for the present purpose. It very quickly became evident, however, that this old survey was not accurate enough to be used for a more detailed geologic mapping than the one undertaken by the Emmons survey. This has necessitated the making of an entirely independent topographic map. The time available for making a topographic and geologic survey of this district has not been so great as might be desired. For this reason, the territory covered has necessarily been somewhat limited, and not all parts could be covered with equal accuracy. Under the description of the maps, an effort is made to indicate roughly the degree of accuracy attained in different parts of the district mapped. The field-work was done during the summers of 1910 and 1911, six weeks being given to the work in 1910 and eight weeks in 1911. This time proved to be rather scant, considering the extremely rugged character of the topography and the difficulty of working at altitudes ranging up above 14,000 feet. But it was not thought desirable to carry the work over to another season.

ORGANIZATION

This survey of the Alma mining district has been made possible by co-operation between the geological department of the Colorado School of Mines and the Colorado State Geological Survey. It has been the practice of the geological department of the School of Mines each year to conduct a survey of some portion of the state, with the assistance of a few selected students who wished to take a geological theme for a graduating thesis. This work, therefore, has been carried on, in part, by such a party, or, rather, parties, consisting of students from the senior class, working under the direction of the geological staff of the department, and in part by members of the geological staff independently. As far as the students are concerned, the work has been done, of course, by comparatively inexperienced men; but as they have been working constantly under the direction of, and in company with, one or more of the department's geologists, the chances of serious errors have been largely minimized.

The student members of the party have been particularly valuable in the triangulation and topographic survey, as their previous training had already given them some little experience along these lines. But even in this department their work has been carefully checked and supervised throughout.

The geologic mapping has been done by, or under the sole direction of, the senior author. Wherever possible, he has gone over the field in person. In some parts of the territory mapped this has been impossible, and the mapping done by student members of the party has been accepted without full revision. Under a division of this chapter devoted to a Description of Maps an effort is made to indicate to what extent the mapping has been left to the student members of the party.

The geological department has also been assisted in this work by Mr. Arthur J. Hoskin, professor of mining at the Colorado School of Mines. Mr. Hoskin has prepared two chapters, on the History of Mining and on Prominent Mines in the district.

The triangulation and topographic work was carried on for the first few weeks of both seasons under the direction of Mr. Charles E. Smith, who was compelled to leave early. On his departure this work was carried on by Mr. Hoskin.

Mr. G. Montague Butler participated in the work for about five weeks during the summer of 1911. The result of his work is embodied in Chapter IX, entitled Ore Deposits North of Alma.

The students participating in this work are the following: For the season of 1910, William C. Douglas, Otto Herres, Jr., James A. Lannon, Emory M. Marshall, Frank B. Saxton, August W. Schneider, Ralph H. Shaw, Roy F. Smith; for the season of 1911, Daniel L. Beck, Clarence E. Copeland, Verne Frazee, Nelson S. Greensfelder, Charles R. Hill, Chester B. Neiswender, Hugh A. Stewart, Lester C. Thomas.

LOCATION AND EXTENT OF THE DISTRICT

The town of Alma, from which the name of the district under consideration is taken, is located near the source of the South Platte River in Park County, Colorado, at the eastern base of the Mosquito Range, in longitude 106° 4′ and latitude 39° 17′. The mining territory tributary to this town embraces the region drianed by the South Platte and its tributaries north and west of the town. Owing to the limited time available for the survey, it was necessary to choose the boundaries of the area somewhat arbitrarily. This was done partly with a view to accessibility, and partly with the object of including as large a part of the important mines and prospects of the district as possible.

On the west a natural boundary was found in the crest of the Mosquito Range. This divide runs in a fairly north-and-south direction in the southern part, and in an irregularly northeast direction in the northern part, of the area mapped. On the south, east and north no such natural boundary could be utilized. These boundaries, therefore, have been made to run parallel to the points of the compass. The southern boundary runs east and west at a point about two miles south of the town of Alma. The eastern boundary runs due north and south from a point just east of the Alma railroad station. The northern boundary runs east and west from the northern edge of the larger of the two Wheeler Lakes. The line runs diagonally across the continental divide and strikes the county road running from Alma to Breckenridge about one mile north of Hoosier Pass.

The area thus outlined embraces about fifty square miles, and measures approximately eight miles in a north-and-south and seven miles in an east-and-west direction. It embraces Mounts Lincoln and Bross, that rise to elevations of over 14,000 feet above sea-level; also the lower-lying London Mountain, Loveland Mountain and Pennsylvania Mountain; and the intervening Buckskin and Mosquito Gulches. Along the western line of the district, and forming prominent peaks on the crest of the Mosquito Range, are Mosquito Peak and Mount Democrat.

Alma is situated southwest of and about sixty-seven miles from Denver, if measured in a straight line. It is reached by the rather circuitous route of the South Park branch of the Colorado & Southern Railway, being distant by rail from Denver 120 miles. It lies a little north of a line running directly east from Leadville and distant from that noted mining camp some twelve and one-half miles in a straight line. Considering the extremely mountainous character of the country, the Alma district is traversed by several unusually good roads that are owned and kept in repair by the county. One road leads northward up the Platte valley and over the comparatively low Hoosier Pass to Breckenridge, distant some fourteen miles in a straight line, and perhaps two or three miles longer by road. Another road leads up the valley of Mosquito Gulch, follows the north branch of that gulch, and passes over the Mosquito Range at Mosquito Pass at an elevation of nearly 13,200 feet, and down on the west side to

Leadville. A third well-kept road follows up Buckskin Gulch some four miles. To the east a good road leads down the Platte valley into South Park, passing the county seat, Fairplay, at about six miles.

In addition to these county roads, there are numerous secondary roads and trails that lead to the more important mines, and even close to the summits of the highest peaks. These mining roads have in part been long abandoned and are not available for wagons. In other cases they are still kept open and are in more or less constant use. In spite of the great ruggedness of the district as a whole, almost every part is accessible on horseback on account of the numerous trails.

The timber line varies in elevation from about 11,500 to 12,000 feet. This means that at least one-half of the area surveyed lies above timber line and is entirely free from tree growth. In the lower portion of the territory the mountain slopes are usually covered with a fairly heavy growth of spruce, balsam and pine. Still lower the aspen appears in great abundance. The valley bottoms are mostly free from timber. Water is plentiful throughout the district, as the heavy winter snows lie in drifts during most of the summer.

DESCRIPTION OF THE MAPS

Two maps have been prepared of the Alma district: first, a topographic and mining-claim map; second, a geologic map. Unfortunately, for financial reasons, the survey has been obliged to publish these maps on a very small scale, smaller, in fact, than was contemplated when the maps were prepared.

The topographic and mining-claim map (see Plate I, in pocket) contains the usual cultural features—such as roads, houses and streams—and contour lines spaced to represent differences in elevation of 100 feet. These contours have been prepared with considerable care, and in most cases may be considered to be fairly accurate—subject, of course, to the limitations of the rather small scale on which the map is published. Great pains have usually been taken to have the contouring accurate in the vicinity of important mines and buildings. In such cases the contour lines have been checked by a triangulation survey. The public will find it a great convenience to have the mining claims placed in correct position with reference to the contours. The map contains all the patented claims within the district covered by the survey.

This claim map was compiled with great care by Mr. Hoskin from the maps in the government Land Office, and from the extremely valuable and accurate maps prepared by Mr. W. H. Powless, deputy mineral surveyor at Alma. The claim maps prepared by Mr. Powless have proved to be invaluable. Without their aid it would have been impossible to have covered the district within the time available.

This map likewise contains the section lines represented as they actually are. For this feature we are also indebted to the maps of Mr. Powless. Frequent testing of these section corners in the field has shown that they are reliable.

The geologic map (see Plate II, in pocket) is intended to represent the areal geology; that is, the rock formations as they appear on the surface. Literally it is not possible to prepare a geological map exactly as the formations appear on the surface, unless one wishes to map the ordinary surface soil and wash. In such a case an areal geological map would show little but soil and wash. It is customary, therefore, for the geologist to map the formations as they would appear on the surface, provided the soil and wash were stripped away. This necessitates that one read the rocks through the soil that covers them. While this is quite possible to a trained eye in some cases, in many other cases it is not at all possible, even to the most experienced. This necessitates a certain amount of interpretation of the geology, and the sketching of formations from few or many isolated outcrops. Often this cannot be done except by the merest guesswork. In such cases no attempt has been made to map the underlying formations in detail. For instance, it will be seen from a glance at the map that the area contains a large number of igneous rocks in the form of dikes and sheets or sills. Such igneous intrusions may be quite regularly interbedded with sandstones or other sedimentary rocks. But again they may cut these formations very irregularly. There is no possible way of telling the exact course of such an intrusion, unless it can be traced step by step on the surface. In such cases as this, where one rock occurs cutting another one, it is not mapped unless its presence can be positively determined. The rock that may be called the country rock of the place in question is mapped solid.

As a case in point, for several miles above the town of Alma the formation on each side of the Platte River is the Weber Grits series, in which lie several porphyry sheets. These sheets of porphyry undoubtedly extend for long distances, as is shown on the map of the Emmons survey; but, as a matter of fact, they cannot be traced continuously nor to any great distance, as they are covered deeply by glacial drift. Furthermore, so thick and continuous is this drift that it is impossible to tell how many of these porphyry sheets actually occur. In this case no attempt has been made to interpret the course of the porphyry beneath the surface. The porphpry has been mapped only for such small areas as it actually appears upon, either in solid outcrop or in thickly strewn float.

The present-day custom has been followed of mapping Quarternary deposits, such as glacial drift and alluvium. The glacial drift, however, has not been mapped except where it has deeply buried the underlying rocks, so as to render them quite invisible for considerable distances. This means that more or less drift material occurs in all the valleys above where the drift is shown on the map, but in such cases the drift may be presumed to be too thin completely to obscure the solid formations beneath.

DEGREE OF ACCURACY.—As stated above, the senior author is responsible for the areal geology, but it has not been possible for him carefully to check up all the territory without carrying the work beyond the time available. As far as possible, those portions of the territory that bordered on important mining ground were covered with considerable care, and those areas remote from such mining work were either somewhat hastily covered or were turned over to student assistants. In general, the territory thus hastily covered is the region lying north of Alma and east of the Platte River; also, the extreme northern portion of the map lying north of the Platte and the area around the headwaters of the Platte—that is, the area north of Democrat Mountain. Finally there should be mentioned a small area at the upper end of Buckskin Gulch around the diorite mass to the east of the Kite-Shaped Lake; the east slope of the Mosquito Range lying west of this same lake; and the northern and southern slopes of Buckskin Peak. For the areas above described the author cannot claim as great accuracy as for the balance.

On account of the small scale of the map, it is impossible to show many narrow dikes without greatly exaggerating their apparent width. This is particularly true where several such dikes or sills occur close together. In this case it has been necessary to omit some of these altogether. A case in point is to be seen on the steep sides of Pennsylvania Mountain and of Loveland Mountain. Here occur two or three, and sometimes more than three, sheets of igneous rock interbedded with the Cambrian sedimentaries. It is impossible to show these comparatively flat-lying sheets, as they outcrop on the extremely steep edges of these flat-topped mountains, without exaggerating the thickness both of the porphyry sheets and of the intervening sedimentary beds. Also, where more than three such sheets occur in the same vertical section, it has been found impractical to show them all.

DESCRIPTION OF MINING-CLAIM MAP

BY ARTHUR J. HOSKIN

The map of the mining claims in this district has been prepared with the expectation that it will prove useful to the prospectors and miners who are acquainted with the district. It is presumed that persons unfamiliar with the district may also consult it with benefit.

The map is intended to be an accurate plan of the boundaries of all mining properties that have passed through the official survey that must precede the granting of patents by the government of the United States. The map is believed to contain every patent survey—both lode and placer—within its area, and to be accurate up to May 1, 1912. Infallibility is not claimed, however, and omissions may have occurred.

It is true that maps showing the approximate positions of most of the *mines* in this district have been heretofore prepared; but it is not believed that there has been issued any single map showing the *lines* of every patent survey within this entire area.

It is expected that some criticism will be made concerning this map by persons who are intimately familiar with particular properties. The lines generally shown upon this map are as approved by the surveyor-general of Colorado. At times, during the past few years, rulings have emanated from the General Land Office at Washington requiring patent surveys to be shown upon maps exactly as they were originally reported, regardless of any subsequent disclosures of error in the original surveys. Another ridiculous ruling was to the effect that every claim must be plotted upon the official maps solely according to its tie to a section corner, no matter how erroneous this tie may have been subsequently proved.

Through the application of such illogical rulings, almost irremediable errors were incorporated into the official maps of many mining districts. The districts most seriously affected were those having their greatest activity in the survey of claims prior to or immediately after the promulgation of these rules. The office of each surveyor-general was required to reconstruct maps in such a manner as totally to misrepresent the actual relative positions of claims on the ground, under the untenable theory that maps must show, not actualities on the ground, but the approved erroneous notes appearing in the records. Such a theory will not stand in law, but mischief was wrought in the official records of the government offices, which should be considered as highest authority.

With this explanation, let the reader understand that the preparation of the mining-claim map herewith was not without hindrances. During the course of the field-work in connection with this report, the writer found numerous discrepancies between existing claim maps and the lines upon the ground. The map herewith will not check absolutely with any official maps, since it has been endeavored to make this map represent real conditions. And while this has been the aim, it is not presumed that all discrepancies have been covered. On the whole, however, it is believed that this map will prove valuable. Any discrepancies that exist are not of great moment.

The map shows at a glance where unpatented ground remains; but, on the other hand, it must not be understood that all the claims shown are really patented. While the majority of claims that are officially surveyed are also subsequently patented, there are frequent instances of claims that are never pushed through to the issue of patent. Such surveys will show upon this map. They may remain perfectly valid through the regular performance of annual expenditures by the locators, the same as with simple locations; or, on the other hand, some of these claims may have reverted to the public domain and be now open to relocation.

The map, therefore, shows only such mining claims as have undergone patent survey. There are within this area very many valid mining claims that have never been thus surveyed or given official numbers. Such claims are, in every particular, just as much respected by the miners of the district as though bearing numbers. For instance, the Kentucky Belle mine (elsewhere described) does not show upon the map, although it is part of a large group of located claims. It was not deemed advisable to make a map showing mere locations; they are too numerous, and often too transitory, to be given place upon a map that is already quite complicated and crowded.

This map was prepared to show also the lines of the public survey. A person unfamiliar with section lines in mountainous regions of the West may imagine the lines in the Alma district to vary unusually from their theoretical positions. However, the writer was very well pleased to find the section lines plot as well as he did. At the best, the running of subdivision lines in rough mountains is difficult. When it is further remembered that all such work was done by contractors at prices far too low to warrant accurate surveying, one can expect a line joining two adjacent monuments on the ground to be in considerable error both as to course and length.

All of the public survey monuments that are known to exist in this area have been shown by round dots. It will be observed that very many corners and quarter-corners are missing. Some of these may never have been set. However, it is presumed that practically every monument required was originally set, although there may not have been the desirable amount of attention given to its perpetuity. One must be lenient in accounting for missing monuments in such regions; for it is frequently found that the exact position for a corner falls upon a site that is quite unsuited to the erection of anything durable. Thus, corners may have been set upon sloping mountain-sides covered with sliding rocks that have caused the monuments to topple over and to become buried. Landslides have been known to destroy well-set corners. The building of wagon-roads sometimes obliterates corners, and even a mine dump may bury such a monument. There are many sufficient reasons why section corners are scarce in rough mining districts.

On the present map, all of the known section corners were located by their ties to mining claims or to other fixed features. The section lines were then traced upon the map according to the practice in the field when re-establishing lost corners, as directed by instructions from the General Land Office. It is therefore assumed that the map represents the lines as they would actually lie upon the ground if all the missing corners were to be reset.

During the progress of the topographic field-work (mentioned elsewhere in this report) numerous careful astronomical observations were taken to determine meridian, but no attempt was made to determine latitude and longitude, since the party was not equipped with all the necessary instruments of precision, and these quantities were thought to be determinable with sufficient accuracy from the many maps of reference. Therefore, the writer took the average of several standard maps of Colorado in determining the latitude and longitude of the northeast corner of Township 9 South, Range 78 West (along the right-hand margin), and from this point scaled and plotted the meridional and longitudinal lines.

The map is supposed to show every building in the area. These structures—mine buildings or cabins—are shown as rectangular black dots, and the attempt is made to properly orient them. Very many cabins, shaft-houses, and even large mill buildings of early days, have either gone completely into decay or have been removed, so that they do not appear upon this map. The buildings are shown upon the map to afford the prospector or stranger a ready means of locating himself upon the ground. With the buildings as a rough guide to his immediate vicinity, a person can soon find one or more patent corners, and thus accurately decide his position.

An index of the officially surveyed claims—i. e., all the claims shown upon the map—is included herewith. The map is published upon a scale that prohibits the insertion of the names of claims. Accordingly—except in the cases of placers taken up as lots or subdivisions of the rectangular system of survey—claims are given merely by survey numbers.

The index is arranged both numerically and alphabetically.

Large groups of claims are often included in a single survey.

This index will be found in Appendix B.

In the case of a claim lying in more than one section, the index states the section in which the greater portion of such claim lies.

The writer is under obligations to Mr. W. H. Powless, United States mineral surveyor, of Alma, for the use of his private maps of the district. It is believed that these maps are the most reliable extant, and the correlation of these many maps into one comprehensive map on a smaller scale was the chief labor of the writer. The writer also wishes to express his appreciation of the favors rendered him by Hon. Timothy O'Connor, United States surveyor-general for Colorado, and by the various clerks in his office.

LITERATURE

Elsewhere in this report is given a bibliography of writings bearing more or less directly on the Alma district. Pre-eminent among these writings for completeness and practical value is the well-known monograph on the Leadville district by S. F. Emmons.* In this work a large amount of space is devoted to a description of the Mosquito Range, and maps and sections covering nineteen miles of the range are presented in the atlas that accompanies the monograph. Although Emmons has not treated this larger part of the territory mapped with the same detail and accuracy as is shown in his treatment of the Leadville district proper, he nevertheless gives a very clear and satisfactory description of the general geological features of the region, and his maps, on the whole, give a fairly accurate idea of the prevailing geologic features. That the maps are often at fault in detail was, of course, to be expected, considering the difficulties under which the survey was conducted, and the all too short time at his disposal. The writer, therefore, will take the liberty of frequently referring to this work of Emmons, and it will be understood that this monograph is referred to when Emmons is quoted. The writer wishes at this point, too, freely to acknowledge the very great assistance this work has been to him in conducting this survey.

ACKNOWLEDGMENTS

It is a very great pleasure to make acknowledgment of the many favors and courtesies that have been extended to various members of the party, as, without the hearty co-operation of those extending these courtesies, it would have been impossible to have carried on the survey effectively. The owners and managers of the various mines have uniformly given every opportunity to make the fullest investigation and have thrown freely open every source of information.

Because of the great interest that is naturally shown in the London mine, the most important of the district, grateful acknowledgments are especially due to Mr. John M. Kuhn, the superintendent, for very many favors, and to others associated with the management and working of the mine. Also to Mr. Charles J. Moore, of Denver, is special acknowledgment due for co-operation in working out the geological problems involved in the complicated fault system of London Mountatin and the London mine, and for the use of the maps of the underground geology prepared by him.

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*S. F. Emmons, Geology and Mining Industry of Leadville. Mon. U. S. Geol. Survey, No. XII, 1886.

For similar reasons grateful acknowledgments are made to Mr. James Moynahan, part owner, and Mr. A. E. Moynahan, superintendent, of the Orphan Boy mine; to Judge H. W. Scott, owner, and Charles Sumner, manager, of the Moose; to R. W. McCoy, at the time superintendent of the Dolly Varden; to H. M. Radford, superintendent of the Hock Hocking; to Charles P. Aicher, manager of the Butte; to Carl Mohr, manager of the Pennsylvania Tunnel; to A. K. McDonald, superintendent of the Kentucky Belle; to C. L. Roles, manager of Roles Placer; to C. C. Warrall, of Denver, president of the Atlantic and Pacific; and to H. W. Cowan, chief engineer of the Colorado & Southern Railway Company, for special courtesies extended.

In addition to those named above, acknowledgments are due to Fred J. McNair and A. J. Dempsey, of Leadville, and to J. J. Shuck, F. A. Weber, and James E. Dollison, and other citizens of Alma and vicinity.

Finally, it is a privilege to repeat here an acknowledgment of the great assistance obtained from the survey maps of Mr. W. H. Powless, to which special reference is made elsewhere.

CHAPTER II

TOPOGRAPHIC FIELD-WORK

BY ARTHUR J. HOSKIN

TRIANGULATION SURVEY

Believing that none of the readers of this report are really interested in the details of the field-work that resulted in the topographic map herewith, no triangulation map is published. However, to give some idea of the work involved in the preparation of the topographic map, a brief explanation of the field-work is here given.

The first duty performed by the field party, after establishing its first camp, was the running of its initial base-line. The most desirable position for this line had been previously selected by the heads of the party, so that the first field-work consisted in setting good monuments at the chosen ends, in accurately determining the meridian by repeated solar observations, and in precisely measuring the length of the base-line.

This line crossed the valley of Mosquito Creek, in sections 11 and 14, southwest of the town of Alma. The line was found to have a bearing of N. 30° 23′ E., and its length was 3,577.12 feet. It would have been preferred to lay off a much longer line, but it was found impossible to obtain a site for such a line that would permit the taking of observations, from both ends, upon the many prominent peaks and other selected points that were to serve as triangulation stations.

While the line was being accurately determined, men were sent into the remote portions of the southwestern portion of the district to establish stations visible from both ends of the line. Very many such stations were thus established, large flags of bunting being attached to them. Decided landmarks—such as peaks, projecting buttes, lone trees, shaft headframes, the gables of cabins, and other objects that could be readily identified—were flagged and given numbers. Upon the return of the men who established such stations, they were required to identify them through the transit telescopes, so that bearings and vertical angles were taken upon every station.

This instrumental work was performed repeatedly, by different persons and with different instruments, as a check. For every observation, an instrument was used in both its direct and its inverted positions, and the horizontal angles were doubled or trebled in order that the bearings could be determined with great precision.

Having thus secured readings upon these secondary stations from both ends of the base-line, office calculations and plotting were done. By ordinary trigonometry, the distance of each station from both ends of the base-line were calculated, and these distances were then scaled upon the map as a check upon the plotting. Next, by multiplying each such distance by the tangent of the corresponding vertical angle, the difference in elevation between the instrument and the station was found, of course by taking into account the height of the transit and the height sighted upon the forward station. Since it was possible to obtain, in this manner, two separate calculations for the altitude of each station, a check was always obtainable. These results were quite satisfactory. Ordinarily the calculations for elevation checked remarkably close, and the average of the two results was accepted.

During the course of the calculations, distances were determined between various pairs of the distant stations. Subsequently, from readings similarly taken at these stations, their differences in elevation were secured, and these served as further checks upon the original calculations. By using as a base a calculated distance between any two triangulation stations, the system was extended repeatedly, until the whole southwestern portion of the area was thoroughly triangulated, and a few peaks in the central portion of the map were also located.

The second season's field-work began with the running of an entirely independent base-line along the valley of the Platte River, commencing at a point east of the river, a short distance northeast of town, and extending northerly. To follow the open country along the valley and to secure a desirable length for the base-line, it was found advisable to include one deflection amounting to an angle of 33° 25′ which occurred about midway of the line. Both portions of this line were given the same attention as was given to the line of the preceding year, and the resulting base-line, calculated as a two-course traverse, was found to be N. 4° 31′ 30″ E., 5,625.75 feet.

From the ends of this base-line, observations were taken upon many stations in the central and northeastern portions of the district. The triangulation was extended as before, and was ultimately connected with the system based upon the first line. An ordinary traverse was also carefully run from the south end of the second line to the north end of the first line. The bearings of the two base-lines were found to agree as to meridian. The elevations, also, were brought to harmony by leveling.

No part of Buckskin Gulch was visible from either of the two base-lines, so that the topography along this stream was necessarily obtained by carrying triangulation over either Loveland Mountain or Mount Bross. Both of these routes were followed, and the junction of the two systems of triangulation proved an unusual degree of agreement. For example, these two systems came together at one point in Section 29, Township 8 South, Range 78 West, near the headwaters of Buckskin Creek. Elevations had been carried (by the methods above described) over the southeastern end of Loveland Mountain, down into the bed of the creek, and thence, from station to station, along this stream. The other set of elevations was carried up the eastern flanks of Mount Bross, around to the saddle between Mount Bross and Mount Cameron, and then down into the same amphitheater of Buckskin Creek. Upon comparison, it was found that the two elevations thus obtained for a given station checked within two feet—a degree of accuracy well within all requirements.

The elevations of prominent points—such as the peaks of the several mountains—were found by averaging many results. For instance, the elevation of the summit of Mount Lincoln was derived as the average of eight computed results, in which only the last significant figure showed difference. Thus, four calculations gave 14,276 feet, two results gave 14,277 feet, one gave 14,272 feet, and one gave 14,278 feet. The proper elevation to the nearest foot is therefore 14,276 feet, as given upon the map.

The datum of all elevations is the head-block of a switch in the main line of the Alma branch of the Colorado & Southern Railway, a short distance east of the station. This point does not quite show upon the map, it being just east of the Platte River. The elevation of this head-block was kindly furnished by Mr. H. W. Cowan, chief engineer of the railway. Level surveys were carried from this station up to each of the base-lines. There were no other well-established elevations within the district. The nearest available bench-mark established by the United States

Geological Survey is at Como, at a distance too far from the district to be of use except at the expenditure of considerable time and money. It is understood, however, that the railroad elevations agree with the government's bench-mark, so that the altitudes herein should check with any subsequent work that may be done in this vicinity by the government survey.

TOPOGRAPHIC METHODS

Thus far in this chapter nothing has been said concerning the mapping of the topography. As the topographic map shows, contours were mapped at intervals representing differences in altitude of 100 feet. During the progress of the triangulation a great many stations were determined for elevation as well as position, and these were so distributed that the subsequent work of running in the contours could be done, in any part of the district, by reference to one or more of the stations.

For the topographic field-work the men worked in pairs, each such pair being assigned to a certain section of the area. This was the same arrangement described elsewhere for the geologic mapping in the field.

The same field maps were used for both the topography and geology. The men assigned to any given territory were required to map all railroad tracks, wagon-roads, trails, streams and buildings.

For working in contour lines, pocket levels were carried by each party. Aneroid barometers were found useful in carrying elevations short distances, but were never relied upon for important determinations. Starting from any triangulated station, the altitude of which was known, a topographer could, by means of his pocket level, work up or down hill the proper distance to place himself upon a contour line. Then, with his combined level and compass, he was able to proceed along this horizontal line and to sketch its courses upon his map. The mapping of the contour in such a case was virtually a simple form of plane-table work. Having completed the distance desired to be run along the first contour, the men would next ascend or descend 100 feet, using the pocket level and employing a level rod, or by moving just the height of the observer's eye in succeeding leveling on nearby small objects lying upon the ground, or upon the sides of rocks or trees. As a rule, it was not required to measure the contour intervals in this manner, for there were usually stations conveniently near to give the datum for each new contour.

Upon surfaces of nearly uniform slope, it was possible for the surveyors to determine and sketch in the contours without actually leveling at all. By means of the clinometer, the slope of the surface could be taken either up or down hill. The natural cotangent of this angle of slope multiplied by 100 gave the horizontal distance between contour lines, so that it was an easy matter to scale off as many such distances upon the map as were required to fill in the horizontal distance between the bottom and the top of the slope. A man would usually have prepared for himself a tiny paper scale giving the divisions representing these horizontal intervals for several of the slopes usually encountered, so that calculations were not ordinarily required in the field.

The different "territories" assigned to the various parties were bounded by natural lines, such as beds of streams, ridges of mountains, etc. Upon reaching such a boundary, the work of any two parties constituted a check each upon the other, and, if discrepancies were discovered, such portions of the work as were found in question were repeated.

CHAPTER III

GENERAL GEOLOGY AND PETROGRAPHY

BY HORACE B. PATTON

RELATIONS OF TOPOGRAPHY TO GEOLOGY

In discussing the topography of the Mosquito Range, Emmons remarks that "it were scarcely possible to select an alpine region more admirably adapted to illustrate the interdependence of topographical and geological structure than that chosen for this study." What is true of that portion of the range chosen by Emmons for his study is equally true of the more limited portion considered in these pages. The Mosquito Range runs in a general north-south direction, approximately parallel to the Arkansas valley on the west. Its crest is often extremely narrow and sharp. On the Arkansas side it drops off comparatively steeply, and, in places, almost precipitously; but on the east is a long, gentle slope reaching down to the level of South Park. This gentle easterly slope is composed of sedimentary rocks, also dipping gently to the east, resting upon a foundation of pre-Cambrian metamorphics and granites. The general structure, therefore, is that of a gigantic hog-back. The range is deeply dissected by streams that rise mostly near the steep western side and that flow easterly, cutting their way through the overlying sedimentaries a thousand or two thousand feet into the crystalline rocks of the pre-Cambrian series. Owing to the resisting qualities of the Cambrian quartzites that lie immediately upon the pre-Cambrian formation, these quartzites occur over considerable areas as a protecting cap on the more readily eroded schists and gneisses. This is strikingly the case on the flat-topped, gently sloping Loveland Mountain and Pennsylvania Mountain, the upper parts of which present almost perpendicular faces.

The effects of glacial action are also very strikingly shown throughout the district. At the heads of the important streams occur finely developed glacial cirques, with their rugged, almost perpendicular, amphitheater walls. In the middle courses of the streams the valleys have the characteristic U-shaped cross-section, while the lower courses are marked by long, flanking, morainal ridges, and the bottom of the valleys by the numerous water-filled depressions typical of morainal ground.

GENERAL GEOLOGICAL DESCRIPTION

The Alma district presents a great variety of rock formations, beginning at the base of the series with the pre-Cambrian metamorphics and plutonics, and passing upward through the Paleozoic well into the Carboniferous.

As the sedimentary rocks dip eastward at angles that usually vary from 15° to 20°, and as the mountains rise to the westward, it naturally follows that the lowest of these rock formations, the Archean, is to be found in the western part of the territory. This is true except in case of the southwestern corner of the district mapped, where the Weber beds of the Carboniferous have been faulted downward over two thousand feet by the London fault. The Archean rocks are also to be seen in the bottom and along the sides of the principal streams that rise along the crest of the range and flow in deeply cut valleys toward the east. These highly metamorphic rocks consist in the main part of widely varying gneisses and schists, in which occur considerable masses of plutonics. These latter consist mostly of granites that are undoubtedly of pre-Cambrian age, as they often participate to a greater or less extent in the shearing of these rocks. Smaller masses of diorite have been found in the Buckskin Gulch area that do not appear to have been subjected to the shearing so commonly seen in the granites, and that may very likely be of later age. The Archean rocks—both the schistose and the plutonic members—are cut by a large number of dikes of greatly varying thickness and length. These dikes are in part ancient pegmatites, and in part porphyritic rocks, of varying character, that resemble those occurring as sheets in the sedimentary series above, and that in a few instances have actually been traced upward into the sedimentary beds.

The sedimentary series of this area is confined to those of the Paleozoic system, and include, from the bottom to the top, the Cambrian, Lower Silurian or Ordovician, Lower Carboniferous or Mississippian, and the Weber grits and shales of the Middle Carboniferous. The overlying formations of the Upper Carboniferous and of the Mesozoic are to be found in succession in the region lying between the Alma district and South Park.

The Cambrian formation covers, together with intruded porphyries, practically the entire surface of Pennsylvania Mountain from the highest point down the eastern slope for a distance of about one and a half miles; outside of this area it occurs mainly as a narrow band circling around Loveland Mountain and the large mountain mass formed by Mounts Bross, Cameron and Lincoln. It may also be seen in several small isolated spots, as at the bottom of gulches where the erosive forces have succeeded in wearing away the overlying Ordovician beds. The most pronounced of these isolated patches is along the gulch that drains the southeastern slope of Mount Bross.

The Ordovician beds cover nearly the whole of the long sloping surface of Mount Loveland, somewhat similar to the occurrence of the Cambrian on Pennsylvania Mountain. It also forms a narrow strip on the lower slope of Pennsylvania Mountain, and skirts around the great Bross-Cameron-Lincoln mass, in practically continuous contact with the Cambrian beneath and the Carboniferous limestone above. Outside of these areas it may be seen in a few small patches on the lower slopes of Mounts Bross, Lincoln and North Star.

The so-called "blue limestone" or Lower Carboniferous formation forms the summit of Mount Cameron, circles around Mounts Lincoln and Bross, and extends in irregular fashion some distance down the eastern slopes of these last-named mountains. It may be seen in narrow bands paralleling the Ordovician on the lower slopes of North Star Mountain and of Loveland and Pennsylvania Mountains, in several small isolated patches on Loveland Mountain, and in a very slender strip comformable with, and immediately west of, the London fault that runs northwestward across the summit of Pennsylvania and London Mountains.

The Weber beds of the Middle Carboniferous occur in a continuous formation extending from the north to the south side of the mapped area, and from the eastern border westward for from one and a half to over two miles. It also continues east of the map boundary for a great, but undetermined, distance. This portion of the district is to a great extent occupied by the valleys of the Platte River and of the Buckskin and Mosquito Gulches, so that the heavy glacial moraines from these valleys now cover most of the Weber beds and render them invisible on the surface. The Weber also sends several tongue-like extensions some distance up the slopes of Mount Bross, forms practically the whole of Bald Hill to the east of Pennsylvania Mountain, and comprises, with the included porphyries, the whole of the area southwest of the London fault.

As above shown, igneous rocks are to be found in all the formations of the district, from the Archean up to the Weber grits. In the Archean they are mostly granites and diorites, which cover considerable territory, while the porphyries are confined to narrow dikes. In the sedimentary series the intruded porphyries appear to occur in the lower formations only in comparatively thin sheets or in narrow dikes, but in the Weber formation, and to a less extent in the Carboniferous limestone, these sheets attain at times very great thickness, being not less than one thousand feet thick in the extreme southwest corner of the surveyed area. At the same time, they are inclined to depart from conformable sheets and occur in more irregular masses that cut the sedimentary formations at various angles, and that often cause the bedded rocks to show very abnormal strike and dip.

Glaciation phenomena are very pronounced over nearly all of the district. In the lower valleys extensive glacial moraines deeply bury the rock formations beneath them. In the upper valleys the moraine material occurs in great abundance, but does not so completely bury the other formations as to altogether hide their identity. For this reason it has been possible to map the underlying rock formation in spite of the covering of morainal drift.

There is no very extensive deposit of alluvium in the district covered by this survey. It is practically confined to a few hundred feet along the bottom of two or three of the streams.

The easterly dip of the sedimentary formations already mentioned, while fairly characteristic of the district as a whole, is subject to local variations of considerable interest. A frequent disturbing factor is the larger and more irregular igneous intrusions that may cause a marked change in both strike and dip of the sedimentary rocks. Other changes in the dip, and to a less extent in the strike, are undoubtedly due to the orogenic forces that were responsible for the tilting of the whole series of formations. This is sometimes manifested in a flattening of the beds to a horizontal, or nearly horizontal, position, or even to a reversed dip toward the west. A marked case of horizontality is to be seen in the Weber grits near the top of Mount Bross.

In some cases the lateral pressure that has caused this deviation in dip has produced a very marked folding of the strata, so as to produce a well-defined S-fold, involving an overthrow to the west. Where this kind of movement has been very pronounced the stress has produced rupturing of the strata and the development of an overthrust fault. The great London fault, with a throw of some 2,500 feet, is a fault of this character. Another beautifully developed fold-fault is to be seen crossing the lower portion of the flat top of Pennsylvania Mountain, running down into Mosquito Gulch and up to the flat top of Loveland Mountain.

These two faults produce very marked effect on the areal geology, as may be seen by a glance at the map. Other faults, not apparently connected with folding of the strata, abound in all parts of the district, but they are not pronounced enough to figure extensively on the map.

THE ARCHEAN

DEFINITION—

The use of the term "pre-Cambrian" in place of "Archean," as applied to the great series of wholly or partially metamorphosed rock that forms the foundation on which rest all the more distinctly sedimentary or stratified rocks from the Cambrian upward, has become increasingly prevalent of late years. This is undoubtedly due, in the main, to the confusion that has been introduced into the terminology of these ancient rocks by efforts to subdivide the so-called "Archean" into several independent formations, and to the departure from the original usage on the part of many geologists. The advantage of the term "pre-Cambrian" over "Archean," or over any other term used to indicate some definite geological formation among these ancient crystalline rocks, lies in the fact of it's indefiniteness, in that it indicates only that the formation in question belongs somewhere below the Cambrian; that is, below the oldest of the known fossil-bearing strata. As it is particularly difficult to determine the geologic age of rocks destitute of fossils, and, in fact, practically impossible at present to correlate widely separated areas of pre-Cambrian rocks, the advantage of the more indefinite term will readily be seen.

In his description of the rock formations of the Mosquito Range in the Leadville monograph, Emmons describes these rocks under the name "Archean," and his map shows an extensive development immediately east of the Mosquito fault, more particularly in the northern half of the map. It is the eastern part of this large area that appears on the map of the district now under consideration.

In spite of the advantages above mentioned of the more indefinite name "pre-Cambrian," and in spite, further, of the fact that the name "pre-Cambrian" has been adopted by Ransome* for what is undoubtedly the same series of rocks in the closely adjacent region of Breckenridge, the writer prefers to retain the term "Archean" as used by Emmons. This preference is based, in part, on the fact that the term "Archean" as applied to these pre-Cambrian rocks of the Mosquito Range is now in universal usage by mining men of Leadville and vicinity; in part, to the undesirability of discarding terms long in use without very strong reasons; and in part, and mainly, for the reason that it appears to the author that the character of the rocks later to be described in detail indicates that they belong to the lower, more highly metamorphosed of the pre-Cambrian series—to that part of this series, therefore, to which the name "Archean" is still customarily given.

GENERAL CHARACTER OF ROCKS—

The rocks of the Archean series are all thoroughly crystalline in texture and appear to belong to the more completely metamorphosed types that usually characterize the lower rather than the upper horizons of the pre-Cambrian era. Quartzite, crystalline limestone, slates and extremely fissile schists are entirely wanting. Instead of these, we have gneisses and schists of various compositions, shading into each other; also granites and pegmatites. While the rocks vary greatly from place to place, there is no very marked difference of one area from another. At least, the distinctions are not marked enough to justify a classification based on differences in age or origin, except in so far as the plutonic granites and the pegmatites are concerned.

Gneisses and schists make up a very large part of the Archean area. It is difficult to distinguish between these two rocks. That is, one finds it difficult to decide whether these rocks should be called gneisses or schists. Not only do the coarser and more crystalline shade into and alternate with the finer-grained and more distinctly cleavable varieties, but even those free, or nearly free, from feldspar—and that, therefore, would

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*F. L. Ransome, Geology and Ore Deposits of the Breckenridge District, Colo., U. S. Geol. Surv., Prof. Paper 75, 1911.

hardly be called gneisses—have very frequently a gneissoid appearance. The tendency toward banded structures is pronounced in nearly all parts of the Archean area. Such banded gneisses and schists may have the contrasting bands produced by alternately white and black parallel streaks, the white portions being composed of minerals almost entirely different from those composing the dark portions. More frequently the banding is due to the segregation of the light- and dark-colored minerals in varying proportions. See Plate XIII, B, and Plate XX.

In contrast to the banded rocks, there are the granite gneisses that often can with difficulty be distinguished from sheared granites. This is particularly true of a considerable area in the upper Platte valley, in the vicinity of the larger Wheeler Lake. In this area there is undoubtedly intrusive granite, and also undoubtedly granite gneisses; but it is by no means easy to draw the line.

DESCRIPTION OF INDIVIDUAL TYPES—

Gneisses.—As already indicated, there are two main types of gneisses: granite gneisses and banded gneisses.

The granite gneisses may extend, as in the case already cited from near Wheeler Lake, over considerable territory, but more frequently they represent merely broad or narrow zones or bands in a gneiss that in a large sense would be designated as a banded gneiss. A fair type of these granite gneisses is seen in a specimen from a tunnel on the north side of the Platte River and nearly north from the summit of Mount Lincoln. (Specimen 128.) This is a fairly medium-grained rock about the color of a light-colored granite, and showing very plainly in the hand specimen quartz, feldspar and, apparently, biotite. The rock hardly shows a distinct parallel arrangement of the constituents, and shearing is not greatly in evidence. The biotite is somewhat irregularly distributed, and this is really the feature that distinguishes the rock from a granite.

Microscopically examined, this rock is seen to be composed of quartz, microcline, plagioclase, chlorite and muscovite. Microcline, the most abundant of the feldspars present, is typically developed, and occurs both in large grains and in aggregates of smaller grains. Plagioclase is not abundant. Undulous extinction is not seen on the feldspars, but is strongly developed in the quartz grains. Muscovite occurs in fairly large plates, closely associated with chlorite; also in small but very sharp plates scattered in all directions through the larger individuals of microcline, orthoclase and plagioclase. What appears in the hand specimen to be biotite is seen under the microscope to be chlorite. This evidently has replaced by alteration the original biotite, which appears to be entirely wanting. Sericitization of the feldspars is almost entirely lacking.

Banded gneisses are to be found in nearly all parts of the territory. The bands may be very fine, measuring one millimeter or less, or they may be comparatively coarse. The colors are usually gray, due to varying mixtures of biotite with quartz and feldspar. The banding is in most cases nearly straight, but sometimes beautifully folded and crumpled. A very beautiful illustration of such folding of a banded gneiss was seen on a boulder in South Mosquito Gulch. In this case the bands are folded into a sharp S-fold, which has then been ruptured and developed into a miniature reverse or overthrust fault.

Schists.—As already stated, the schists of the Alma district are not sharply separated from the gneisses. They are not to be found in any particular part of the Archean area to the exclusion of the gneisses, but rather blend into these latter rocks by insensible gradations, or else alternate with them in more or less irregular fashion. They are, upon the whole, distinctly crystalline rocks, in which the constituents are easily recognizable in the hand specimen. They show little or no tendency to pass into quartz schists, on the one hand, or into excessively fine micaceous schists or phyllites, on the other hand. If the distinction from gneiss is made on the absence of feldspar, as is customary, but few of these rocks could strictly be classified as schists, as they almost all contain more or less of that mineral. Nevertheless, in a great many cases the feldspathic constituent is comparatively small, and the cleavage is pronounced enough to justify the use of the term "schist."

As to mineral composition, these rocks vary considerably. With comparatively few exceptions, they consist for the most part of quartz, biotite and muscovite; besides which there may at times occur an acid plagioclase and sillimanite. In the more basic occurrences muscovite disappears and hornblende comes in; in one instance also garnet. True amphibolites are apparently practically absent, although hornblende, together with biotite, may at times be very much in evidence. Certain types of these schists recur at frequent intervals in different parts of the territory examined, and are worthy of more detailed description.

Type a: Gray biotite-muscovite schist. This type is fairly common and is well illustrated by two specimens collected on the southern slope of Buckskin Peak, at the head of the north branch of Mosquito Creek. This rock has the appearance of a rather fine-grained gneiss. It is distinctly crystalline, and the three main constituents are all easily recognizable in the hand specimen, in spite of the comparatively fine grain of the rock. Both biotite and muscovite are very fresh. The latter occurs at times in somewhat larger individuals (2 to 3 mm), and then shows a brilliant luster that inclines to pearly.

Under the microscope the muscovite is seen to be much less abundant than the biotite and to occur in considerably larger individuals. Biotite and quartz are both very abundant. The two micas penetrate each other to a greater or less extent. Albite is fairly abundant in one specimen, but practically wanting in the other.

Type b: Spotted biotite-hornblende schist. This is a beautiful and very striking rock. It has been observed in a subordinate role in many parts of the territory covered. Black, brilliant-lustered spots of biotite, or of biotite and hornblende, a quarter of an inch in diameter or less, occur thickly crowded in porphyritic fashion in a uniform, fine-grained, crystalline, gray-colored matrix. The matrix shows but little or no parallelism in the arrangement of its constituents, but the lustrous black spots are flat and show a more or less marked tendency to parallelism. The hornblende in these spots is hardly noticeable in the hand specimen. The biotite, on the other hand, is very conspicuous, owing to the fact that one crystal may compose almost the entire spot, as is witnessed by the continuous cleavage.

Under the microscope the matrix of this rock is seen to be composed of quartz and brownish or greenish biotite, together with a little slightly sericitized orthoclase or, possibly, plagioclase. The dark-colored conspicuous patches disclose considerable green hornblende in addition to the biotite, which shows a brownish-green color. The hornblende has marked pleochroism with $\mathfrak{a}$ showing a blue-green color and $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$. Some of the larger hornblende individuals are porous or skeleton-like in form, and are crowded with quartz grains. Some of the smaller grains show distinct prismatic form (110). Accessory titanite and apatite, also some magnetite, occur, especially in the dark patches.

Type c: Biotite-muscovite-sillimanite schist. These are dark-gray, fine- to medium-grained, and sometimes black- and gray-banded rocks. The biotite and muscovite are easily recognizable in the hand specimen. The sillimanite is obscure, owing to its being intergrown with quartz. On the weathered surface are often to be seen lumps a quarter to half an inch long, projecting from the surface. These are composed of intimate mixtures of quartz and sillimanite that have resisted the weathering better than the remainder of the rock.

Microscopically examined, a markedly banded example of this type from the southern slope of Buckskin Peak discloses the lighter-colored gray bands, composed of irregular or roundish, but not interlocking, grains of quartz and, to a much less extent, of feldspar that appears to be both orthoclase and acid plagioclase; also of abundant brown-colored biotite and occasional muscovite plates. The dark-colored bands are coarse-grained and composed of brown biotite, with not a little sillimanite and some muscovite. The sillimanite is in parallel fibrous bunches or tufts, lying in or associated with quartz. The two micas penetrate each other freely, but are not in parallel intergrowths.

Besides the above-described types of schist, others less marked might be mentioned. On the south slope of North Star Mountain, in the upper Platte valley, was collected a fine-grained, dark-colored rock consisting of green biotite, quartz, epidote, striped and unstriped feldspar, and accessory apatite, tatanite and magnetite. Garnet was found in one place only in a sheared garnet-biotite schist occurring at the Homestake mine on the Buckskin side of Loveland Mountain.

Granite.—In strong contrast to the gneisses and schists, with their constantly varying textures and compositions, the granite of this district presents a fairly uniform appearance. The principal variations are due to differences in coarseness of grain, and to the extent to which the rock has been subjected to crushing and shearing.

Outside of a few small, isolated occurrences, the granite of the Archean formation is found in three separate and fair-sized masses. The largest granite mass occupies nearly the whole of the basin at the upper end of the North Mosquito Gulch. This mass is roughly circular in form and occupies the area between the London fault on the southwest and the middle of the southwesterly slope of Buckskin Mountain. In the other direction it extends from the lower end of the North London tram in a northwesterly direction, a distance of two miles or more, to the crest of the Mosquito Range and to an undetermined distance on the west side of this range. With the exception of some comparatively narrow dikes, the granite occupies the entire area above outlined.

Another granite area, of nearly equal size, occurs in the upper basin of the Platte River. This area measures about two miles in a north-south, and a similar distance in an east-west, direction. On the west it extends to the summit of the range, and perhaps beyond. On the north it extends to and beyond the bounds of the mapped area. This Platte River area, however, is not occupied wholly by granite, but contains also several sizable masses of schists or gneisses that are sometimes nearly or quite surrounded by granite.

The third granite area is much smaller than the other two, and is found at the upper end of the Buckskin Gulch, on the southeasterly slope of Mount Democrat.

As these three granite masses are composed of practically the same kind of rock, they probably represent parts of one continuous intruded mass, separated from each other by erosion.

Aside from the above-described occurrences, granite is to be found in numerous narrow or irregular dikes cutting the schists and gneisses on London Mountain, and on the slopes of Pennsylvania and Loveland Mountains.

Judged by their mineral constituents, all these granite occurrences belong to the same type of rock; namely, to a normal or biotite-muscovite granite. Texturally they may be divided into two types, a and b.

Type a is represented by the large areas at the upper ends of the North Mosquito and Buckskin Gulches and of the Platte River. These are usually uniform, fine-grained, light-gray rocks, showing both black and white mica in the hand specimen. None of the constituents are porphyritic, although occasionally a feldspar individual shows a slight tendency toward idiomorphic form. Upon the whole, these rocks are distinctly fine-grained, the constituent minerals measuring one to two, or possibly three, millimeters. In places, however, these fine-grained granites become distinctly coarser in texture and pass insensibly into the much coarser granite of Type b.

Under the microscope this granite is seen to consist usually of quartz, orthoclase, microcline, microperthite, oligoclase, biotite and muscovite. The feldspathic constituents fluctuate greatly in

Plate V—View of Pennsylvania Mountain from near the South London mine. To the left are Archean rocks cut by pegmatite dikes and capped with sedimentaries. The sharp knob to the left of the center is the "Butte." To the right of the center are Weber grits with a strong porphyry sheet, all dipping to the east. (See pp. 104 and 107.)

Colorado State Geological Survey—Bulletin No. 3, Plate V

C. M. Bauer

relative percentages. They are sometimes about equally represented. Orthoclase and microperthite are the most persistent, and are inclined to show Carlsbad twinning. Microcline and oligoclase may in some cases be altogether wanting. All the feldspars, except microcline, show a tendency to sericitization. The sericite may be thickly distributed throughout the feldspar grain, so as to cause a marked clouding, or it may appear in single or grouped, thin, sharp scales that measure from .17mm to .07mm or much less in length.

Primary muscovite is invariably present, but in much smaller amount than the biotite. It occurs in perfectly fresh irregular plates. The biotite has a greenish or brownish-green color, and is often more or less altered to chlorite. In one case pleochroic halos were seen around small roundish grains of strong refractive powers and high double refraction. These roundish grains are presumably zircon—a mineral that otherwise was not noted.

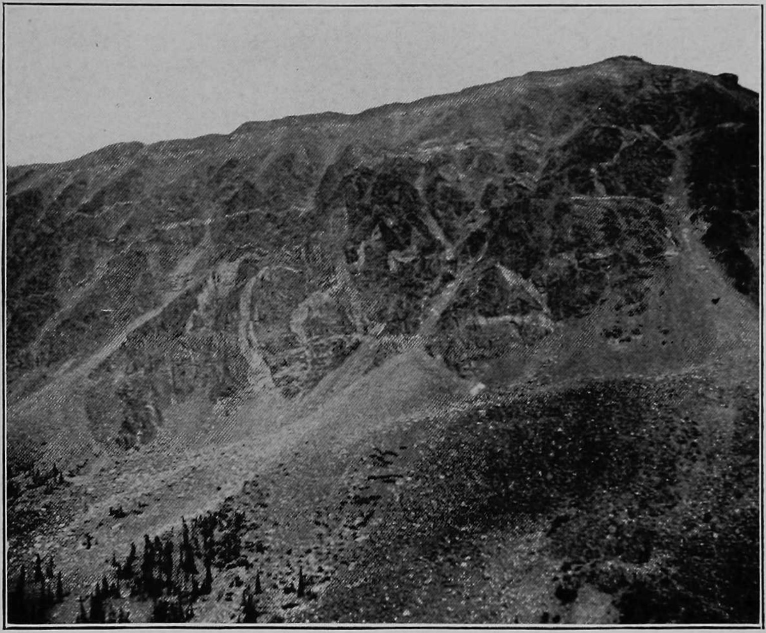
This Type a granite is undoubtedly intrusive in the schists and gneisses. Near the edges of the large masses it frequently enclosed large and small fragments of the schistose rocks, and at the contact the two rocks interlock in very pronounced fashion—at times so that it is difficult, if not impossible, to map the line of contact. This marginal interlocking with the schists is very pronounced on the west end of the marked ridge that runs out eastward into the North Mosquito area from the crest of the range. At the east foot of this ridge many large masses of schists are to be seen enclosed in the granite. Possibly this place is at or close to the lower contact of the granite with the schists.

In the region west of Wheeler Lake there appear to be two distinct granite intrusions, one being much coarser than the other. Although the contact between the two could be traced for a short distance, there did not appear to be any essential difference between them. To the south and east of Wheeler Lake the granite is greatly crushed, and develops a distinctly gneissoid appearance, so that it is difficult to draw the line between granite and gneiss.

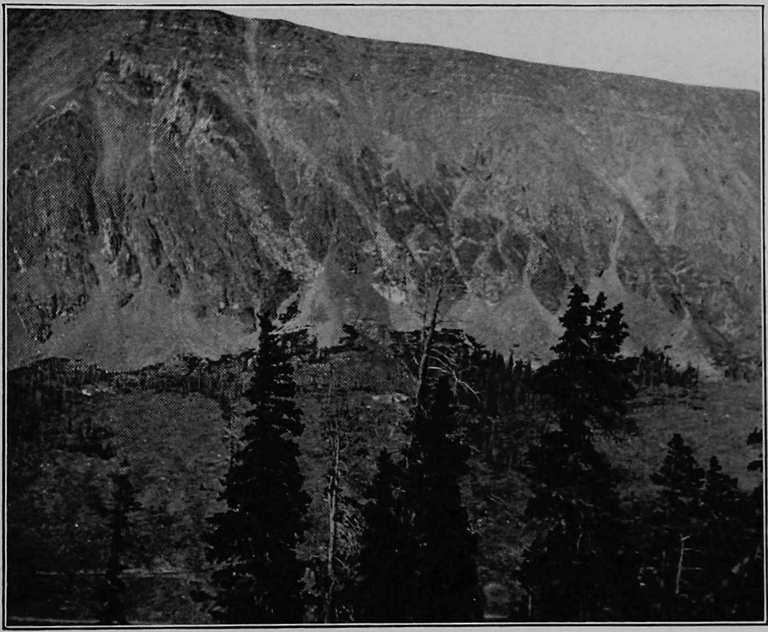
Type b granite is apparently confined to the southeastern part of the mapped area; that is, to Buckskin and North and South Mosquito Gulches. Mineralogically this granite appears to be the same as Type a. Its difference lies in the manner of occurrence and in the texture. This granite occurs only in small, irregular masses, and in narrow dikes and stringers. These stringers may not be over six inches in width. Then again they may

Plate VI—A. View of the cliff under the top of Pennsylvania Mountain, showing the cap of sedimentary rocks and the pegmatite dikes cutting the Archean schists and gneisses. (See p. 46.)

B. View of Loveland Mountain from the east slope of London Mountain, showing the cap of sedimentaries and the Archean schists and gneisses cut by pegmatite dikes. (See p. 46.)



B



widen out into dikes fifty or one hundred feet wide. They are invariably coarse-grained, and contain large tabular orthoclase crystals that show Carlsbad twinning and that have a marked parallel arrangement, the flat sides of the tablets being arranged parallel to the sides of the dike or stringer.

Except for the fact that transitional textures between those of Types a and b may be met in the northern part of the district, this type of granite does not occur north of Buckskin Gulch.

This type of granite frequently comes into contact with pegmatites in such a way as to make it difficult to distinguish between the two, as they may appear to run together, or to be so intermixed as to make it difficult to determine which is the younger. In two instances, however, narrow dikelets of the granite, with parallel orthoclase tablets, were seen to cut a pegmatite so as to prove that the granite is the younger. One of these two cases was at the foot of Pennsylvania Mountain, and the other on the south foot of Loveland Mountain near the forks of Mosquito Creek. The granite dikes in these cases were, respectively, two and six inches in width. Emmons* gives a sketch of a complex of coarse granite, pegmatite and quartz veins in which the pegmatite is shown cutting the granite, and remarks that the pegmatites are invariably younger than the granites. According to the observations of the writer, this is probably generally the case, but not invariably so. It would appear that some granite intrusions took place after some of the pegmatite dikes had been formed.

In only one case was a granite encountered that does not contain both muscovite and biotite. This single instance of a biotite granite or granitite was observed in a very small outcrop in the Buckskin amphitheater. This occurs along the bed of a small creek that flows from the east into the creek draining the Kite-shaped Lake, at a point near the junction of the two creeks and about half a mile below the lake. At this point both granitite and diorite appear in contact. How extensive this granitite is cannot be determined, on account of a heavy covering of alluvial wash. The rock consists of quartz, orthoclase, biotite and a very little oligoclase. Microcline and microperthite, so abundant in the other granites of the district, appear to be entirely missing.

Pegmatite.—It is a well-known fact that the more thoroughly crystalline rocks that always compose the lower part of the Archean formation are usually intersected by numerous vein-like

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*Loc. cit., page 52.

or dike-like masses of light color and very acid composition. These rocks, to which the name "pegmatite," is given, are usually very coarse-grained, and the fissures filled by them are of all dimensions—from an inch or less up to several hundred feet across. Such pegmatites are of very frequent occurrence in the Alma district, and they sometimes form most conspicuous features in the landscape. Wherever the Archean rocks are well exposed, as is the case in the high glacial amphitheaters and on the steep slopes of some of the deep-cut gulches, these pegmatites abound. They sometimes form a veritable network of crossing and intersecting dikes and dikelets that penetrate the rock in all directions. Again, they appear on a larger scale, and as gigantic streaks and gashes standing out in strongest contrast against the black walls of gneiss and schist. On account of the conspicuousness of these pegmatite dikes, it has been thought well to map the larger occurrences, although the scale of the map will not allow the mapping of any but the most conspicuous. Some of the most striking examples may be seen in Mosquito Gulch on London Mountain, and on the steep slopes of Pennsylvania and Loveland Mountains; in Buckskin Gulch on the sides of Loveland and Bross; and on the northern slope of Mount Lincoln. Some of these pegmatite masses measure three or four hundred feet, or even more, in the narrowest direction. These pegmatite dikes are well shown on Plate VI, A and B, and on Plate XIX, A.

The pegmatites of the district vary greatly in size of grain and in mineral composition. They consist of quartz and whitish or pinkish feldspar, with or without muscovite, and occasionally biotite. In some cases the rock is made up of quartz and muscovite in grains one or two inches across, feldspar being all but absent. More commonly the feldspar is the prevailing mineral. The coarseness of the grain and the fluctuation of mineral ingredients appear to bear little or no relationship to the size of the pegmatite dike.

The most abundant feldspar is microcline. Albite may also occur in abundance, both in individual grains and in the customary intergrowths with microcline. In no case was orthoclase noted.

Tourmaline, beryl, and other fluorine- and beryllium-containing minerals that so frequently occur in pegmatites, appear to be entirely lacking.

As to the origin of pegmatites, it is now generally recognized that they result from superheated vapor of water and other gases escaping under great pressure from cooling, deep-seated granites and other plutonic rocks, and that they fill fissures in the overlying rocks. As considerable masses of granite occur in the Archean rocks of this region, it may reasonably be inferred that the pegmatites are genetically connected with these granites. They may also be connected with deep-lying granite magmas that do not appear on the surface. They have been noticed cutting the granite in many places, but not so frequently as the gneisses and schists. It is evident that some of the pegmatites are younger than the granite; but this is not invariably the case, as a case was noted in Mosquito Gulch, where a pegmatite dike is cut by granite. It is more than likely that the period of pegmatite formation extended over a great interval of time; that it began long before the intrusion of the granites now visible on the surface; and that it continued after the granite intrusions had ceased.

Aplite.—Closely associated with pegmatite, as well as independent of the same, are to be found narrow veins and veinlets of fine-grained quartz and feldspar that occur cutting gneisses and schists, and likewise granites, pegmatites and diorite. These veins are usually very narrow—one inch or half an inch, less frequently several inches or a foot, in diameter. At times they seem to pass insensibly into pegmatites. Again, they cut the pegmatites in sharply defined veins. Upon the whole, they would seem to be younger then the pegmatites proper. This is borne out by the fact that veins of aplite have been observed cutting the diorite from which the pegmatite appears to be excluded.

Mineralogically the aplites are composed of small, irregular grains of quartz and microcline. With the microcline may sometimes be seen a little orthoclase.

SEDIMENTARY FORMATIONS

INTRODUCTORY—

The terms used by Emmons in describing the sedimentary formations of the Mosquito Range were decided upon as the result of fossil forms discovered in the rocks, and after careful comparison with similar formations in other parts of Colorado. More recent investigations of these and of similar formations in the state, and a more careful study of the fossil forms collected by Emmons, have thrown some doubt on the determination of some of the geological horizons. This is more particularly true of the so-called "white" or "Yule" limestone, which Emmons places in the Silurian. As to the presence of Silurian rocks in this district, it may be well to quote from Girty,* who, in connection with his paper on The Carboniferous Formations and Faunas of Colorado, gives a résumé of all the paleozoic formations of the state. On page 147 Girty says:

> There is no evidence of the presence of Upper Silurian strata in Colorado. The only Silurian known is that of the Ordovician, though many of the older surveys employed this term to include the Cambrian also. In central Colorado this is a limestone formation, and has received the name of the Yule limestone.

And again, on page 156:

> In view of the extreme rarity of Upper Silurian strata in the West, considering besides that none are known elsewhere in Colorado, and that the Yule limestone has in many places furnished an Ordovician fauna, it is only fair to reason that Upper Silurian time is not, so far as known, represented in the rocks of the state, and that the evidence for its existence near Leadville is due to the imperfect condition of the fossils or to ill-considered identifications.

It would seem, therefore, that the white or Yule limestone of the Leadville district does not include rocks of the Upper Silurian and must be limited to the Lower Silurian, to which the name "Ordovician" is now customarily given. For the above reasons, the term "Ordovician" is here used in place of "Silurian."

As to any further changes in nomenclature, under the present uncertainty as to the proper position for the various paleozoic formations, it has not been deemed desirable to depart from the terms used by Emmons, with which all interested in the district are thoroughly familiar.

CAMBRIAN—

Description.—The extremely persistent, but not overly thick, series of beds assigned by Emmons to the Cambrian are to be found everywhere lying directly upon the Archean rocks. These beds, therefore, are the oldest of the sedimentary series in this district. Their exact horizon within the Cambrian is not definitely known. The writer is informed by private communication from Professor J. D. Irving, who is at present engaged in the preparation of a report on a resurvey of the Leadville district, that, according to Professor Charles Schuchert, who has recently gone over Emmons' Leadville monograph with a view to deter-

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* George H. Girty, The Carboniferous Formations and Faunas of Colorado, U. S. Geol. Surv., Prof. Paper 16, 1903.

mining the horizon of these rocks, the fossils given by Emmons on page 60 indicate that the lower half of these Cambrian rocks belong to the uppermost Cambrian. If this should prove to be correct, the Lower Cambrian is missing in the district under consideration.

Although the Cambrian beds are usually strongly tilted with an easterly dip, as are all the other overlying formations, they invariably lie on a flat Archean floor. They represent, therefore, sediments that were laid down on a level ocean bottom composed of planed-off pre-Cambrian rocks.

The Cambrian rocks represented in the district are readily divided into two distinct divisions of nearly equal thickness: a lower division consisting of thick-bedded crystalline quartzites, and an upper division in which the beds are comparatively thin and contain much calcareous material. The lower division of the Cambrian was designated by Emmons the "lower quartzite," in distinction from a somewhat similar quartzite that occurs above the overlying "white limestone."

The Cambrian series varies somewhat in thickness in different portions of the district. It is seldom under 150 feet, and is usually between this figure and 200 feet. The variation in thickness is mostly confined to the lower part of the series, which varies between fifty and 100 feet. The upper part is more apt to maintain a fairly uniform thickness of about 100 feet. The "lower quartzite" is very conspicuous on nearly all cliff sections, especially on both sides of Mosquito and Buckskin Gulches, and in some of the amphitheaters on the slopes of Mounts Lincoln and Bross. It appears as a light-colored or whitish cliff, that stands out in strong relief from the dark-colored Archean rocks below and from the brown-colored beds of the formation overlying it. This "lower quartzite" appears to act as a unit that resists erosion more effectively than do the overlying and underlying rocks. Actually, however, this quartzite is composed of a number of separate beds that vary in thickness from two or three up to ten feet or more. The separate beds may have a thin parting of shale between them, but this is not at all necessary. In texture this quartzite is granular and may weather to a sandy-looking surface. At the very base it often changes to a fine quartz conglomerate that measures usually less than a foot in thickness.

The upper, thin-bedded portion of the Cambrian beds is very variable. It consists of alternating quartzite and dolomitic limestone, or of calcareous and dolomitic quartzite, in varying percentages of silica. The change, moreover, is gradual from thin-bedded quartzite or calcareous quartzite at the bottom, to more or less siliceous limestone at the top. In fact, it is hardly possible to draw a sharp line between these calcareous quartzites of the Cambrian and the limestones of the so-called Ordovician above, as the latter are often extremely siliceous.

The more distinctly quartzose beds of the upper half of the Cambrian do not appear to differ greatly in appearance from the more massive quartzite of the lower half of the same formation when the rock is freshly broken, but most of these beds have a strong tendency to weather to a distinct brown on the exposed surfaces. For this reason the beds show up strongly on the cliff sections, because of the prevailing brown color. This contrast between the white color of the lower half and the brown of the upper half of the Cambrian is strongly brought out on the cliff of Pennsylvania Mountain that faces Mosquito Gulch on the north. At this point a strongly easterly-dipping fault-plane occurs with an overthrust fault that has caused the Cambrian beds to overlap each other, so that there is a repetition of the series, each showing the white quartzite below and the brown-colored beds above. See Plate XV.

Toward the top of the Cambrian occurs a most peculiar bed that varies from one foot to several feet in thickness, and that consists of a whitish crystalline dolomite thickly spotted with red or brownish red. To this rock Emmons has given the name "red-cast bed." The spots vary from a quarter of an inch to an inch or more in length, and are usually two or three times as long as wide. At times the color changes to a brown. This "red-cast bed" is surprisingly persistent, being found in all parts of the territory; and as it occurs within a few feet of the top of the Cambrian, it serves as an excellent means for drawing the line between the Cambrian and Ordovician in the field. In some places this "red-cast bed" consists of a bed of dolomite several feet thick, in which occur two, or possibly three, parallel streaks that show the reddish spots. In other places the spots may be confined to a two- or three-inch streak, or they may all but disappear; but they may usually be found if searched for wherever the rock exposures are not too deeply buried beneath heavy float. This dolomite with the reddish spots is apt to be siliceous to such an extent that the quartz grains stand out on the weathered surface in a way to suggest a sandstone.

Fossils.—The only fossils from the Cambrian found in the Alma district were collected from a talus slope at the foot of a cliff on the south side of Buckskin Gulch. These were brachiopods, and were determined by Mr. Edwin Kirk, of the United States Geological Survey, as probably referable to Billingsella coloradoensis (Shumard), and are considered by him as undoubtedly Upper Cambrian. Emmons reports some fossils from Quandary Peak, to the north of the Alma district. These he attributes to the genus Dicellocephalus.

ORDOVICIAN OR LOWER SILURIAN—

Description.—The Ordovician or Lower Silurian, in the Leadville monograph designated as Silurian, lies conformably upon the Cambrian series. It has a total thickness of about 200 feet on the average, and has been divided into two formations: (1) the lower formation, to which the name "white limestone" has been given; and (2) the upper, or so-called "parting quartzite."

(1) *White Limestone.*—This rock is very familiar to the miners of Leadville, as it is one of the two limestones that are intimately associated with the ores of that district. It lies directly upon the calcareous, thin-bedded quartzites and siliceous limestones that form the upper part of the Cambrian series. It is known locally among the miners as the "white lime." Its name is given to it because of the prevailing light-drab to white color; yet the name is often misleading, for the color is often far from white, and may be a dark gray or blue-gray, resembling that of the higher-lying "blue limestone" of the Carboniferous. It is composed of rather thin-bedded dolomites, that contain, according to Emmons, 10 per cent or more of silica. The silica is usually not uniformly distributed, but forms irregular streaks and patches from half an inch up to many inches in longest diameter. These streaks of silica are not very noticeable on the freshly broken rock, but they resist the weathering, and, therefore, stand out strongly on a weathered surface and form a very ready means of recognizing the formation. This dolomite has at times a fine grain and breaks with a smooth, concoidal fracture; but usually it is coarse-grained and breaks with a rough fracture. The thickness of the formation averages about 150 feet, but it may vary from this figure by ten or twenty feet on either side.

(2) *Parting Quartzite.*—Above the dolomite of the Ordovician occurs a strongly developed quartzite formation that does not differ very materially in appearance from the quartzite at the base of the Cambrian series. It averages about fifty feet in thickness, but may depart widely from that figure. Its name was given to it by the miners of Leadville for the reason that it lies between the upper and lower limestone. It is very apt to assume a sandy appearance on the weathered surface, owing to the unequal weathering of the original grains and the cementing silica. This property, however, is not confined to this particular quartzite and cannot be used as a means of identifying the horizon. It can be recognized only by its position with reference to underlying or overlying formations.

Owing to the small scale on which the map is published, this quartzite formation has not been mapped separately from the white limestone. Both have been mapped as Ordovician. Some doubt as to the geological position of this quartzite has been expressed. Spurr has described a somewhat similar quartzite at Aspen* as presumably Devonian, but Girty,† in his review of the paleozoic formations in Colorado, is inclined to discredit this and considers it more likely Ordovician.

While the parting quartzite is usually very persistent over most of the territory covered by the Mosquito Range, in places it breaks down and is entirely wanting. This is the case at the summit of Mount Lincoln and on the cliff section on the sides of the gulch running east from the summit of Mount Bross. Evidence as to its absence in the intervening territory is lacking, but in general this quartzite is thin in the region of Mount Bross and thickens toward the south, attaining its greatest thickness south of Mosquito Gulch. This absence of the parting quartzite in the places above designated is interesting as corroborating the testimony of Emmons to the effect that evidences of unconformity between the parting quartzite and the Leadville limestone (blue limestone) above were noted near Leadville.

Fossils.—The only fossils found in the Ordovician came from about half-way up the slope of Pennsylvania Mountain. These were cystids, in a poor state of preservation and indeterminable, but, according to Mr. Edwin Kirk, of the United

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* U. S. Geol. Surv., Mon., Vol. 31, 1898.

† U. S. Geol. Surv., Prof. Paper No. 16, 1903, p. 161.

States Geological Survey, to whom they were submitted, they represent types so far known only from the Ordovician.

CARBONIFEROUS—

General Description.—The Carboniferous rocks of central Colorado naturally fall into three divisions—a lower, a middle, and an upper division; to which, respectively, have been applied the names "Leadville limestone," "Weber grits," and "upper coal measures." There is some difference of opinion as to whether the terms "Mississippian" and "Pennsylvanian," now in common use for the Lower and Upper Carboniferous, respectively, can be applied to the divisions of the Carboniferous as they are developed in central Colorado; or, if so, as to where the line should be drawn. For the present, therefore, it seems best to adhere to the terms employed by Emmons, and familiar to all interested in mining at Leadville and in the regions adjacent thereto. Only two of the three divisions of the Carboniferous are represented in the Alma district; namely, the Leadville Limestone at the base of the series, and the Weber Grits above the limestone.

Leadville Limestone.—In his Leadville monograph, Emmons gave the name "blue" or "ore-bearing limestone" to the limestone formation at the base of the Carboniferous. Among miners it is known by the shorter name "blue lime." In 1898, some twelve years after the appearance of the Leadville monograph, the Tenmile District Special Folio, also by Emmons, was published by the United States Geological Survey. In this folio Emmons gave the name "blue" or "Leadville limestone" to this same formation. Since then the name "Leadville limestone" has been generally adopted.

This limestone is dolomitic, like the white limestone below. According to chemical analyses given in the Leadville monograph, it is almost a pure dolomite, carrying very little besides carbonates of calcium and magnesium in nearly normal proportions. Its color is commonly a bluish gray, but this color may be locally bleached so that the rock may be as white as the so-called white limestone of the Ordovician. It occurs usually in thick beds, and is nearly free from the numerous streaks of quartz that characterize the Ordovician limestone. Toward the top of the limestone, which customarily varies from 150 to 200 feet in thickness, the color often becomes almost black, and black, roundish cherts are apt to appear. A feature that often serves to identify the horizon is what Emmons describes as a "ribbing so fine and regular as to produce an appearance resembling that of *Eozoon.*" This ribbing consists of alternating bands of white and gray color. It does not appear in the white limestone. The Leadville limestone is usually a fine-grained rock, not extremely dense, but noticeably finer than the white limestone. It may, however, become quite coarse-grained in places, especially in the vicinity of ore deposits.

Emmons makes comparison between these two limestones, and says:

> The characteristics which may serve to distinguish the rock of the Blue from that of the White Limestone are as follows:
>
> 1. Color, which is darker.
> 2. Composition, the former being almost free from silica, the latter containing 10 per cent and upwards.
> 3. Texture, the former being generally crystalline, while the latter is more compact.
> 4. Chert secretions, which in the former are always black and in the latter nearly white.
> 5. Structure, the Blue Limestone being generally more heavily bedded than the white.

The observations of the writer in the Alma district corroborate the above statement, with the exception of the third, concerning the texture. With the statement of Emmons in mind, careful and constant observation was made as to the fineness of grain of the two limestones, with the result that a reversal of Emmons' statement would more nearly represent the customary conditions. That is, the blue limestone as a rule is much more compact in texture than the white limestone. In fact, the comparative coarseness of the white limestone was much more valuable as a means of identifying the white limestone than was the color. There are many exceptions to this rule, but, as a general thing, the blue limestone is fine-grained in regions remote from mineral veins, and coarse in proximity to such veins. For instance, on the summit of Mount Bross and on Mount Lincoln, where many mines and mining prospects are located, the blue limestone is unusually coarse-grained. It is possible that the Emmons survey of this part of the Mosquito Range was largely limited to the portions where active mining was going on, or had been going on, and little time was put on the portions barren of ore. There is, in fact, much internal evidence to sustain this conclusion, as the geologic mapping was done with much greater accuracy of detail in the mineralized portions of the range than in the non-mineralized portions. It is natural, therefore, that the character of this limestone, as it occurs in the those portions most closely studied, should have made a strong impression on the mind, and the conclusion have been drawn that the character shown in such places was the prevailing character.

The coarseness of grain of the blue limestone in the vicinity of mineral veins is undoubtedly due to metamorphism. This metamorphism may be due to two causes: first, to the proximity of large intrusions of igneous rocks, at contact with which or near which the ore veins are apt to occur; second, to the effect of extensive crushing, which also is very much in evidence in proximity to many mineralized zones.

The Leadville limestone lies apparently conformably on the parting quartzite, except in those parts where this quartzite is missing. It outcrops on some of the cliff sections and forms large areas of the easterly-sloping surfaces of Lincoln, Bross, Loveland and Pennsylvania Mountains. It is extensively cut by many porphyry intrusions and is intimately associated with most of the ore deposits on Mounts Lincoln and Bross, as is also the case at Leadville.

No fossils were found in this formation.

Weber Grits.—The formation lying apparently conformably upon the Leadville Limestone, and here considered under the name "Weber grits," has been divided into two: a lower, comparatively thin series, consisting mainly of shales, called the "Weber shales;" and a higher, very much thicker series, composed of coarser sediments, called the "Weber grits." The line between the two is very difficult to draw in the territory investigated, for the reason that extensive porphyry intrusions have usually taken place in the shales, or between the shales and the grits, and for the further reason that the easily weathered shales are often difficult to recognize under a heavy covering of wash. For the above reasons it was impossible to determine with satisfaction the thickness of the Weber shales. Emmons puts the thickness as between 150 and 300 feet. These two formations have, therefore, been mapped as one. The entire series is known by mining men under the name "Weber grits," and it seems desirable to apply this name so as to include both the shales and the grits proper.

The lower part of the Weber grits series, to which the name "Weber shales" should properly be applied, consists for the most part of very compact shales and argillites that pass into or alternate with thin-bedded quartzites or shaly, calcareous beds.

The quartzitic beds are sometimes extremely black in color, due probably to admixture of coaly matter. The more compact argillites vary greatly in color. Grays, browns and drabs prevail. In the lower part a peculiar greenish color is often to be noticed, that furnishes a ready means of identifying the horizon. This is particularly pronounced on the southeastern slope of Mount Bross.

The calcareous shale may pass into thin beds of nearly pure limestone that are likely to be fossiliferous. The only fossils actually discovered were crinoid stems, that could not be positively identified. These were found in two places: one, the ridge running to the west from the summit of London Mountain; the other, a gulch on the west side of the Platte River, about three miles above Alma. This series of quartzitic and calcareous shales is transitional between the blue limestone beneath and the coarse grit formation above.

The Weber grits proper form a very thick series, the thickness of which has been estimated at some 2,500 feet. Only the lower part of this series lies within the territory surveyed, the higher-lying beds extending far to the east in the direction of South Park. Together with the intruded porphyries they cover a third or more of the area mapped, and are to be found in two distinct parts of that area. The greatest portion lies along the valley of the Platte, from a mile or so below Montgomery on the north to the southeastern edge of the map. The other area of Weber grits is in the southwestern part of the district and lies west of the great London fault, having been let down on the west some two or three thousand feet by means of that fault.

These rocks are, in the main, very coarse sediments of a distinctly arkose character, being composed of coarse and largely angular or subangular grains of quartz and feldspar, the latter being both orthoclase and microcline in abundance. These rocks are supposed to have resulted from the erosion of Archean granites. In places these distinctly gritty arkoses pass into very hard, thick-bedded quartzites. Again, they pass into thinner-bedded shales that are apt to be micaceous. Conglomerates are also met with locally, with more or less rounded pebbles of quartz and feldspar, the pebbles rarely becoming more than an inch or two in diameter. One or two thin limestone beds were also encountered. In color these grits are gray and white, passing into pink, with occasionally coal-black streaks.

The Weber grits have nearly everywhere, like the underlying bedded formations, a strong easterly dip. Exceptions to this easterly dip are to be found on the summits of Mount Bross and Mount Lincoln, where they assume a horizontal position, with a possibly slight westerly dip in places; also west of the London fault, where the beds have been greatly disturbed by the folding that preceded and accompanied the faulting. This matter will be taken up in more detail later.

QUARTERNARY—

The highest of the formations that compose the solid rocks of the Alma district are the above-described Weber grits that belong in the Carboniferous period. If any formations of later age than the Carboniferous were laid down on top of those now present, they have been completely removed by erosion. In a large part of the district, however, the solid rock formations are deeply buried in an unconsolidated accumulation of detritus. This detritus does not represent merely surface wash and talus, but has been accumulated by special geological agents or forces acting within definite time limits. These deposits are considered worthy of distinct mapping. They are presented under three heads; namely, (1) Glacial Moraines and Drift; (2) Landslides and Rock Streams; (3) Alluvium.

Glacial Moraines and Drift.—That the Mosquito Range, like all other high mountain ranges of Colorado, has been the center of extensive glacial activity in the not very remote past has long been known. In fact, Emmons devotes some space to the discussion of glacial phenomena in the Mosquito Range, and in a general way indicates the extent of such glaciation. His map, however, does not show the glacial deposits, but gives the rock formations as they would appear if all superficial material, glacial as well as more recent wash, were stripped away. In the map accompanying this report the glacial formations have been mapped wherever they are thick enough effectually to obscure the character of the underlying rocks. This glacial material is to be found thickly covering the valley bottoms of the Platte River from near Montgomery to the edge of the map, and of the tributary streams some distance up from their junction with the Platte. Material thus distributed by a retreating glacier over the floor of the valley is usually designated as a "ground moraine." This ground moraine is of unknown depth, but may easily be one or two hundred feet thick. Again, it may be very

Plate VII—A. View of placer washings opposite Alma, showing the unstratified glacial gravels of the Platte valley ground moraine. In the distance is seen the town of Alma, and beyond this Buckskin Gulch, with Mount Bross on the right and Loveland Mountain on the left. (See pp. 59 and 61.)

B. Glacial moraine gravels of the Platte valley ground moraine, opposite Alma. These gravels have been worked as placer gravels. (See pp. 59 and 61.)

Colorado State Geological Survey—Bulletin No. 3, Plate VII, A

B

thin, or even entirely lacking in places, so that the rocks beneath outcrop on the surface and appear on the map as islands in the midst of the drift. Again, the morainal deposit may take the shape of "lateral moraines" that represent the deposits of the glacier along the sides of the valley. Such lateral moraines may take the shape of a bench on each side of the valley, or of a thinner covering of glacial boulders, the upper edge of which marks the upper limit of the ice action. Where a glacier leaves a narrow valley and comes out into a wide valley, or where two glacial streams come together, there is usually formed a ridge-like extension of the lateral moraine out into the open valley. Such glacial ridges are often very pronounced, with steep sides and possibly with a sharp, narrow, ridge-like summit. Such ridge-like moraines are very common in the Mosquito Range. A good illustration is the long ridge that separates Mosquito Gulch from Buckskin Gulch at Alma. This ridge is thickly covered with, and largely composed of, glacial material. On the Mosquito side it starts about opposite Park City, and has an elevation of some 500 feet above the level of the valley. From this point the ridge extends eastward, at constantly lessening elevation, for about two and a half miles, to where the Mosquito Gulch joins the Platte valley. How much of this ridge is composed of glacial material it is impossible to say. No rock formation is exposed in this entire ridge, except near the base along Buckskin Gulch. It is possible that nearly the whole of the 500 feet of thickness at the beginning of the morainal ridge is composed of glacial material, but this is not at all likely.

The material of which the glacial moraines and drift are composed is well shown in the great cuts of hydraulic placering on the north side of the Platte valley, opposite Alma. Here we have an unassorted mixture of sand, gravel and boulders in all sizes up to three or four feet in diameter, with just enough clay to make a binding material that causes the embankment to stand in vertical walls. Among the boulders of this placer ground may be found many that show the scratching or grooving that characterizes glacial boulders. See Plate VII, A and B.

These deposits of glacial drift in the valley bottoms and along the sides of the valley do not represent the full extent of the glaciers. Above the region of heavy drift isolated glacial boulders or parallel scratches on the sides of the mountains may often be seen, both testifying to the presence of vanished glaciers. The great extent of these glaciers, and their great thickness at the point where the contributing streams of ice issued from the higher mountain valleys, may be judged from the fact that the glacier issuing from Mosquito Gulch spread out to the left and completely covered Bald Hill, which rises to a height of over 1,000 feet above the valley at Park City, situated at its foot.

While all the larger valleys of the district contained glaciers of considerable size, the Platte valley glacier was much larger than any other, and was the dominating glacier to which the others were tributary. This glacier filled the entire valley to a height of fully 500 feet above the valley bottom at Alma, and to 1,000 feet or more at Montgomery and above. While the main glacier was formed in the great glacial cirques that are to be seen at the head of the Platte valley, and passed down the valley past the site of Montgomery, it was joined by tributaries on the right, from Lincoln Amphitheater on the east slope of Mount Lincoln, probably from the Quartzville Gulch between Mount Lincoln and Mount Bross, and from the gulch on the east slope of Mount Bross, and by very large tributaries from Buckskin and Mosquito Gulches. The Platte valley glacier, augmented by the large tributaries just mentioned, passed down the valley as far as the junction of Sacramento Creek with the Platte River, about five miles below Alma station and an equal number of miles beyond the boundaries of this map.

The glacial moraines and glacial drift that cover the territory above described all belong to what is called the last glacial epoch. It has been definitely determined that there were two distinct glacial epochs in the Rocky Mountain region—an earlier and a later epoch, with an interglacial epoch of long duration, during which the glaciers completely disappeared and extensive erosion and rock decomposition took place. The first glacial epoch apparently had about the same extension as the later one, but its drift has been almost completely covered by the later drift. In the area covered with this report none of the older glacial drift is visible, and, therefore, it does not appear on the map. However, the drift at the extreme end of the older glacier is to be seen protruding beyond the lower limit of the later drift, just above the town of Fairplay, as is shown on the map by Capps.*

In the higher portion of the valleys that carried the glaciers the glacial drift is often not so thick as to obscure the character of the underlying rocks. For this reason the drift has not been

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* Stephen R. Capps, Jr., Pleistocene Geology of the Leadville Quadrangle, Colorado, U. S. Geol. Surv., Bull. No. 386, 1909.

shown on the map. Such regions show the strongest evidence of glaciation in the numerous striated boulders, in the grooved and striated bottom and sides of the valley, in the U-shaped valleys, and in the presenec of lakelets in the higher cirques. Glacial action is also shown by the numerous striking cirques, with their almost vertical surrounding walls, at the heads of all the main valleys.

The glacial phenomena of the Mosquito Range have recently been made a subject of careful study by Stephen R. Capps, Jr., who has published a detailed description and a map showing the distribution of the glaciers. This map of Capps covers the whole of the Leadville Quadrangle, and embraces portions of the Mosquito and Sawatch Ranges. It is published as Bulletin 386 of the United States Geological Survey. To those interested in securing further information as to the glaciation of the Alma district, this paper by Capps is highly recommended.

A good idea of the unstratified glacial drift of the Platte glacier may be seen on Plate VII, which is a photograph of the old placer washings opposite the town of Alma.

Landslides and Rock Streams.—Landslides are very common features in many high mountain regions, and have been described in many localities in the Rocky Mountains. They are produced by the movement of large masses of loose material, or of superficial rocks masses, down a steep mountain-side. This movement is often quite slow, but at times attains considerable velocity. It often involves areas a mile or more in extent. Such landslides have been described in most of the folios of the United States Geological Survey for the San Juan Mountains of Colorado.*

The landslides within the Alma district are comparatively inconspicuous features. The largest one is located at the foot of Pennsylvania Mountain, at the highest point of the mountain.

The distinction between landslides and rock streams has only very recently been recognized. The term "rock stream" was first used by Cross and Howe in the text of the Silverton Folio of Colorado.† It was applied to certain landslide-like masses that occur on the floors of high glacial cirques of the San Juan Mountains, and that present strong evidences of stream-like motion. At a later date Howe‡ published a more extensive and superbly illustrated paper on Landslides in the San Juan Mountains, Colo-

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*See, for instance, Folio No. 153 of the Ouray Quadrangle, by Cross, Howe and Irving.

†U. S. Geol. Surv., Silverton Folio, No. 120, 1905.

‡Ernest Howe, U. S. Geol. Surv., Prof. Paper 67, 1909.

rado, in which rock streams as well as the more common landslides were described, and in which rock streams were attributed to a large mass of rocks breaking loose and rushing with tremendous speed down the mountain-side, stopping as suddenly as it began. The motion is so rapid that, in spite of the size of the rock fragments, the mass moves as though it were a liquid.

The rock streams of the San Juan Mountains are all on the open floor of the glacial cirques and do not flow down a contracted valley. In 1910 the writer described a very unusual rock stream that flowed down a narrow valley on the west side of Veta Peak, Colorado.* A rock stream somewhat similar to that on Veta Peak is to be seen in the bottom of Lincoln Amphitheater, a very narrow and steep-sided valley on the east slope of Mount Lincoln. It occupies the entire width of the gulch, and is from 300 feet to 600 feet wide and over half a mile long. Its material consists mainly of Archean rocks that broke loose from the precipitous rock slope at the head of the gulch. A more detailed description will be found in a later chapter. This rock stream is shown on Plate XIX, A and B.

There are several other landslide masses that bear some resemblance to a rock stream, but the only one presenting the peculiar characteristics that justify the use of the name "rock stream" is a small one, 1,500 feet long, close to Emma Lake, at the head of Buckskin Gulch.

Alluvium.—The term "alluvium" is customarily applied to the recent deposits of sediments brought down and spread out by the flood waters of present streams. Such material is mostly wanting in the Alma district, as the rapid descent of the valley bottoms has prevented the deposition of sediments by the streams. With a few exceptions, the narrow strip of alluvium along the creek-beds is too narrow to map. Most of the loose material occupying the valley bottoms was deposited by glacial action.

IGNEOUS ROCKS (POST-ARCHEAN)

INTRODUCTORY—

Among the rocks described in the foregoing pages as forming part of the Archean are some that might properly be included under the list of igneous rocks, in that they are igneous intrusions in the Archean rocks, and therefore of later age than the rocks into which they were intruded. This is more particularly

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* Horace B. Patton, Rock Streams of Veta Peak, Colorado, Bull., Geol. Soc. of Am., Vol. 21, p. 663, 1910.

true of the granites, and might perhaps also be held to be true of the pegmatites and aplites. All of these rocks, however, show such an intimate relationship to the Archean rocks, and have been subjected to crushing to so great an extent, that their age must greatly antedate the lowest of the overlying sedimentaries.

There are many other igneous intrusions in the Archean formation that are either identical with, or that bear some resemblance to, the intrusions found in the sedimentary series, and that are very evidently of more recent origin than the Archean. These rocks occur in dikes in the Archean, and in dikes or sills or more irregular masses in the sedimentaries. Their age is apparently in all cases younger than that of the lowest of the Cambrian beds, and possibly in all cases younger than that of the highest of the sedimentary beds. All such rocks are here included under the designation "igneous."

As to the classes of igneous rocks here represented, with the exception of the few occurrences of diorite, they may all be designated as effusive rocks, in the sense in which this term has customarily been employed by the writer, following the usage of Rosenbusch. That is, the term "effusive" is used to cover all igneous rocks that have flowed either to or toward the surface, and have taken the form of dikes, sills and surface sheets or flows. The term "effusive," as thus employed, distinguishes these igneous rocks as a class from the plutonic or deep-seated igneous rocks, of which granite is the most common type. Effusive rocks, as thus defined, fall under two heads: extrusive rocks, those that have been poured out upon the surface; and intrusive rocks, those that have been intruded into the overlying rocks, either as dikes, or as intercalated sills or sheets that lie often conformable to the overlying and underlying strata. All the igneous rocks here considered are of the intrusive type, with the exception, perhaps, of the diorites, which may more properly be classified as plutonic.

The igneous rocks of the Mosquito Range are described with great accuracy and at considerable length in an appendix to Emmons' Leadville monograph, written by Whitman Cross and entitled "Petrography." Inasmuch as these descriptions by Cross cover quite fully the district here under consideration, it seems hardly necessary or desirable to attempt a very detailed description of the various rock types at this time. The writer, therefore, will content himself with a general description of the rock types involved, and give details in cases where his observations may not altogether agree with those of Cross, or where a later and additional study may have disclosed new facts.

Cross divides the igneous rocks of the Mosquito Range into an "Older" and "Younger" series. The "Younger" rocks are altogether missing for the district considered in this paper and need not be further referred to. The "Older" series Cross divides into "Quartz Porphyry," "Diorite" and "Porphyrite." The most abundant of these, the quartz porphyries, he further divides into several distinct types; namely, "Mount Zion Porphyry," "White or Leadville Porphyry," "Pyritiferous Porphyry," "Mosquito Porphyry," "Lincoln Porphyry" and "Gray Porphyry." Similarly he discusses the porphyrites under the heads: "Principal Group," "Sacramento Porphyrite," "Silverheels Porphyrite" and "Miscellaneous Porphyrites." As to the porphyries, with the exception of the "Lincoln porphyry" and the "white porphyry," the writer found it quite impracticable to attempt to make any distinction between the different types in field mapping. Owing to very extensive alteration of the original composition, and consequent change of texture, that has taken place in most cases, and owing, further, to almost endless transitions between these types, no satisfactory line can be drawn that can be used in the field. Furthermore, even under the microscope in thin section, most of the types recognized by Cross so blend into each other that an attempt to make sharp distinctions seems needlessly arbitrary. In the study of these rocks, both in the field and in the laboratory, the writer has probably had access to a much greater number of rock specimens than was available to Mr. Cross, and so the transitional types have been more numerous and the distinctions less marked.

With the exception of the "white porphyry," all the porphyries of the Alma district have been found to belong to what is now very commonly designated as "monzonite porphyry," or, to be more exact, "quartz monzonite porphyry." This term, which was not in use at the time Cross prepared his appendix to the Leadville monograph, has of late years been found to apply to many of the older porphyries of the Rocky Mountain region. Most recently Ransome* has described, as occurring in the closely adjacent Breckenridge district to the north, both monzonite and quartz monzonite porphyries, most of which appear to differ materially from the rocks here described. With comparatively few exceptions, the rocks included under this head

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*F. L. Ransome, U. S. Geol. Surv., Prof. Paper 75, 1911.

contain quartz among the phenocrysts, or at least in the form of sizable grains in considerable quantity. A few specimens were collected in which the quartz was found to be almost entirely confined to the groundmass, and to such rocks the name "monzonite porphyry," instead of "quartz monzonite porphyry," could very well be given. But, as it was not practicable to map these rocks separately, their description is included under that of the prevailing type.

The Lincoln porphyry type has been retained, as this type, when strongly developed, is very striking and characteristic, and as the name has also been used by Emmons in connection with the porphyries of the Tenmile district,* and by Ransome in his description of the rocks of the Breckenridge district just referred to. Yet even in the case of this very marked type it is not possible to draw the line either in the field or in the laboratory, and an arbitrary line has been drawn in mapping the Lincoln porphyry. The line has been drawn at the prominence of the orthoclase and quartz phenocrysts. Where these two ingredients are specially pronounced and large, the rock has been mapped as Lincoln porphyry; otherwise as quartz monzonite porphyry.

For a somewhat similar reason it has not been found desirable to attempt to discriminate on the map between the different types of porphyrites. The principal type, as described by Cross, has been allowed to stand, but the other types have been merged either into the principal type or into the quartz monzonite porphyries. The retention of the name "porphyrite" will likely meet with criticism in some quarters, inasmuch as the United States Geological Survey has discontinued its use; but the term seems to the writer still to have merit, and no confusion can arise from its use. There is a distinct advantage in employing a term that is based on the absence of alkaline feldspars.

DIORITE—

General Description.—In the Leadville monograph Cross describes diorite under the list of "older eruptives," as occurring in several broad dikes in the Archean of Buckskin Gulch. The Archean both of Buckskin Gulch and of other gulches in the Alma district is cut by numerous dikes of igneous rocks of greatly varying types, all of which come very properly under

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* Tenmile special district folio (No. 48), Geol. Atlas U. S. Geol. Surv., 1898.

what Cross calls the "older eruptives"—rocks that are practically identical with dikes and intrusive sheets found in the overlying sedimentary rocks. In most cases, however, these dikes cutting the Archean are of no very great dimensions, being rarely more than one or two hundred feet wide. Judging from the description given by Cross, and from the width of the dikes as shown on the geological map of the atlas accompanying the Leadville monograph, the occurrences to which Cross refers are dikes not greater than those just referred to as occurring frequently in the Archean. But, aside from these dikes of diorite mapped by Emmons, there occur in the same immediate vicinity two other intrusions of diorite, of very irregular shape and of much greater width. These two masses lie one on each side of Buckskin Gulch, separated from each other by a strip of alluvial wash about 1,500 feet wide. Under the very likely supposition that these two separated masses are really continuous under the wash, we have here an irregular dike-like mass 8,500 feet long and 1,000 to 1,500 or more feet wide.

In spite of certain resemblances in mineral composition between this diorite and some of the porphyritic intrusions of the sedimentary series, there is no proof that there is any generic connection between them. No diorite has been found certainly cutting the sedimentaries. It is true that Emmons' map shows a dike on the east side of Buckskin Gulch in the so-called Red Amphitheater, running up into the Cambrian formation; but, as stated, it is uncertain whether the dike enters the Cambrian or spreads out in the Archean beneath the Cambrian.

Cross refers to, and gives brief descriptions of, three types of diorite that occur in as many independent dikes. These he describes under the names "quartz-mica diorite," "hornblende-diorite" and "augite-bearing diorite." While it is quite possible that these different types are due to separate and independent intrusion, it would seem from a study of the large mass above mentioned that these and other diorite types represent facial varieties of the same dioritic magma. The exposures of this diorte are not sufficiently continuous or marked to allow a very accurate mapping of their extent and relationships, and it is possible that all the types described below are to be found in different parts of the same intrusive mass.

Hornblende Diorite.—This fairly coarse-grained normal diorite was collected from the large mass on the east side of Buckskin Gulch. It is rather light-colored and resembles a hornblende granite. Both hornblende and plagioclase are fresh-lustered and are readily recognizable in the hand specimen.

Under the microscope this rock discloses an abundance of dark-green hornblende in irregular and more or less cellular grains, and of plagioclase of the variety andesine, showing extinction angles of 18° in the zone at right angles to (010). The rock also contains a small amount of quartz and of greenish-brown biotite; also accessory magnetite, apatite and titanite.

Quartz-Biotite Diorite.—One specimen of this type comes from the upper edge of the large mass on the east side of Buckskin Gulch. It bears a close resemblance to a granitite. It has a light-gray color, is fairly coarse-grained, and discloses quartz, plagioclase and biotite in the hand specimen. Under the microscope the main constituents are shown to be quartz, plagioclase and biotite. The plagioclase appears to be fairly basic and to lie between andesine and labradorite, but the grains are so clouded through sericitization as to render the determination unsatisfactory.

A second specimen of this type was collected in a stream-bed close to the road at a point about half a mile south of the Kite-shaped Lake. This rock is in contact with a biotite granite. It is much finer-grained and darker-colored than the other specimen. The plagioclases are rectangular, or approximately so, and are sharply defined where in contact with quartz. It lies between andesine and labradorite, as it shows a maximum extinction angle of 23° in sections at right angles to (010). The biotite has a greenish-brown color and occurs in very irregular grains. In both of these specimens quartz occurs in abundant but very irregular grains, filling the spaces between the plagioclase individuals. A small amount of accessory magnetite, apatite and titanite occurs.

Quartz-Hornblende Diorite.—This is also from the large mass on the east side of Buckskin Gulch. It is fairly coarse-grained and light-colored. Under the microscope the plagioclase was determined to be andesine, much altered through sericitization. The hornblende occurs in large prismatic individuals of a dark bluish-green color. Calcite is also developed as an alteration product of the plagioclase. Accessory magnetite and apatite are sparingly present.

Monzonite-Diorite.—The large diorite mass above referred to as occurring on the west side of Buckskin Creek extends from the alluvial wash in the creek bottom up the mountain slope, almost to the top of the ridge running in a southeasterly direction from Mount Buckskin. As already stated, this mass on the west side of the gulch may be a continuation of the approximately equal mass on the opposite side. So far, however, as the specimens collected are concerned, there would seem to be a slight difference. All the specimens collected from the western side, of which six have been studied in this section, show the presence of considerable orthoclase, in addition to the other constituents. This association of minerals would serve to identify the rock as a monzonite. As the orthoclase is rather fluctuating in quantity, and as quite similar-appearing rocks on the other side of the gulch appear to be lacking in orthoclase, or, at least, poor in this mineral, the name "diorite-monzonite" has been chosen as better showing its relationship to the diorite types just described.

With one exception, the main constituents of the monzonite-diorite are quartz, orthoclase, plagioclase, hornblende and biotite. The exceptional case will be described below. In the hand specimen these rocks are fairly light-colored, fine- to medium-grained, and have about the appearance of normal diorites. Hornblende, biotite and plagioclase can readily be identified; also the orthoclase, after one has become accustomed to its appearance. Quartz is in too fine grains to be visible.

Under the microscope in thin section plagioclase appears as the dominant mineral. It occurs in rectangular or short, lath-shaped individuals. In the spaces produced by the intersection of the plagiocalse, hornblende and biotite individuals are to be seen both quartz and orthoclase. Both of these last-named minerals show, therefore, irregular, angular shapes, and both have a tendency to show simultaneous extinction over areas considerable larger than appear to be occupied by one individual. The plagioclase is of a variety intermediate between andesine and labradorite. Zonal structure is often quite pronounced, and margins of acid feldspar are common.

The hornblende occurs in very irregular grains that are often cellular, the spaces being filled with enclosed plagioclase laths and accessory minerals. The color is green or brownish-green. Biotite occurs in irregular, brown-colored individuals, that also may enclose plagioclase laths. The relative percentages of hornblende and biotite vary greatly in different specimens. Accessory minerals are the same as observed in the other diorites; namely, magnetite, apatite and titanite. The alteration products are sericite, calcite and epidote.

Toward the southeastern edge of this monzonite-diorite mass the rock appears to be greatly brecciated, fragments of darker color appearing in the midst of a somewhat lighter-colored matrix. These darker-colored fragments, as disclosed by the microscope, are diorite containing more hornblende and less biotite than the rest of the rock. Apparently little or no orthoclase occurs in the fragments, but, owing to extensive alteration of the feldspar ingredient, this is difficult of proof. The presence of these fragments of diorite enclosed in diorite would seem to point to more than one intrusion of dioritic magma.

The one exception referred to above as occurring in the diorite area west of the creek is a rock of similar nature and of practically identical structure, but differing in containing abundant augite. This mineral occurs in almost colorless, irregular grains that in places show a slight alteration to hornblende. With this exception, hornblende is apparently missing. In the Leadville monograph Cross* describes a similar augite diorite as forming the dike on the east side of Red Amphitheater. Mr. Cross also remarks on the significance of this rock as being the only augite-bearing rock in the district. It is not certain whether this augite-bearing rock is a continuation of the dike in Red Amphitheater, or whether it is an independent dike, or whether it may not possibly be a local facies of the main mass. It was collected on a tunnel dump near the creek level, associated with blocks of the more normal monzonite-diorite. As the tunnel was not accessible, the exact position of this rock could not be ascertained.

It is to be regretted that the mapping of these diorite and diorite-monzonite rocks was not undertaken until a few days before it became necessary to close the work in the Alma district. The geological relationships of this and other intrusive rocks in this part of the Buckskin Gulch proved to be much more complex and difficult of solution than had been anticipated. The rocks form an interesting series, and, had more time been available, it might have been possible to prove whether these diorites and diorite-monzonites represent one intrusive act, or whether they represent several successive intrusions. The mapping of the diorite area on the northeast side of the gulch had to be left almost entirely to two of the student members of the

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* Loc. cit., p. 334.

party, Messrs. Beck and Stewart, who, though unusually careful and observant, were necessarily lacking in experience. From their description it would seem that portions of this diorite area consist of rocks containing orthoclase, although such thin sections as were prepared do not show the presence of this mineral. One specimen collected by them on the northwest side contains a single crystal of orthoclase that is nearly an inch long and that shows Carlsbad twinning. This would seem to indicate the presence of this mineral in the rock mass.

This diorite on the northeast side of the gulch comes into contact with a mass of Lincoln porphyry that bears a very close resemblance to a granite. At the line of contact where the two rocks were exposed considerable crushing and deposition of quartz seems to have taken place, so that it could not positively be determined which of the two is the older.

WHITE PORPHYRY—

The name "white" or "Leadville porphyry" was given by the Emmons survey to an igneous rock of prevailing whitish color that covers extensive areas in the vicinity of Leadville and in the southern part of the Mosquito Range, and that was described as having a very close relationship to the ore bodies of Leadville. While this rock does not occur in extensive masses in the district covered by this investigation, it nevertheless does occur as dikes in many plaes from the northern to the southernmost part of the district, and it also is very closely associated with the ore bodies of the London mine, the most important mine here considered.

This rock can usually be very readily recognized by its light-gray to white color, its extremely uniform, compact texture, its freedom or apparent freedom from phenocrysts or visible crystals, and especially by the absence of all dark-colored or ferromagnesian minerals, such as biotite or hornblende. Strictly speaking, it is not free from phenocrysts, except in a few cases, as a close examination of the hand specimen discloses small, angular grains or crystals with distinct forms. These are mostly quartz, but feldspar may also be represented. In size they are usually about one to two millimeters in diameter, occasionally a little larger.

The white porphyry occurs in dikes and sheets that never reach a thickness of over 150 feet and that are usually much less than this, some being only a very few feet thick. The most extensive and persistent sheet occurs in close proximity to the London fault, following this fault on the west side for its entire length across the mapped territory, and occasionally splitting into two or more parallel running sheets. In the form of dikes it occurs cutting the sedimentaries on Mount Lincoln and on North Star Mountain, on the northern edge of the map; also cutting the Archean in the upper Platte valley, on Mount Buckskin, and in the amphitheaters at the head of Buckskin Gulch and of North Mosquito Gulch.

In describing the microscopical character of the white porphyry, Cross says:

> The essential constituents of the White Porphyry are plagioclase, orthoclase and quartz, developed in a remarkably uniform-grained mass, in which lie occasional crystals of one or more of the same minerals. Orthoclase seems to predominate, but never very greatly, and the chemical analysis confirms this view. Compared with the Mount Zion Porphyry, it is found that plagioclase occurs also in microlitic forms, but less abundantly, and in some of the more compact modifications may be wanting.

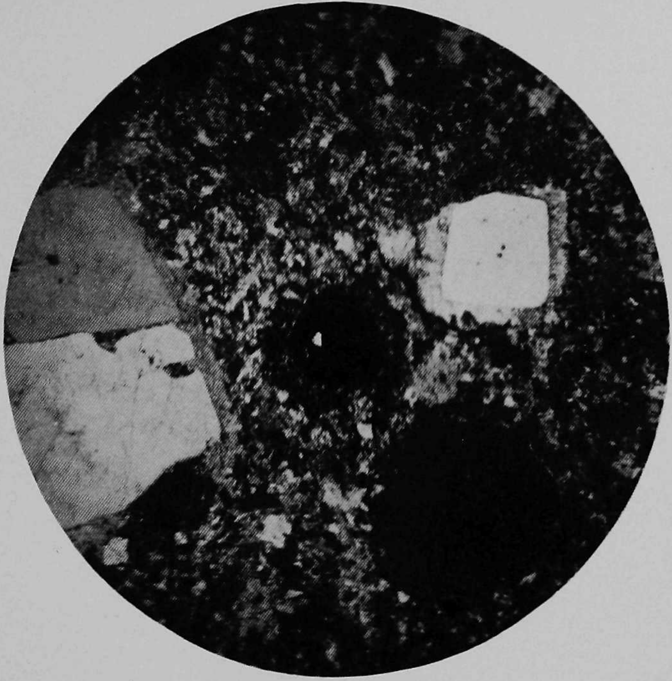
In thin sections prepared from sixteen different localities the microlitic form of the plagioclase appears in but one case, and that only at the edge of a dike 150 feet wide in the upper Platte valley (Specimen 134), whereas a specimen taken from the central part of the same dike fails to show any microlites (Specimen 133). In fact, it is impossible in all but one or two cases to recognize any plagioclase at all, and even then only in very small amounts. It may be that this mineral forms a considerable part of these white porphyries, but, if so, the writer has been unable to prove it. The chemical analysis above referred to, and which is given on page 81, would seem to suggest the presence of plagioclase on account of the relatively large amount of CaO present; but as the rock is admittedly far from fresh and contains CO_2, it is more than likely, as Cross suggests, that much of the CaO is due to the presence of calcite brought in from the adjacent dolomite. The grain of these rocks, while fairly fine, is never excessively so; in fact, it is coarser than that of many of the other porphyries of the district. The average size of the quartz and feldspar grains is about .03 mm or from that to .05 mm. In one case, that from the center of a 150-foot dike, the grains reached to .08 mm. But even in case of the smallest grains noted, the microscope should distinguish between plagioclase and orthoclase, unless they are greatly decomposed. In the single case where plagioclase micro-

Plate VIII—Photomicrographs of white porphyry from dike near summit of Mount Lincoln (Specimen 269).

A. Polarized light. ×15. Nicols crossed. Shows a groundmass of quartz and feldspar, enclosing countless minute secondary muscovite scales not visible in the plate. The five large rounded and angular grains are quartz, the one in the center being cut parallel to the basal pinacoid. Each of these is surrounded with a fringe or margin of secondary quartz of like orientation to that of the grain around which it occurs. This margin is crowded with minute scales of muscovite like those in the groundmass. (See p. 73.)

B. Enlarged portion of A, representing the whitest grain of quartz under same conditions of light, ×52. The magnified margin of secondary quartz. shows many of the enclosed muscovite scales as dark-colored specks. (See p. 73.)

Colorado State Geological Survey—Bulletin No. 3, Plate VIII, A



B

lites were observed, observations on the refractive power indicated that the microlites have a lower index than either the quartz or the orthoclase present in the same slide. This would indicate the presence of albite.

Muscovite is an extraordinarily abundant mineral in these rocks, but does not appear to be an original constituent. It occurs occasionally in parallel intergrowth with chlorite in distinct but small plates that were probably originally biotite. They also occur in separate scales and in felted aggregates of scales partially or completely replacing the larger feldspar crystals. But mostly this mineral is scattered widely through the fine-grained mass of the rock. It occurs thus in minute to very minute (down to .007 mm) scales or shreds, with more or less tapering ends or edges that lie in the feldspar grains in all directions. Nor are these muscovite scales confined to the feldspar grains. They sometimes occur also in the quartz grains exactly as abundantly and as evenly distributed as in the feldspar. This was demonstrated by studying the refraction of the grains that contain the muscovite scales in rocks where every grain is crowded with them. It was readily shown that some of these grains have a higher index of refraction and some a lower index than that of the surrounding Canada balsam. The former are quartz and the latter feldspar, presumably orthoclase.

As a further, and still more conclusive, demonstration that these muscovite scales are enclosed in quartz as well as in feldspar, wherever this appears to be the case throughout the mass of the rock, it may be noticed that the larger quartz grains or phenocrysts are surrounded by a border or rim that extinguishes simultaneously with the interior grain. But whereas the interior grain is entirely free from these muscovite inclusions, the border is crowded with them exactly as in small grains of the groundmass. This may be seen to advantage in the case of several dikes: one a long dike that cuts the prominent ridge in the midst of North Mosquito Amphitheater (Specimen 221), two small dikes near the summit of Mount Buckskin (Specimens 223 and 224), one dike southeast of Lake Emma in Buckskin Amphitheater (Specimen 242), and a dike cutting across the top of Mount Lincoln (Specimen 269). On Plate VIII are shown two photomicrographs of a thin section prepared from the white porphyry on Mount Lincoln. They are both taken with crossed nicols. The upper figure shows several of the quartz phenocrysts rounded by corrosion and encircled with a broad rim of secondary quartz that is crowded with brilliantly polarizing muscovite scales. Similar muscovite scales may be seen in the quartz and orthoclase of the surrounding groundmass. The rim measures .17 mm in width. The lower figure shows an enlarged portion of the upper figure, also with crossed nicols. In these cases a definite relationship exists between the width of the border and the size of the grains constituting the groundmass. The larger the grains of the groundmass, the wider is the border around the quartz phenocrysts. In one case the quartz phenocrysts shows a sharp-edged form at the inner edge of the border, while the outer edge of the border is irregular and intergrown with the grains of the groundmass.

From the above-described phenomena it would seem necessary to draw the conclusion that the groundmass consisting of quartz, orthoclase and muscovite is all secondary; that is, that the original groundmass of the rock has been completely recrystallized. It is evident that this is not a mere superficial weathering, but a metamorphic change of far-reaching effect. That the development of minute muscovite scales throughout the mass of this porphyry is due to metamorphism, rather than to weathering processes, may perhaps account for the fresh appearance of most of these white porphyries.

Chemically considered, the analysis of white porphyry given on page 81 indicates a somewhat more acid rock than is the case with the Lincoln porphyry, or as is the case with the other porphyries described later. The evident alteration that has taken place in the rock analyzed makes it difficult to draw a definite conclusion as to its original character. The observations of the writer, however, would indicate the absence of any basic plagioclase, and therefore would take this rock out of the monzonite porphyry class.

Quartz Monzonite Porphyry—

Under this head will be understood to come all rocks of porphyritic type in which there is abundant quartz, either among the phenocrysts or in the groundmass, or both, and in which both orthoclase and a basic plagioclase appear as phenocrysts. Such rocks have a wide distribution in the district as sheets and dikes in the sedimentary rocks, and as dikes in the Archean. They will be described under the heads: (1) Prevailing Types; (2) Lincoln Porphyry Type.

Prevailing Types.—It is difficult to describe the varying types of porphyries with a view to drawing a sharp distinction between them, as they are connected by so many transitional types that a real distinction becomes almost impossible. But, with comparatively few exceptions, these rocks all have a markedly porphyritic habit. That is, they contain well-defined and fairly sizable phenocrysts imbedded in a distinct and fairly fine-grained groundmass. The few exceptions are those cases where the phenocrysts are small and unusually numerous and the groundmass comparatively coarse-grained (Specimens 202, 208, 258, 259, 273). Even in these cases the porphyritic texture was doubtless originally marked, but has become obscured by extensive alteration of the constituents. With the exception of the Lincoln porphyry type, to be described later, the phenocrysts average from an eighth to a quarter of an inch for the feldspars and quartz, and about one-half this size for the biotite. Plagioclase is almost always much more abundant than orthoclase, although both of them are present. Biotite is invariably present in numerous thick plates, that in some cases have retained their original freshness almost intact. Muscovite is never seen as a primary constituent, but is almost universally present as an alteration product of the other constituents. Hornblende is also missing, except in case of the "Sacramento Porphyrite" of the Leadville Monograph, to be mentioned later.

Where these rocks are fresh, they have a fairly dark-gray color, the biotite crystals are black and lustrous, and the feldspar phenocrysts stand out in strong relief against a dark-colored groundmass. The freshest rocks are usually to be found as dikes in the Archean, especially in upper Buckskin and North Mosquito Gulches. This is probably due to the extensive glacial erosion that has characterized these valleys. As decomposition progresses, the rock loses its fresh luster, the biotite crystals become green, owing to the formation of chlorite, the groundmass assumes a much lighter color, and the contrast between phenocrysts and groundmass becomes less marked. In more advanced stages of alteration the rocks become bleached and may closely resemble the white porphyry.

Only under the microscope is the true character of these rocks brought out. As above stated, monzonite porphyries are characterized by the presence of both orthoclase and basic plagioclase. The microscope shows in these cases that, while both of

PLATE IX—A. Photomicrograph of quartz monzonite porphyry from dike in North Mosquito Gulch (Specimen 31). ×52. Crossed nicols. Shows a plate of biotite altered to a parallel growth of muscovite and chlorite. (See p. 77.)

B. Photomicrograph of Lincoln porphyry from a dike on the east slope of Mount Lincoln. ×52. Crossed nicols. Shows a crystal of plagioclase altered to muscovite, the latter occurring in distinct plates that lie in all directions. (See p. 83.)

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B

these feldspars are present, the plagioclase greatly exceeds the orthoclase in quantity. In fact, it is invariably abundantly represented, while orthoclase may be very sparingly present among the phenocrysts in some cases, or may be at times apparently entirely confined to the groundmass. The plagioclase belongs to the labradorite or andesine-labradorite variety. This is disclosed by the extinction angles in sections at right angles to the twinning plane (010). Invariably the extinction angle is large. Many measurements taken range from 20° to 26°. In one case 30° was noted. Both orthoclase and plagioclase show a strong tendency to alter into muscovite. The muscovite may form isolated, sharply defined leaves in an otherwise fresh-looking crystal, or they may form felted aggregates completely filling the crystal and eventually entirely replacing it. Calcite and epidote are also frequently seen as alteration products of the plagioclase. This is particularly true in cases of more advanced decomposition.

The biotite crystals have a brown or greenish-brown color in unaltered rocks. Usually there is more or less of an alteration to parallel-growing chlorite. More advanced alteration causes the biotite to change into chlorite and muscovite. Usually these two minerals occur in parallel growths, with a slender rim of muscovite around the edges and with leaves of the same alternating with leaves of chlorite in the interior. In other cases the biotite breaks up into a felted aggregate of chlorite and muscovite. In still other cases, comparatively rare, secondary biotite occurs replacing the original biotite phenocrysts (Specimen 123). In this case the secondary biotite has a green color, with pleochroism closely resembling that of chlorite, and distinguished from that mineral by the strong double refraction. The minute scales or shreds of secondary biotite are intimately interwoven in a felted aggregate with muscovite and chlorite scales, and similar green-colored chlorite also occurs in the groundmass of the rock, along with some chlorite and muscovite. The above described alteration of biotite into parallel growing muscovite and chlorite is shown on Plate IX, A.

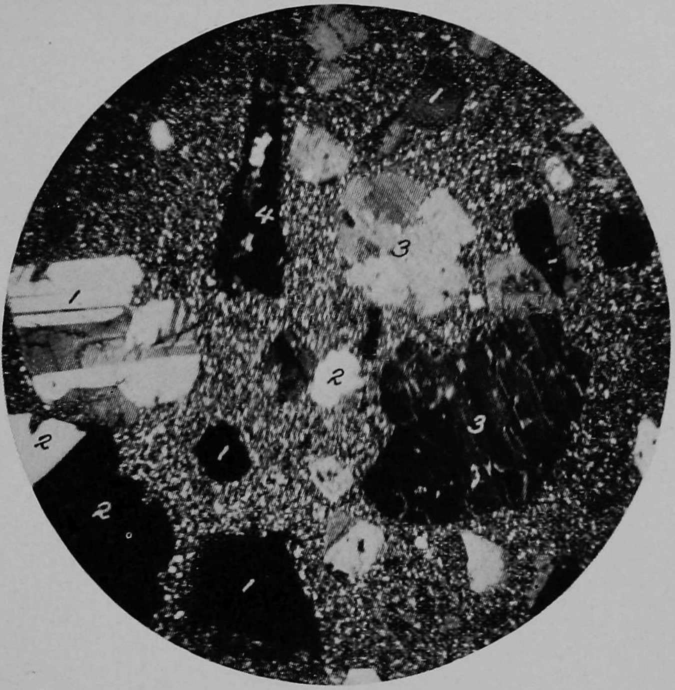
The quartz phenocrysts sometimse occur in sharply defined crystals with the customary pyramidal terminations. In most cases, however, these crystals are more or less corroded, assume rounded forms, and show embayments of the groundmass. (See Plate X, A.) Marginal growths around the edges of the quartz phenocrysts, with minute scales of presumably secondary muscovite, such as were described as occurring in some of the

Plate X — Photomicrographs of quartz monzonite porphyry from the ridge between Buckskin Peak and Loveland Mountain.

A. (Specimen 238). ×15. Crossed nicols. Shows the common condition of the groundmass, and the following phenocrysts: 1, plagioclase; 2, quartz; 3, biotite; 4, chlorite. (See pp. 77 and 79.)

B. (Specimen 237). ×15. Crossed nicols. Shows a groundmass of quartz and orthoclase, differing from that in A only in greater coarseness; also the following phenocrysts: 1, orthoclase; 2, plagioclase; 3, biotite. (See p. 79.)

Colorado State Geological Survey—Bulletin No. 3, Plate X, A



B

white porphyries, are by no means rare. This is well shown in the porphyry sheets at the upper end of Loveland Mountain (Specimens 143, 144, 150).

Among the accessory minerals are apatite, titanite, allanite, zircon, magnetite and pyrite. The last-named mineral is probably in most cases secondary, the others primary, constituents. The comparatively rare mineral allanite does not occur in all specimens examined, but its occurrence is frequent enough to lead to the conclusion that it is probably present in small quantity in nearly, if not quite, all occurrences of these porphyries. Sharp-twinned crystals were observed in a rock (Specimen 251) that occurs in a strong sheet east of the Platte River near the placer ditch reservoir. The rock in question approaches the Lincoln porphyry type.

The groundmass of these quartz monzonite porphyries consists, when fresh, of quartz, orthoclase and plagioclase, in greatly varying proportion and texture. There are two prevailing types, based on the texture: First, a type characterized by the presence of quartz and orthoclase, and presumably also plagioclase, in sharp, angular grains of fairly uniform dimensions. The size of the grains varies between an average of .03 mm in some rocks (Specimen 26) to .08 mm in others (Specimen 235). In extreme cases the grain may sink to .01 mm or a little less (Specimen 236), or rise to a maximum of .2 mm (Specimen 237). For an example of great variation in size of grain in dikes close together, see Plate X, A and B.

The second type of groundmass is one characterized by very ragged-edged grains of quartz and of othoclase that usually enclose microlites of plagioclase and that invariably contain muscovite scales. The presence of these muscovite scales in the quartz as well as in the orthoclase has already been referred to in the description of the white porphyry. Where this is the case, it usually happens that the quartz phenocrysts are enveloped by a margin of secondary quartz, likewise enclosing muscovite scales. (For plagioclase microlites in quartz see Specimens 29 and 229.) The writer ventures the opinion that this particular texture is not original, but is the result of a thoroughgoing recrystallization of the rock through secondary causes. Whether the plagioclase microlites are also of secondary growth there may be some doubt, but it would seem almost necessary to assume this, because of the fact that they occur intimately associated with muscovite scales enclosed in the quartz grains.

The two types based on texture of the groundmass, while the most common types, are not the only ones observed. In one case the groundmass consists of comparatively large cellular quartz grains, 0.5 mm to 1 mm in diameter, interlocking with each other and filled with feldspar microlites of uncertain character (Specimen 208).

Mention has already been made of secondary biotite replacing biotite phenocrysts. The occurrence of secondary biotite along with muscovite in the form of minute green-colored scales and shreds was noted in a number of cases (Specimens 25, 26, 123, 219) as forming part of the groundmass. This alteration does not usually extend to the biotite phenocrysts. The minute scales are scattered through the groundmass, or bunched in irregular or longish clusters in such a way as to suggest that they have replaced hornblende crystals (Specimen 26).

A typical example of quartz monzonite porphyry is seen on Plate XII, A.

Chemical Analyses.—The analyses given below, under Columns II and III, represent two of the types distinguished by Cross. No. II is a gray porphyry, and represents probably the commonest of the types referred to in the above description. No. III represents a Lincoln porphyry, the description of which follows. As the difference in the analyses of these two is very slight, both may be referred to in this place. The two most noted features are the comparatively high percentages of CaO and of Na_2O in orthoclase-bearing rocks. These are characteristics very suggestive of monzonites and of monzonite porphyries. As these rocks are comparatively fresh and show no very high percentages of CO_2, the CaO may be attributed mostly to the plagioclase. The relatively large percentage of SiO_2 explains the development of quartz as a phenocryst as well as in the groundmass.

The chemical analyses given below were carried out by chemists of the United States Geological Survey, and are taken from the Leadville monograph, as are also the following descriptions of these analyses:

> Analysis I was made upon a typical specimen of White Porphyry from the quarry in California Gulch at the southwest base of Iron Hill. The specimen is no longer fresh, but it is not in an advanced stage of decomposition. It was taken as a representative of the main sheet near Leadville.
>
> Analysis II is of Gray Porphyry, Onota shaft, Johnson Gulch, near Leadville; fresh-appearing, but somewhat altered.

Analysis III is of Lincoln Porphyry, summit of Mount Lincoln. It is quite fresh in appearance, although showing some muscovite, calcite and chlorite, when examined microscopically.

Analysis IV is that of a porphyrite of the typical hornblendic variety, occurring in thin intrusive sheets on the sides of Buckskin and Mosquito Gulches. The specimen analyzed came from the Northern Light claim, in lower Buckskin Gulch. The rock as a whole is quite fresh, although the few biotite leaves and occasionally a hornblende crystal are more or less decomposed, chlorite and calcite being the chief products. The plagioclase is still quite fresh, but some filmy calcite is scattered through the groundmass. Apatite is rare in this rock.

All of these analyses were made by W. F. Hillebrand.

	I	II	III	IV
SiO_2	70.74	68.10	66.45	56.62
TiO_2	....	0.07	0.10	....
Al_2O_3	14.68	14.97	15.84	16.74
Fe_2O_2	0.69	2.78	2.59	4.94
FeO	.58	1.10	1.43	3.27
MnO	0.06	0.09	0.09	0.15
CaO	4.12	3.04	2.90	7.39
BaO	0.03	....	....	....
SrO	trace	0.08	0.07	trace
MgO	0.28	1.10	1.21	4.08
K_2O	2.59	2.93	2.89	1.97
Na_2O	2.29	3.46	3.92	3.50
Li_2O	....	....	trace	....
H_2O	2.09	1.28	0.84	0.92
CO_2	2.14	0.92	1.35	1.15
Cl	trace	0.03	0.05	....
P_2O_5	....	0.16	0.36	trace
Total	100.29	100.11	100.09	100.73
Specific gravity	2.680	2.636	2.670	2.768

Lincoln Porphyry.—This rock is the most striking and, when typically developed, the most easily recognized of the porphyries of the Alma district. Its peculiarity consists mainly in the presenec of large, sharply developed, pinkish orthoclase crystals that occur as phenocrysts, embedded in a fairly compact groundmass. The name was given by the Emmons survey because of the fact that this rock forms the summit of Mount Lincoln—the highest and most conspicuous mountain peak in this part of the Mosquito Range. The Lincoln porphyry is by no means confined to the summit of Mount Lincoln. On the contrary, the Mount Lincoln mass is quite insignificant in comparison with other occurrences. This rock also forms the summit of Mount Bross and is widely distributed on the southeastern slope of this mountain. Again, it is found extensively developed in Mosquito Gulch on the north slope of Bald Hill above the Hock Hocking mine. Two other considerable masses are to be found in the Archean at the upper end of Buckskin Gulch. With the exception of these last-named areas in the Archean, all the other large masses of the Lincoln porphyry occur either in the Weber beds, not far from the contact with the Carboniferous blue limestone, or at the contact of these two formations. There are also smaller sheets and dikes either in the Weber formation or in the Archean; and two additional dikes are to be seen cutting up through the Cambrian and Ordovician into the blue limestone. One of these dikes is on the eastern ridge of Mount Lincoln, and the other in Dolly Varden Gulch on the southeastern slope of Mount Bross. These last-mentioned dikes apparently served as feeders for the large masses lying in the Weber formation.

The Lincoln porphyry is inclined to be very irregular in its manner of occurrence, in that it varies greatly from place to place in thickness and does not readily confine itself to intercalated sheets. The larger masses must be several hundred feet thick, but thin out rapidly and readily pass from one geological horizon to another.

The Lincoln porphyry is a good illustration of a quartz monzonite porphyry, in that, in addition to abundant quartz both among the phenocrysts and in the groundmass, it contains considerable quantities of both orthoclase and a distinctly basic plagioclase. Cross gives the following excellent description of this rock as it appears macroscopically:

> The essential constituents are quartz, orthoclase, plagioclase and biotite, all occurring in distinct crystals and imbedded in a compact groundmass of varying importance. A part of the orthoclase appears in large, stout crystals, frequently two inches in length, usually pinkish in color, and so fresh and glassy as to resemble markedly the sanidine of younger rocks. They are often Carlsbad twins and contain noticeable inclusions of biotite leaves. For most occurrences of the porphyry these large orthoclase crystals are eminently characteristic, though their development has been hindered in some cases, particularly in dikes and small masses. In some of these instances small crystals of pinkish color are plainly more numerous than in the type rock, but in others they cannot be well distinguished from the triclinic feldspar. Plagioclase is always very abundant in white individuals, seemingly less fresh than the orthoclase, although a striation can often be seen on the basal cleavage surfaces. Biotite occurs in small hexagonal leaves, which are sparingly but uniformly scattered through the whole. They are seldom fresh, and usually appear to be changed to a green chloritic mineral. The quartz appears as a prominent macroscopic constit-

uent, showing, as a rule, a development of pyramidal planes, to which the prism is occasionally added. The groundmass is dense and homogeneous in appearance, usually grayish in color in fresh rocks, and very distinct. Only occasionally does it become subordinate. Ore particles are plainly distinguishable in it.

The size and prominence of the quartz phenocrysts to which Cross refers are sometimes remarkable. For instance, on the eastern slope of Mount Lincoln, not far below the summit, occurs a dike of this porphyry from which quartz phenocrysts have weathered out. These quartz crystals measure from half an inch to a full inch in length, and show frequently, in addition to the double pyramidal terminations, prism faces about two millimeters wide.

Under the microscope the plagioclase is seen to be much more abundant than the orthoclase, the latter mineral being largely restricted to the large, conspicuous crystals that are not likely to be cut in any one thin section. These plagioclases show often the Carlsbad in addition to the customary albitic twinning. Extinction angles in sections at right angles to (010) measure as high as 25° and indicate an andesine-labradorite plagioclase. In corroboration of the extinction angles is the observation of the index of refraction, which is invariably noticeably higher than that of the balsam and also higher than that of quartz. This would call for a plagioclase more basic than oligoclase.

The quartz crystals are usually not sharply crystallized, but are rounded by corrosion and show embayments filled with groundmass. The biotite is brown or greenish brown in color and shows alteration to chlorite. In some cases muscovite also appears as an alteration product of biotite. The accessory minerals are apatite, zircon, allanite, titanite and magnetite, the last-named often quite abundant.

The groundmass stands out under the microscope in strong contrast to the phenocrysts. It consists of small irregular grains of orthoclase and quartz. Usually the grains are too small to enable one to definitely distinguish between the two, the average size of the individual grain being .02 mm or less. Where the groundmass is a little coarser, there is no difficulty in distinguishing the orthoclase by its lower refraction, its cleavage and clouded aspect.

The feldspars of both the groundmass and the phenocrysts show a strong tendency to alter to muscovite. The large crystals often contain the muscovite in sharp scales either more or less

PLATE XI—Photomicrographs of Lincoln porphyry.

A. (Specimen 245). From a dike in the Archean, northwest of Emma Lake, head of Buckskin Gulch. ×15. Crossed nicols. Shows the normal development of the groundmass and phenocrysts. Phenocrysts present are: 1, plagioclase; 2, quartz; 3, biotite. (See p. 85.)

B. (Specimen 156). From the large mass on the east side of Buckskin Gulch, in the Archean. ×15. Crossed nicols. In the hand specimen this rock appears to be plutonic. The thin section, as shown in the plate, shows a distinct but coarse groundmass of quartz and orthoclase. The phenocrysts shown are: 1, plagioclase; 2, orthoclase; 3, quartz. (See p. 85.)

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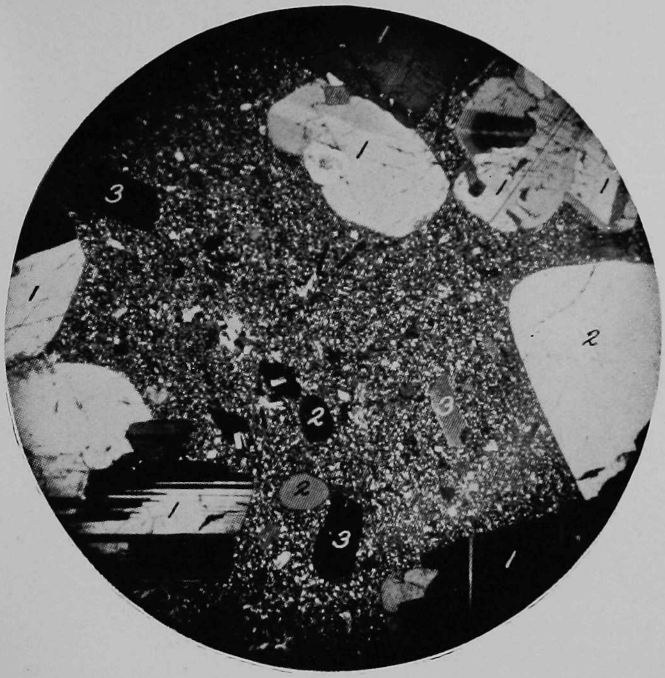

B

isolated or in loosely felted aggregates. The groundmass is apt to be thickly crowded with minute scales or radiating clusters of such scales. Another common alteration product of the groundmass is chlorite in light-greenish scales that give a pale-greenish color to the whole mass. In a few cases secondary biotite of a greenish color similar to that of the chlorite, and in the form of minute scales, was observed in the groundmass.

The two largest masses of this porphyry that occur in the Arhcean at the upper end of Buckskin Gulch are quite different in appearance from all other masses of this rock, in that, in the field and in the hand specimen, the rock appears to have a plutonic texture. In fact, when this occurrence was first observed, the rock was mapped as granite, although it was noted that locally it was very difficult to decide as to whether the rock should be termed a porphyry or a granite. But, in spite of the striking granitic appearance of the hand specimen, a thin section of this rock discloses a most marked porphyritic texture with a groundmass of irregular quartz and orthoclase grains, somewhat coarser than is usual in the Lincoln porphyry, and occupying not more than one-third to one-fourth of the mass of the rock. The texture is strikingly suggestive of the so-called "mortar structure" seen in many crushed quartz rocks.

The freshest examples of the Lincoln porphyry were this granitic type from Buckskin Gulch (Specimen 156), the dike cutting the Cambrian in the bottom of Dolly Varden Gulch (Specimen 161), and a dike on the ridge running southwesterly from Mount Democrat (Specimen 245).

Plate XI shows two photomicrographs of the Lincoln porphyry. The upper figure presents the normal type, with abundant, holocrystalline, but fine-grained groundmass. The lower figure is taken from the granite-like mass at the head of Buckskin Gulch and discloses a very scant groundmass, composed of relatively coarse grains of quartz and orthoclase. Both photomicrographs taken with crossed nicols. Plate XII, B, shows a specimen of this porphyry from Dolly Varden Gulch.

DIORITE PORPHYRITE—

General Description.—The porphyrites of this district are usually very easily recognized. They are much darker in color than are the porphyries, and have as a rule a fresher appearance. They are usually porphyritic in habit, with conspicuous dark-green or black, prismatic hornblende and stout, but not very

Plate XII—A. Quartz monzonite porphyry. A typical, fresh type from a dike in the Archean in North Mosquito Gulch. (See p. 75.)

B. Lincoln porphyry from Dolly Varden Gulch. Shows a large phenocryst of orthoclase and many small phenocryst of plagioclase. (See pp. 81 and 85.)

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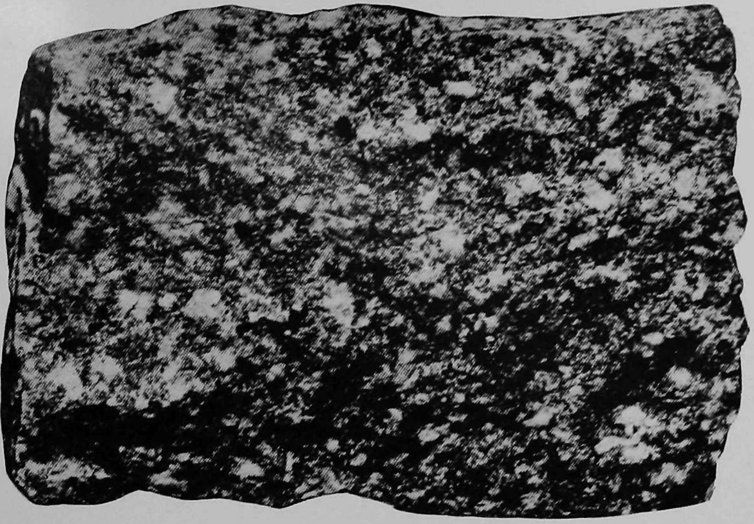

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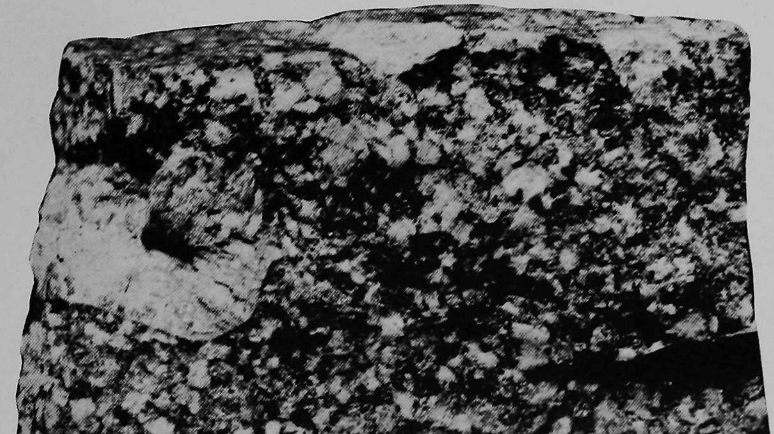


large, plagioclase crystals as phenocrysts. Occasionally they are fine-grained rocks of very dark color and with little trace of porphyritic texture visible in the hand specimen.

There is one very extensive intrusive sheet of porphyrite that lies in the Cambrian quartzite, and is to be seen on the south side of Buckskin Gulch, and in the bottom and on both sides of Mosquito Gulch, outcropping on the steep sides of Pennsylvania and Loveland Mountains. This is the only occurrence of this rock in sheet form. It is occasionally met with in dikes of no great width, cutting the Archean of Buckskin Gulch and of the ridge that separates this gulch from North Mosquito Gulch, also of the upper Platte valley. It may also be seen in small dikes on Mount Lincoln.

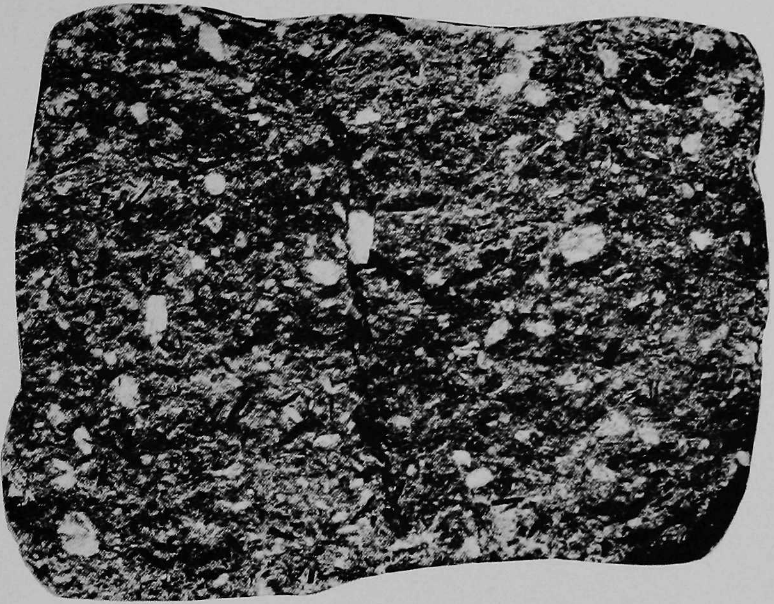
Within the territory studied there occur, in the extreme southwestern portion on the west slope of Pennsylvania Mountain and on the east slope of the main range, several sheets of rock that Cross designated as "Sacramento porphyrite," and that contain hornblende and considerable plagioclase. As far as the specimens studied by the writer are concerned, these Sacramento porphyrites are much more closely allied with the monzonite porphyries, as above described, than they are with the porphyrites of the district. They have accordingly been mapped as such, and are not here considered in the description of the diorite porphyrites.

These diorite porphyrites are all holocrystalline rocks with sharply defined phenocrysts of plagioclase and of either hornblende or biotite, or both. Quartz rarely appears among the phenocrysts and, with one exception that will be specially described later, is not a very abundant ingredient in the groundmass. Pryoxene appears to be entirely wanting. The different occurrences of this rock show various transitional stages of texture and composition, so that it is difficult to make sharp distinctions between the types represented. There are, however, four varieties of these porphyrites that seem worthy of being designated as separate types.

Type I: Hornblende diorite porphyrite.—This is the prevailing type of the district and covers perhaps three-quarters or more of all the occurrences noted. It forms the intercalated sheet in the Cambrian quartzite of Pennsylvania and Loveland Mountains, and most of the dikes in Buckskin Gulch and adjacent territory, and dikes on the east slope of Mount Lincoln.

PLATE XIII—A. Diorite porphyrite from a dike cutting the diorite on the ridge running from Buckskin Peak to Loveland Mountain. Shows white plagioclase and black hornblende phenocrysts. (See pp. 89 and 209.)

B. Banded gneiss from a float specimen in South Mosquito Gulch. (See pp. 37 and 95.)



B

In the hand specimen the porphyritic texture is quite pronounced, with black, glossy hornblende prisms 2 to 6 mm, or even to 8 mm, long, and stout, whitish plagioclases of about the same dimensions.

Under the microscope both hornblende and plagioclase stand out in strong relief, with sharply developed faces. The hornblende is of the customary dark-green color when fresh, and shows the following crystal forms (110) (010) (001) ($\bar{1}$11). The plagioclase is probably a little more basic than in the monzonite porphyries of the district. Extinction angles in sections at right angles to the twinning plane measure up to 30°, and indicate the presence of labradorite. Biotite phenocrysts are usually absent, or at most very sparingly present, and then indicate transition to Type IV.

The groundmass consists of very sharp and slender, rod-like prisms of hornblende of the same color as the phenocrysts of this mineral, embedded in a granular mass of orthoclase and plagioclase. The exact nature of the plagioclase of the groundmass is not easy to determine. Judging from the not very large extinction angles, and from the refraction which is sometimes above and sometimes below that of the Canada balsam, the plagioclase is oligoclase-andesine. The accessory minerals are apatite, magnetite, titanite, and occasionally zircon and allanite.

On Plate XIII, A, is a photograph of this type of porphyrite, and on Plate XIV, A, is seen a photomicrograph of a rock of this type, in which may be seen a large hornblende phenocryst, also minute rods of the same in the groundmass.

Under Column IV in the table of chemical analyses is given a chemical analysis of a diorite porphyrite of this type taken from the Leadville monograph. From this it may be seen that the rock is decidedly more basic than is the case with the porphyries, magnesium and iron are noticeably higher, and sodium shows a considerably higher percentage than potassium.

Type II: Biotite diorite porphyrite.—This type is represented by only one occurrence; namely, in Buckskin Gulch (Specimen 24). This rock in the field hardly shows a trace of porphyritic texture. It is moderately fine-grained, dark gray in color, and might be mistaken for a fine-grained plutonic rock.

Under the microscope the porphyritic texture is plainly brought out. The phenocrysts are small, and consist of plagioclase and green biotite. A somewhat similar rock in North Mosquito Gulch (Specimen 117) also contains considerable horn-

Plate XIV—Photomicrographs of diorite porphyrites from the ridge between Buckskin Peak and Loveland Mountain.

A. (Specimen 234). ×52. White light. A typical example of this rock. Shows: 1, hornblende; 2, biotite; 3, magnetite. The dark-colored crystals in the groundmass are hornblende. (See pp. 89 and 209.)

B. From a dike cutting monzonite diorite (Specimen 233). ×52. Crossed nicols. Shows: 1, plagioclase; 2, quartz; 3, chlorite; 4, magnetite. The white mineral partly surrounding the large plagioclase crystal is a single grain of porous quartz that shows simultaneous extinction. (See p. 91.)

Colorado State Geological Survey—Bulletin No. 3, Plate XIV, A

B

blende and lies intermediate between this and Type IV. The groundmass is made of sharply developed plagioclase microlites, green biotite scales, and an unstriped feldspar. The plagioclase microlites seem to be somewhat more basic than the groundmass plagioclase of the first type. Extinction angles and refractive power indicate an andesine plagioclase. Chlorite, epidote and calcite are abundantly developed as alteration products.

Type III: Quartz diorite porphyrite.—This is a plainly porphyritic rock of much lighter color than is the case with all the other porphyrites. It closely resembles some of the quartz monzonite porphyries. It contains phenocrysts of stout plagioclase, black, hexagonal biotite in crystals that measure 2 or 3 mm, and much smaller green hornblende. The groundmass consists of quartz, oligoclase-andesine plagioclase, orthoclase and a little green biotite. The quartz is abundant and occurs in large cellular patches that envelop all the other groundmass ingredients. This character of the quartz of this rock is brought out in Plate XIV, B.

Only one example of this type of porphyrite was found. This was a dike on the ridge that connects Mount Democrat with Loveland Mountain, and that cuts the large diorite mass near the upper limit. This close association with the diorite which, at this place, is probably a monzonite-diorite, is interesting and suggestive, inasmuch as the porphyrite very closely resembles the monzonite diorite in composition. It furnishes a link that indicates a genetic connection between the diorite and monzonite-diorite and the porphyritic rocks of the district. (See Specimen 233.)

Type IV: Hornblende-biotite diorite porphyrite.—This type, perhaps, is less deserving of recognition than the others, in that it is less sharply separated from the other types. It is best represented by a dike on the northern slope of Mount Lincoln (Specimen 286). This rock shows green hornblende, green biotite and plagioclase as phenocrysts, and green biotite, plagioclase microlites and orthoclase in the groundmass.

RELATIVE AGE OF THE IGNEOUS ROCKS—

As already stated, there is no definite proof that any of the igneous rocks that occur extensively developed in the Archean areas are younger than the sedimentary rocks. As to the granites, there is no doubt that this is true, but it is more than possible that the diorites are younger than the sedimentary series, inasmuch as they are so closely related in composition to certain of the diorite porphyrites that are known to cut the Cambrian quartzites and other still younger formations. As to the porphyritic rocks that occur as narrow dikes in the Archean, they have been traced directly from the Archean into the overlying bedded rocks in numerous instances. This is true of the quartz monzonite porphyries, the white porphyry and the diorite porphyrite. These rocks, therefore, may safely be attributed to a period later than the Paleozoic.

The white porphyry has been observed in several cases cutting both the porphyrite and the other porphyries, but on the west slope of London Mountain along the London fault it appears to be cut by the gray porphyry. On the north slope of Pennsylvania Mountain the diorite porphyrite cuts the sheets of quartz monzonite porphyry. In other cases the position of these two rocks is reversed. It would seem, therefore, that these different porphyry types are all products of the same eruptive activity that extended over a period of considerable length.

METAMORPHISM IN CONNECTION WITH IGNEOUS INTRUSIONS

In connection with the intrusion of the smaller dikes and sheets of porphyry and porphyrite, it could hardly be expected that any noticeable effect would be produced on the adjacent country rock. Even in the case of the larger intrusions, as these are probably all irregular sheets or sills, the effect upon the sedimentary series would not be likely to be very extensive. In fact, little, if any, difference was noted on approaching the larger igneous masses in the character of the sedimentary rocks. Undoubtedly most of the rocks have undergone considerable metamorphism at some stage of their history. As an instance of this change may be cited the development of quartzites in the Weber grits, and the almost universal change of the limestones into dolomites. These changes, however, are undoubtedly the result of regional metamorphism and were accomplished before the intrusion of the eruptives.

As already stated, the Carboniferous limestone on Mounts Lincoln and Bross are inclined to be unusually coarse-grained. It is possible that the intrusion of the heavy masses of Lincoln porphyry into the Carboniferous limestone may be responsible for this change in the customary character of this rock. It is also possible that the large vein-like quartz replacements, so common in the Carboniferous limestone, may have been produced in connection with the intrusions of the porphyries. If so, this could not be considered as contact metamorphism in the ordinary sense. It would have been brought about by means of aqueous solutions escaping from the igneous magma, and might be effective long distances from the actual contact.

Ransome* reports a similar condition as prevailing in the adjacent Breckenridge district to the north. In this region occur very similar porphyry intrusions in sedimentary rocks; many of them are of the nature of irregular sheets or sills of considerable thickness, and appear to have produced no general metamorphism.

Emmons mentions the occurrence of serpentine and marbelized limestone in Red Amphiteater on the west side of Mount Bross, and attributes their presence to the effect of contact metamorphism. In view, however, of the lack of contact metamorphism elsewhere, this explanation may well be questioned.

The larger intrusive masses, such as granite and diorite, do not come into contact with the sedimentary rocks, and do not, therefore, show any metamorphic effect.

Evidences of the effect of the sedimentary and other rocks on the igneous intrusions are very common, and take the form of change of texture from coarse to fine as the contact is approached. Occurrences of this sort are so very common that instances are hardly called for.

THE AGE OF MOUNTAIN-MAKING AND OF IGNEOUS INTRUSION

During the Paleozoic and early part of the Mesozoic eras the regions now occupied by the Mosquito Range are presumed to have been covered by the waters of the ocean and to have received sediments from the adjacent land on the west. This western land was situated west of the site of Leadville, where now the Sawatch Range is located. During the diastrophic movements that closed the Cretaceous period these sediments were at first gently folded, and then more distinctly crumpled and faulted, and raised to great distances above the sea-level. It was probably during the earlier stages of folding that the great intrusions of igneous rocks took place. That the intrusion could not have taken place after the folding and faulting is shown by the fact that the porphyry sheets have participated in the folding, and have been cut and disrupted by the faults.

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* Frederick L. Ransome, Geology and Ore Deposits of the Breckenridge District, Colo., U. S. Geol. Surv., Prof. Paper 75, p. 75, 1911.

Inasmuch as the ore deposits are, as a rule, subjected to the same faulting, they may be presumed to have been formed originally before the faulting took place, but after the sheets of igneous rocks had been intruded into the sedimentaries. As will be seen in reading Chapters VIII and IX on the ore deposits of the district, there is reason to believe that some of the ore bodies may have been deposited later than the faulting of the rocks.

CHAPTER IV

GEOLOGIC DESCRIPTION OF INDIVIDUAL AREAS

BY HORACE B. PATTON

SOUTH MOSQUITO GULCH

GENERAL DESCRIPTION—

A little over two miles above Park City the deep-cut Mosquito Gulch at the east base of London Mountain divides into two main branches, called, respectively, the South Mosquito Gulch and the North Mosquito Gulch. The sides of these two gulches are very steep and rise to an elevation of about 2,000 feet above the stream-bed. The lower slopes are largely covered by rock debris from the cliff above, or by glacial material brought down the valleys. The gulches end above in fine glacial cirques that once were the places of accumulation of snow and ice that fed the great Mosquito glacier. The great London fault, that will receive individual treatment later, cuts across South Mosquito Gulch about a mile above the junction of the two branches of Mosquito Creek, crosses over the summit of London Mountain, and continues in a northwesterly direction to the crest of the Mosquito Range. To the east of this fault the Mosquito Creek has eaten deeply into the crystalline rocks of the Archean. To the west of the same the Weber grits have been faulted down to the creek-level.

ARCHEAN—

This formation covers the entire eastern half of London Mountain and all of Pennsylvania Mountain, but a comparatively thin covering of stratified rocks on the sloping upper surface. In spite of the resisting powers of the Archean rocks, they do not resist erosion as much as do the bedded quartzites that form the upper part of Pennsylvania Mountain, since the latter stand up much more precipitous than the Archean rocks. The Archean rocks in this section are almost entirely gneisses and schists, sometimes beautifully banded. (See Plate XIII, B.) These schistose rocks are, however, cut by a very large number of pegmatite dikes that, because of their very light color, stand out in strong relief against the very dark-colored schists and gneisses. A most conspicuous illustration of this is seen in the very precipitous northern slope of Pennsylvania Mountain. This is fairly well brought out in Plate VI, A. One very conspicuous mass of pegmatite of exceptionally white color occurs on the lower slope of Pennsylvania Mountain, not far above the forks of the creek. This white mass can be seen for miles down the valley and forms a conspicuous feature in the landscape. In addition to pegmatite dikes, there are quite a number of coarse-grained granites occurring in narrow dikes and in larger, more irregular masses. These granites all have tabular orthoclase crystals that show Carlsbad twinning and that have a marked parallel arrangement, the flat faces of the crystals arranging themselves parallel to the sides of the dike. There may also be seen a narrow dike of white porphyry a little to the east of the large white pegmatite mass spoken of above.

Weber Grits and Porphyries—

The Weber grits of the Alma district seem to be very favorable to the intrusion of porphyry sheets. Nowhere is this as pronounced as in the upper part of South Mosquito Gulch. These grits form the main country rock between the London fault and the crest of the Mosquito Range. They have a strong, but somewhat fluctuating, easterly dip until they approach the London fault, when they usually develop a synclinal fold by bending upward toward the fault. This upward-bending on approaching the fault is sometimes fairly abrupt and sometimes quite gradual, and is particularly pronounced in the bottom of the valley. High up on Pennsylvania and London Mountains, as described later, these beds bend suddenly downward on approaching the fault.

Owing to the heavy covering of wash and of glacial drift over much of the upper basin of the South Mosquito Gulch, it is not possible to locate the numerous porphyry sheets with exactness, and no attempt has been made to trace these sheets beneath the surface where they do not actually show on the surface. The several short, isolated patches of this rock in nearly every case are merely parts of an extensive sheet. These rocks have been mapped as quartz monzonite porphyry. It is quite likely that a distinction might be made between some of these rocks, if more time were available. But this would require the collection of a large number of rock samples from all parts of the field, the preparation and study of thin sections prepared from these samples, and a still further study of the rocks in the field. The large mass in the extreme southwestern corner of the map is the heaviest intruded mass in the district studied. It continues to the south to the head of Sacramento Gulch, and there, according to Emmons, reaches a thickness of 1,200 feet. This rock has been described by Cross in the Leadville monograph as a hornblende porphyrite under the name "Sacramento porphyrite." It bears, however, a very close external resemblance to the quartz monzonite porphyries found in the more northerly parts of this district, so that it is impracticable to make a distinction in the field. It is not known, therefore, just how far to the north this great intrusive mass extends. Apparently it could be traced continuously clear to the London saddle, and beyond this to the crest of the range, but it cannot positively be asserted that there is not a break somewhere. It is quite possible, and even likely, that different portions of an extensive igneous mass of this description should have suffered different development in different parts of the mass, and that it may contain hornblende in the larger southernmost part, and be free from this mineral in the more distant parts.

The formations that occur along the London fault are described at length later in this chapter, under a special head.

GEOLOGIC SECTION—

An interesting geologic section through the formations that underlie the flat basin west of London Mountain has been disclosed as the result of a diamond drill hole that has been sunk by Mr. C. T. Carnahan and Mr. W. C. Mosher on the Salvator claim of the so-called Carnahan group of claims. This drill hole is 900 feet deep and is situated near the center of the Salvator claim at a point 3,920 feet from the portal of the South London tunnel in a direction that bears S. 75° 51′ W. therefrom. The diamond drill cores from this hole have been preserved but, owing to the protracted and very serious illness of Mr. Carnahan, it has been impossible for the writer to gain access to them. Fortunately through the kindness of Mr. Chas. J. Moore of Denver, to whom Mr. Carnahan had before his illness granted permission to study the drill cores and to take notes on the same, it is possible to present a complete record of the formations penetrated.

Owing to the fact that the formations are dipping to the eastward at an angle of possibly some 15° the thickness of the beds given in the table below is somewhat greater than it would be if cut perpendicular to the bedding. It is possible that the writer would have preferred to change some of the rock names given had he been given an opportunity to examine the cores, more particularly in case of some of the dozen or more porphyry sheets cut by the drill hole. Owing to the fact that the gray porphyry is often very difficult to distinguish from the white porphyry when the rock has been altered, as is evidently the case here, it may safely be presumed that there are not as many white porphyry sheets as are given in the table. It is a little uncertain where the division lines should be drawn between the Cambrian, Ordovician and Carboniferous. The divisions made in the table are only provisional.

VERTICAL SECTION AS DISCLOSED BY DIAMOND DRILL HOLE ON THE SALVATOR CLAIM IN THE CARNAHAN GROUP, SOUTH MOSQUITO BASIN

		Thickness of formations, in feet	Total depth, in feet
Weber Grits	Weber Grits	49	49
	Mottled white porphyry	6	55
	Black shale	2	57
	White porphyry	4	61
	Gray grits above and white porphyry below	30	91
	Siliceous gray grits	11	102
	Mottled porphyry	4	106
	Decomposed white porphyry	19	125
	Weber shale	6	131
	Gray porphyry	7	138
	Shale	3	141
	Mottled white porphyry	18	159
	Shale	9	168
	Siliceous gray porphyry	2	170
	Gray porphyry transitional to white porphyry	7	177
	Siliceous white porphyry	6	183
	White porphyry	2	185
	Decomposed white porphyry	12	197
	White porphyry	83	280
	Black shale	10	290
Leadville Limestone	Pyritiferous ore	10	300
	Pyritiferous blue limestone	18	318
	Blue limestone	169	487
	Coarse quartz porphyry	10	497
	Blue limestone	8	505

		Thickness of formations, in feet	Total depth, in feet
Ordovician	Blue limestone and chert passing into quartzite, presumably "parting quartzite"	25	530
	Gray porphyry	30	560
	Siliceous limestone	15	575
	Pyritiferous porphyry	15	590
	Limy shale	10	600
	Green porphyry	50	650
	Pyritiferous porphyry and shale	13	663
	Lithographic limestone	30	693
	Pyritiferous shale and porphyry	7	700
Cambrian	Quartzite	23	723
	Sandy rock	10	733
sheep mtn	Indurated shale	17	750
Cambrian	"Red beds" (probably an indurated limy shale)	29	779
upper			
watch mid	Close grained dolomite	29	808
lower Qtz	Quartzite to bottom of hole (Cambrian)	92	900

GLACIAL FEATURES—

Glacial phenomena are very beautifully illustrated in all the higher portions of the Alma district. In the upper parts of the South Mosquito Gulch the former glaciers are manifested by several glacial lakelets seen to the south and west of London Mountain, in the scattered glacial boulders, and in the scratching of the underlying rock surface. This last feature is well marked on the slope of the Mosquito Range on the extreme southern edge of the mapped area. In this case the glacial striations are running in a northeast direction and indicate that a part of the ice accumulation at the head of Sacramento Gulch flowed over the saddle west of Pennsylvania Mountain and joined the glacier occupying Mosquito Gulch. The depth to which the South Mosquito glacier cut down the level of the gulch is seen in two marked benches—one on the Pennsylvania and the other on the London side of the gulch. On the Pennsylvania side the bench is seen where the white porphyry dike runs up the mountain slope. These benches probably represent the approximate level of the valley bottom before the glacial epoch began. The glacier moving strongest and swiftest in the center of the valley has cut down through the Archean rocks to a depth of some five or six hundred feet. Farther down the valley heavy deposits of glacial drift so completely cover the underlying rocks that they have been mapped independently of the rocks in place below.

OTHER QUARTERNARY DEPOSITS—

In the upper Mosquito region the rapid descent of the valley has prevented the accumulation of alluvial deposits to any marked etxent. There are, however, several examples of landslides shown in this district. The largest is at the foot of Pennsylvania Mountain, below the highest part of the mountain. A very large mass of rock has broken loose from the higher part of the mountain, beginning at the very top and extending two-thirds of the way down the slope. The material from this higher part has precipitated itself in a great avalanche upon the valley below, and now is to be seen as a great, jumbled mass of huge, broken rocks. This is to be seen at the Butte mine and extending from here down the valley for over 2,000 feet. The breaking loose of this landslide material is responsible for the splendid exposure of rugged, forbidding rocks, gashed with pegmatite and granite dikes, that marks the slope of Pennsylvania Mountain at this point. Two other conspicuous landslides are to be seen—one higher up on Pennsylvania Mountain just above the Pennsylvania tunnel, the other on the south slope of London Mountain above the portal to the South London mine.

NORTH MOSQUITO GULCH

ARCHEAN—

Except for a very small corner west of the London fault beyond London Mountain, the entire area of North Mosquito Gulch is covered with Archean rocks. In the lower part of the gulch these are not materially different from those in the South Mosquito Gulch. Here, too, we find numerous dikes of pegmatite and of granite, with parallel tabular orthoclase crystals. These dikes are particularly well marked on the steep slope of Loveland Mountain, three-quarters of a mile above the fork of the creek. The flat, easterly-sloping top of Loveland Mountain is, like that of Pennsylvania Mountain, characterized by Cambrian quartzites, with conformable sheets of porphyry and porphyrite. These formations will be more particularly described later under separate headings.

The upper part of the north branch is characterized, first, by a large granite mass; second, by numerous and somewhat variable porphyry dikes. The granite occupies a circular area about two miles across. The granite is fine-grained, in general quite uniform in texture, and contains both white and black mica. As described in Chapter III, this granite interlaces with the schists around the edges in such fashion that it is difficult to map the boundary. It also appears to hold large fragments of the surrounding schist. The area of sedimentary rocks west of London fault is described later in connection with the London fault.

Igneous Rocks—

The various igneous dikes that dot the amphitheater at the head of the north branch of the valley have received more or less extended description in Chapter III. There are two marked varieties—the so-called white porphyry and the quartz monzonite porphyries. Both of these rocks are found here typically developed. The quartz monzonite porphyries occur in numerous instances in extremely fresh exposures, due doubtless to the erosive effect of the glaciers that have scraped off the weathered portions and left the fresh rock exposed to view. These rocks give fairly typical examples of this class of porphyritic rock. There are also several dikes that have a much darker color than usual and appear to represent types somewhat transitional to the porphyrites of the district. There is at least one well-defined porphyrite. The relative ages of the igneous rocks within the area mapped are difficult to determine, because of the lack of exposures showing these rocks in actual contact. Within the basin here under consideration is one marked case of a white porphyry dike that cuts two dikes of quartz monzonite porphyry. This was not actually seen by the writer, but was reported by one of the student assistants and may be taken as correct. In this case the white porphyry is the younger rock. But it should not be assumed that this is necessarily always the case. In fact, this does not appear to be true in the upper Platte valley.

Glacial Features—

The glacial features do not differ essentially from those of the South Mosquito Gulch. No less than eight glacial tarns dot the surface and attest the presence of former glaciers. The glacial drift is usually not so thick as to prevent the recognition of the underlying rocks, and has not, therefore, been mapped except along the valley bottom.

OTHER QUARTERNARY DEPOSITS—

There are two cases of landslides worthy of note. One lies on the northwest foot of London Mountain west of the North London mine; the other, west of this. In the latter case the material of the slide came down, not from London Mountain, but from the lower slope of Mosquito Peak on the main Mosquito Range. These two slides practically unite at their bases. The slide from Mosquito Peak shows some features suggestive of a rock stream, but these are not pronounced enough to justify designating it as such.

THE LONDON FAULT

GENERAL DESCRIPTION—

Attention has already been drawn in Chapter III to the area of Weber grits that covers the southwestern part of the area mapped, and to the sudden change in the character of the formations along the so-called London fault, which limits the Weber grits formation on the east. The line of this great fault is very plainly marked on the geological map. Except for a short distance on the summit of Pennsylvania Mountain, the east side of the fault is indicated by the presence of Archean rocks, while on the west side we have rocks well up in the Carboniferous. This fault has been traced by the Emmons survey from beyond the summit of the Mosquito Range on the north to a point considerably south of Sheep Mountain on the south—a distance of some fifteen miles. It is often difficult to locate it with definiteness on the surface, on account of the large amount of debris that litters the surface and prevents the rock outcrops from being seen. Neither can it be located by a fault-scarp, as erosion has entirely removed all trace of such scarp. The presence of such a fault may readily be recognized, however, by viewing from a distance the steep, wall-like rampart of Pennsylvania Mountain, as seen from the flat to the west of London Mountain. On the left the upper easterly slope of Pennsylvania Mountain is formed of bedded formations that lie upon a sloping Archean floor and that rise steadily up to the highest point of the Mountain, where they end just before reaching a prominent rocky knob that stands up perpendicularly and that is known as the "Butte." To the right of the Butte the western ridge of Pennsylvania Mountain slopes gently toward the saddle that lies between Pennsylvania Mountain and the main Mosquito Range. The beds that form this ridge are composed of Weber grits, with one very pronounced porphyry sheet. These beds dip plainly to the east, but suddenly disappear before reaching the above-mentioned Butte. It is very evident that, should they continue their course farther to the east, they would run directly into the Archean rocks that form the greater part of Pennsylvania Mountain to the east of the Butte. They are, in fact, cut off by the London fault before reaching the Archean.

The very great displacement of the formations that is so evident on the north slope of Pennsylvania Mountain, and that characterizes the London fault for the entire distance, is not the result of a simple fault slip, but of a fault slip combined with extensive folding of the strata. The movement that culminated in the fault first developed a great S-fold of anticlinal or slightly recumbent character, with the steep or overturned side of the fold facing the west. That is, the fold caused the beds on the east to be elevated, or those on the west to be depressed. This movement finally resulted in rupturing the beds and developed into a great thrust-fault, in which the eastern flank was shoved up above and somewhat over the western. How much of the total displacement, which Emmons estimates as at least 2,000 feet, is to be attributed to the fault movement cannot be determined, as the fault plane for a considerable distance runs approximately parallel to the dip of the upturned strata, so that the apparent fault displacement is largely due to folding. From observations of the writer, he is inclined to put the total displacement considerably higher than 2,000 feet, and to consider 3,000 feet as a minimum.. This conclusion is largely based on the observed fact, as will be shown later, that on Pennsylvania Mountain the fault plane follows parallel to the steeply upturned strata for a total vertical distance of at least 1,800. This enables us to account for this much displacement by folding alone. Quite aside from this, it is very evident that there has been a real vertical fault movement of certainly over a thousand feet.

As will be shown in the detailed description that follows, the fault plane has a dip to the east of about 65° to 70°. The position of this plane with reference to the axis of the anticlinal fold varies considerably. This could hardly be otherwise, because of the unsymmetrical character of the fold, which is overturned or recumbent in places. In the region to the northwest of London Mountain the fault plane lies apparently to the west of the axis; on London Mountain it lies to the east, and on Pennsylvania Mountain again to the west.

In speaking of the London fault, it has always been the custom to refer to it as a single slip along the Archean contact. This is the idea that Emmons had of this fault, and is a very natural one, because there is no other line of marked unconformity than that between the Archean on the east and the younger formations on the west. It seldom happens, however, that a great fault is confined to one clean line of slip, but the movement is distributed, in that several parallel-running fault slips, that may be close together or many hundreds of feet apart, combine to account for the total fault movement. This distribution of the fault is also usually accompanied by a greater or less mashing of the fault blocks, so that we have a mashed fault zone of varying, but often of very considerable, width. Such distributive slipping and mashing of the ground adjacent to the Archean contact within the area of the sedimentary formations is everywhere in evidence in the underground mine workings. But, aside from this development of a mashed fault zone, there is evidence, that appears quite conclusive, of a second very considerable fault slip, distant at places some four or five hundred or more feet from the Archean contact, but upon the whole running approximately parallel to it. This second, more westerly located fault plane has been called the West London Fault, as it is well exposed in the London mine. The amount of the movement along this fault plane is not known, but it can hardly be under several hundred feet.

On Pennsylvania Mountain—

The exact location of the main London fault on Pennsylvania Mountain cannot well be determined from surface observations. Fortunately, there are several mine tunnels and shafts located at the bottom, midway up the north slope, and at the summit, that throw much light on the structure of the mountain and make it possible to locate the fault with considerable certainty. These mine workings were none of them opened at the time Emmons made his survey, so that he was obliged to locate the fault largely by conjecture and inference. The location of the Archean fault plane, as it crosses the ridge of Pennsylvania Mountain, depends upon the interpretation put upon the abovementioned Butte that Emmons refers to under the name "dark knob." This Butte consists of a very compact quartzite, which in places, especially on the east side, has a peculiar structure that Emmons describes as "a light frothy mass of cavernous quartz." Emmons is constrained to interpret this quartz rock as belonging to the "parting quartzite" which forms the top of the Ordovician. This conclusion he came to because of an apparent curving of the beds of the "knob," to the east as though forming part of the anticlinal arch of the fold. This would require that the fault plane pass to the west of this quartz "knob." The writer is convinced that this is a mistake, that the Butte represents an altered portion of the Carboniferous blue limestone, and that the fault plane passes just east of the Butte.

Aside from the failure of the writer to observe the supposed curvature of the beds forming the Butte to the east, the real reason for this conclusion is based upon a careful study of the formations along the London fault in many mine exposures as well as on the surface. In the first place, it has been definitely ascertained that the formation in contact with the main fault in most of the places where this contact could be observed, both on Pennsylvania Mountain and on London Mountain, and northwest therefrom, is the blue limestone of the Carboniferous, and that where this limestone is not in actual contact it is separated from the contact by comparatively few feet of porphyry. In the second place, the peculiar porous quartz that composes the "dark knob" has nowhere else been observed in the parting quartzite, but, on the other hand, exactly such quartz masses have been observed in many places as an alteration of the blue limestone—so much so that dike- or vein-like masses of similar porous quartz may be said to be fairly characteristic of the Carboniferous limestone of the Alma district. In the Pennsylvania tunnel that cuts the main fault plane at a level about 800 feet below that of this butte, a similar quartzite is met with at, or close to, the fault plane. Finally, it may be added that a microscopic examination of a thin section of the quartz of the Pennsylvania Butte shows no trace of a structure suggestive of a sandstone or true quartzite. It is composed of an aggregate of irregular quartz grains occurring in patches and streaks of varying fineness—just such structure as one meets with in quartz replacements of limestone.

Having placed the main fault plane on the west of the Butte, Emmons found it difficult to account for the beds on the west of the fault plane, except upon the hypothesis that these beds represent the so-called Upper Coal Measures of the Carboniferous—a formation that otherwise is not represented in the district. Without entering into the reasons given for this assumption, the necessity for it falls to the ground if the rock of the Butte is admitted to be the Carboniferous limestone, and if the main fault plane is located to the east of the Butte. As a further reason for so locating the fault plane, it may be stated that two porphyry sheets—one a gray porphyry, the other a white porphyry—have been traced almost continuously along the west side of the main fault plane from London Mountain to Pennsylvania Mountain, with the gray porphyry usually on the east, and that these same porphyry sheets appear on the summit of Pennsylvania Mountain immediately west of the Butte in their proper relationship.

There is an inherent difficulty in explaining the structural features at this point, which was recognized by Emmons, and which is not lessened by placing the Butte in the Carboniferous limestone and the fault east of it. This is the fact that, on approaching the fault from the east and from the west, the beds appear to arch downward toward the fault on both sides—a feature that is difficult to explain on any accepted theory of faulting. For instance, coming from the east, it is very plain that the bedded formations that form the eastern slope of the mountain, on reaching the summit, suddenly bend downward before reaching the fault. Similarly, on ascending the ridge from the saddle on the west of the mountain, one passes over Weber grits that dip eastward at an angle of about 20°, and in so doing ascends from lower to higher beds in the geological series. As one approaches the fault, the beds rapidly become steeper, until they dip 80° to the east. Apparently there is no break, but the dip simply becomes steeper on approaching the fault. Thus the higher beds are facing the fault plane. But if one starts from the fault plane and goes west along the flat that leads to this same ridge, it is equally evident that the higher beds are not facing the fault, but are facing the west. Thus we have:

Succession of Strata from the Fault Westward

Blue limestone, altered to quartz, 100 feet.
Gray porphyry, 35 feet.
Shale or limestone, 25 feet.
White porphyry, 35 feet.
Shales, 27 feet; dip, 81° E.
Quartzite, 90 feet; dip, 75° E.
Quartzite, 33 feet; dip, 77° E. Shows considerable shearing, indicating faulting parallel to bedding.
Quartzite, 60 feet; dip, 75° E.
Rusty-brown porphyry, greatly sheared parallel to bedding.
Quartzite and siliceous shales; dip, 80° E.

This series of rocks and the succession indicated are exactly like that met with wherever an opportunity to study the rocks west of the main London fault is afforded, and the succession as given is from the bottom to the top. These facts require that somewhere along the flat leading to the steeper part of the ridge running west from the summit of Pennsylvania Mountain there must occur a sudden change from westerly-facing to easterly-facing strata. As already stated, on passing over the surface there appears to be no such break; and yet, on going a little distance down the north slope of this ridge, a little farther west than the siliceous shales last mentioned above, the Weber beds that were dipping gently to the east become suddenly contorted and form several rolls with easterly and westerly dips, finally ending to the east in nearly vertical beds.

This sudden crumpling of the strata as seen on the slope of the ridge indicates the possibility of faulting, that is further emphasized by strongly sheared rocks in several places west of the main fault, two of which were mentioned above. It seems impossible to account for the structures above described except upon the assumption of an additional fault plane, or perhaps more than one such, at some distance west of the main fault. As will appear later, this assumed fault plane on top of the ridge is made all the more likely by the observed presence of faults in a similar position in the Pennsylvania tunnel and in the Maumee tunnel farther down the same slope.

An attempt to interpret the structure on this ridge, as above indicated, is shown in Plate III, Section E-E. In this section two faults west of the main London fault are assumed, as is more than likely. But the structure can be accounted for with only one such additional fault plane.

The Weber grits that compose the ridge west of Pennsylvania Mountain, and that dip for the most part uniformly to the east, contain, in addition to the three porphyry sheets specified above, two others. One, a very strikingly exposed sheet seen on the north slope of the ridge, is at the top of the steep part of the ridge and measures forty feet in thickness. The other lies near the base of this ridge, close to the saddle, and appears to split into two. These rocks are quartz monzonite porphyries. They are an exception in this district, in that they contain more or less hornblende. (These rocks are named by Cross, in the Leadville monograph, "Sacramento porphyrite.") Plate V, facing page 42, presents a photograph of the upper part of Pennsylvania Mountain and of the ridge to the west, in which the conspicuous porphyry sheet and the Butte are plainly seen; also, the unconformity is made evident by the failure of the Weber grits to extend beyond the fault plane which runs down from the east side of the Butte.

Contrary to the supposition of Emmons, who showed the London fault dipping to the west, this fault dips in the opposite direction at an angle of 65° where it crosses the ridge of Pennsylvania Mountain. This dip was determined by mapping the fault plane on the surface and 800 feet below in the Pennsylvania tunnel, which penetrates to a point nearly east of the Butte. The apparent curve of the fault plane, as it appears on the map, is probably not due to an actual change in the direction of the strike, but to the fact that the fault dips strongly to the east, so that the trace of the fault plane on the northerly-sloping mountainside would necessarily run strongly to the east. An easterly dip to the fault is what would naturally be expected in a fault produced by overthrust, in a case where the upthrow is on the east side.

On the top of Pennsylvania Mountain, about 200 feet south of the Butte, a fifty-foot shaft was sunk in 1911 by Mr. Carl Mohr, the general manager of the Pennsylvania tunnel. At the bottom of the shaft is a cross-cut tunnel, about seventy-five feet long, that runs at right angles to the strike of the formations. In this tunnel there are exposed, beginning on the east, (1) quartzite, (2) gray porphyry, (3) shale, (4) white porphyry. This is exactly the same as was seen on the surface immediately west of the Butte. But whereas these formations could be recognized with difficulty at the surface, their nature was very readily recognized in the tunnel.

PENNSYLVANIA TUNNEL—

The Pennsylvania tunnel was driven in 1910 and 1911, by the Pennsylvania Mining Company, under the direction of General Manager Carl Mohr. The tunnel portal lies 800 feet below the Butte, on a comparatively level shelf on the north slope of Pennsylvania Mountain. It runs in an easterly direction for 1,200 feet, until it cuts the Archean schists to the east of the main London fault. A section along the line of the tunnel is shown in Plate XXVI. From this it is seen that the tunnel passes through a porphyry sheet near the bottom of a synclinal fold. Beyond this the Weber beds become gradually steeper, dipping to the west. They show great disturbance, and in places plain evidences of faulting. The heavy sheet of porphyry is probably the same sheet that shows so plainly on the slope of the ridge west of Pennsylvania Mountain. Some distance before reaching the Archean a narrow sheet of rotted porphyry is struck. Immediately against the Archean is white porphyry, about twenty-seven feet wide. In the midst of this porphyry is a fault slip that contains fragments of schist, which probably have been dragged in from above. The main fault plane against the Archean is surprisingly sharp and narrow. The occurrence of white porphyry against the Archean is unexpected. But the same feature occurs in the Maumee tunnel, about 700 feet lower down the mountain, where the white porphyry splits into two parallel sheets, one of which is in contact with the Archean. Experience in other mine workings along the London fault shows that the white porphyry is somewhat erratic in its position. As a general thing, it keeps some distance away from the Archean, with a gray porphyry sheet in between; occasionally it comes close to the Archean contact.

From where the small fault was struck in the white porphyry a drift was run to the south, cutting irregularly through the formations for some 300 feet, and again cutting the Archean by a short cross-cut. The formations here shown are difficult to determine, and their relations appear to be greatly mixed. Apparently there is some limestone that in places has a sandy or shaly appearance, and in another place is silicified.

THE BUTTE MINE AND THE MAUMEE TUNNEL—

The Butte mine is located near the creek-level on the west side of Mosquito Gulch, at the foot of Pennsylvania Mountain. The Maumee tunnel is situated 200 feet vertically up the slope from the Butte mine. From these two most valuable information was obtained as to the structural relationships of the London fault. Part of the information here given was obtained by personal observation, and part was furnished by Mr. Charles P. Aicher, general manager of the Butte mine. Mr. Aicher says that, before undertaking the development of the Butte mine, he opened up the old Maumee tunnel with a view to examining the rock formations to the west of the London fault. Figure 1 shows the rock strata as described by him. This tunnel was worked in 1887. The tunnel was driven sixty feet on the contact of the white porphyry on the east and the Weber grits on the west. From this point a cross-cut was run to the Archean, a distance of 250 feet, and disclosed in succession:

Weber grits.	
White porphyry,	40 feet.
Gray porphyry,	60 feet.
Blue limestone,	100 feet.
White porphyry,	20 feet.
London fault.	
Archean schists,	30 feet.

The formation from the fault to and including the westernmost white porphyry dips about 75° to the east, the Weber grits 70° to the west, thus indicating an unconformity, due to faulting, just west of the white porphyry. It may be stated here that this white porphyry, with the gray porphyry in contact with it on the east, corresponds to the position of the London vein in the Butte mine and on London Mountain, which is fully described in Chapter VIII.

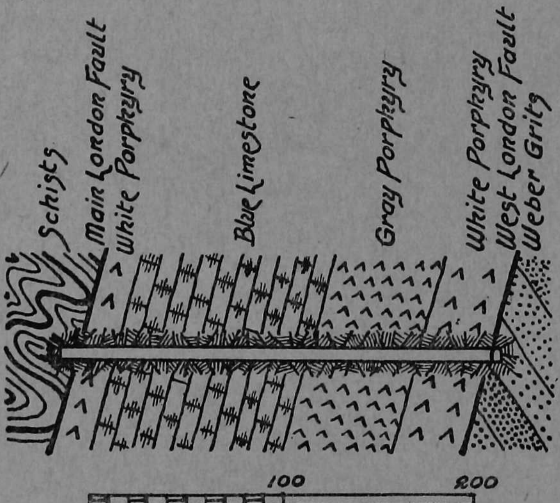

Fig. 1

FIGURE 1—Section along the cross-cut in Maumee Tunnel, Pennsylvania Mountain, showing the Main London fault and the West London fault.

In the Butte mine a tunnel has been driven, mostly along this same contact of the gray and the white porphyries, for a distance of 2,400 feet from the portal, the direction of the tunnel being S. 35° E. According to Mr. Aicher, the conditions found at 1,900 and 2,400 feet, respectively, are as follows:

At 1,900 Feet from Portal		*At 2,400 Feet from Portal*	
Weber grits.		Weber grits.	
White porphyry,	60 feet.	Gray porphyry,	40 feet.
Gray porphyry,	100 feet.	Blue limestone,	100 feet.
Blue limestone,	100 feet.	White porphyry,	20 feet.
White porphyry,	25 feet.	London fault.	
London fault.		Schists.	
Schists.			

In both of the above cases the strata east of the Weber grits dip to the east, while the Weber grits dip to the west, exactly as in the Maumee tunnel. The Weber grits were cut in several places, showing at 800 feet from the portal a westerly dip of 45°, and at 2,000 feet a westerly dip of 30°. In both the Butte and the Maumee tunnels a well-defined fault, sufficiently great to produce a marked unconformity, occurs at between 200 and 300 feet from the main London fault, and in each case immediately west of a white porphyry sheet.

Near the portal of the Butte tunnel a shaft 150 feet deep, with 800 feet of drift, again exposes the same formations. This shaft was not accessible, but from Mr. Aicher it was learned that just below the surface the dip of the formations changes to 65° west. Evidently, then, the strata that have shown a very steep easterly dip all the way from the summit of Pennsylvania Mountain, and have been dipping with the London fault, rapidly bend back to the normal at about the creek-level. From this it may be seen, as noted above, that, for a vertical distance of some 1,800 feet, the London main fault follows closely the dip of the strata. The importance of this fact as bearing on the total amount of displacement caused by the London fault is commented on elsewhere.

On London Mountain—

London Mountain is cut into two halves by the London fault. To the east of the fault is the Archean formation; to the west, the Weber grits, with intruded porphyry sheets. London Mountain is extremely steep on all sides, except toward the west, where a ridge descends to the saddle. The steep sides are heavily covered with talus, but, in spite of this handicap, it was possible to trace the Archean fault line clear across the mountain, except over the flat to the southeast of the South London mine. The Carboniferous blue limestone in contact with the Archean follows the main fault with remarkable persistency, and with equal persistency there occur two porphyry sheets—one the so-called "white porphyry," the other the "gray porphyry" of the London mine. On the London ridge the white porphyry is to be seen to the east of the gray porphyry, but when partly down the southern slope the gray porphyry crosses the white and appears on the upper or east side. This relative position of these two porphyries continues down to Mosquito Gulch and up over Pennsylvania Mountain, except for certain local variations, noted above.

As was the case on Pennsylvania Mountain, so here there are two distinct faults that run practically parallel courses; one, the Archean-contact fault, here called the main London fault; the other, two or three hundred feet west of this, and located at about the western edge of the two parallel-running porphyry sheets. To this the name "West London fault" is given. This last-named fault cannot be located with certainty on the surface. It has, however, been located in the London mine at the South London tunnel. A full description of this fault, as well as of the main fault, is to be found in Chapter VIII, in connection with the description of the ore deposits of the London mine. But, although this fault cannot be located on the surface, the necessity for such a fault is as much in evidence here as was the case on Pennsylvania Mountain. Section D-D, as shown on Plate III, gives a cross-section that passes along the ridge running from the top of London Mountain to the west. This ridge is nearly a duplicate of the ridge running west from Pennsylvania Mountain. The same series of Weber grits, with intruded porphyry sheets and strong easterly dip, are seen to crumple into a synclinal fold, and then to dip steeply to the east before reaching the London fault. Again, we have the easterly-dipping Weber grits and the easterly-dipping blue limestone, with intruded gray and white porphyry sheets, with the higher beds in each series facing each other. Again, this is explained by the presence of the West London fault.

On the southern slope of London Mountain, from the bottom of the valley up to the flats around the South London mine, are a number of mines and prospect tunnels that have furnished additional information that has been embodied on the map, but that do not call for discussion at this point. Some of these properties are briefly discussed in Chapter VIII.

Plate XXV, prepared by Mr. Charles J. Moore, gives several sections showing the systems of faults on London Mountain.

NORTHWEST OF LONDON MOUNTAIN—

Northwest of the foot of London Mountain the blue limestone broadens out to a wide expanse, owing to the fact that the dip becomes first flat, then either horizontal or rolling. At the same time, the main London fault continues, but comes into contact with the white porphyry, while the gray porphyry seems to disappear. About 2,000 feet from the portal of the North London mine is a very remarkable hill, composed for the most part of the Carboniferous blue limestone. This hill has a very steep, almost precipitous, eastern slope, with the main London fault running along near the base. The limestone strata have been greatly crushed and altered, so that the dip and strike are difficult to make out. With careful observation, however, the strata may be seen to form an anticlinal fold over the top of the hill, and to bend suddenly down on the east side to a vertical position, with a narrow bed of vertically dipping white porphyry between the limestone and the Archean fault plane. The white porphyry bed also appears to the west of this ridge-like hill, on a round-topped hill which the white porphyry completely encircles. Beyond this again, erosion has cut through the white porphyry into the blue limestone along a shallow gulch, and the porphyry reappears on the mountain-side to the west of this gulch. Evidently the white porphyry sheet, with the overlying Weber grits and the underlying blue limestone, all arched over the above-mentioned limestone hill, bending sharply downward on the east side of the hill. Erosion has removed the Weber grits and the white porphyry, and most of the blue limestone, from the crest of the hill. This structure is brought out in Section C-C on Plate III.

The surprising thing in connection with the above-described structure is the bending down of the strata to a vertical position against the west side of the fault plane, which west side is the downthrow side of the fault. That there can be no mistake as to the actual bending down of the strata against the west side of the fault may, perhaps, be shown by a further observation. Less than 2,000 feet from the place where the fault crosses the crest of the Mosquito Range a similar situation occurs with reference to the Weber grits. The Weber grits, with underlying blue limestone and an intervening sheet of white porphyry, all with a gentle easterly dip, suddenly bend down to a vertical position just before reaching the Archean fault plane. The fault plane at this point lies between granite and Weber grits, and is very sharp and perfectly exposed. The actual shearing produced by the fault is in the granite rather than in the quartzite-like grits.

In explanation of this condition, it may be stated that it may be very frequently observed that the strata to the west of the London fault show a preliminary roll with easterly dip before the main S-fold that preceded the faulting is reached. In the case in hand this preliminary roll seems to have been much more pronounced and to have produced a dip to the east that locally became vertical. The Archean fault plane may be presumed here to lie farther to the west of the anticlinal arch than usual, so as to cut through this preliminary fold on the west. If this is correct, the S-fold originally lay entirely to the east of the fault, and has been raised up with the Archean floor and completely removed by erosion.

There is evidence to indicate that the West London fault approaches close to the main fault at the eastern end of the above-mentioned blue limestone hill. Close to the small lake on the eastern foot of this hill, a tunnel, called the Oliver Twist tunnel, has been driven through the London fault. Starting in the Archean, the tunnel cuts through 600 feet of granite and schists, and then cuts the fault plane which strikes nearly north and south and dips 80° east. Weber grits appear in the fault breccia. Forty-five feet beyond this point occurs another fault slip, apparently parallel to the first. This occurs in very soft, rotted material, the exact nature of which could not be determined. At this point bad air compelled a retreat, so that the tunnel could not be followed farther; but blue limestone on the dump indicates that the tunnel penetrated to that rock on the west side of the hill. This second fault is quite possibly the West London fault, which may run into the main fault farther to the west.

LOWER MOSQUITO GULCH, PENNSYLVANIA AND LOVELAND MOUNTAINS

GENERAL DESCRIPTION—

Pennsylvania and Loveland Mountains are remarkably alike in their topographic and geologic features. Topographically, they are fairly flat, narrow surfaces that slope eastward from an elevation of over 13,000 feet until they reach the level of Mosquito Gulch at about 10,500 feet. On the north and south sides they both drop off very steeply, and toward the upper sloping surface, almost perpendicularly, to the level of the deeply cut gulches at their feet. Geologically, these two mountains consist of a comparatively thin cap, two or three hundred feet in thickness, lying on a sloping Archean floor, and consisting of Lower Paleozoic strata, with intruded, conformable sheets of porphyry and porphyrite. So closely alike are the cliff sections of these mountains, as seen from the level of Mosquito Gulch, that they appear to be an exact counterpart of each other. At the base of the sedimentary series, lying on the Archean gneisses and schists, are the thick-bedded, whitish-appearing Cambrian quartzites; and intruded into these, at fairly equal intervals, are several thin sheets of igneous rocks. Above the Cambrian series, and conformable thereto, is the Ordovician limestone. This series of strata, outcropping along the upper edges of the two mountains, gradually descends and crosses the botton of the valley a short distance above Park City. The marked fault shown on both sides of the valley on the geological map will be described under a special head. Where the easterly-dipping strata strike the comparatively level valley, they naturally cover a much wider territory than where their edges are shown outcropping on the very steep mountain slopes. It should be remembered that the sheets of porphyry and of porphyrite that appear along the cliff sections of the two mountains are not very thick. They measure usually from fifteen to twenty-five feet in thickness, so that, in order to show them at all in such a position, it is necessary to exaggerate their thickness on the map. This is also true for the intervening quartzite beds, so that the entire series as shown on the map covers a wider strip than it should, and to that extent the map must be in error.

PENNSYLVANIA FLAT—

The suface of Pennsylvania Mountain is a broad, uneven flat that slopes to the east at an angle somewhat less than that of the strata composing it. These strata have a dip of perhaps 20°, with local fluctuations; but it is extremely difficult to find exposures on this upper surface that afford opportunities for taking the dip and strike. This is due to the very heavy covering of wash that consists of angular fragments of rock broken up by the action of frost, and often carried some distance below the point of origin. About midway up the slope the mountain is traversed by a pronounced fault, which will be described later. Above this fault, with the exception of a small area on the north side close to the fault, this great flat is covered entirely with Cambrian quartzite and porphyry. The porphyry is the same as that composing the sheets which show as narrow bands on the cliff section. The irregular porphyry masses that cover fully one-half of the surface above the fault, whose peculiar distribution is due to uneven erosion—or, perhaps, to minor faults—are extensions of one of these sheets. The particular sheet in question is the one next to the bottom. The lowest sheet does not reach the edge of the cliff, but, just west of the highest point on the north cliff, is seen to bend suddenly down against the London fault. This porphyry, like the other sheets on Pennsylvania and Loveland Mountains, is a quartz monzonite porphyry. This porphyry is everywhere greatly weathered on this mountain, so that it is difficult to determine to what type it belongs.

The hornblende porphyrite appears in two places on the northern half of the mountain, in both places in the form of narrow sheets. This rock also connects with the sheet of similar rock seen on the cliff section. Its appearance in two sheets on the upper surface is due to a fault that throws the porphyrite sheet downward on the west side just at the point where the sheet, ascending diagonally the face of the cliff, reaches the surface. This fault is typical of a series of minor faults that are to be seen in the cliff section on the north of Pennsylvania Mountain, and that throw the strata from four or five to thirty or forty feet. The upthrow is invariably on the east side. Undoubtedly these faults cross the flat surface of the mountain, but their course cannot be followed very far. They probably have much to do with the distribution of the porphyry areas above mentioned.

In the case of this mountain the writer was unable to make the geology of the flat upper surface conform to the mapping of these formations as shown by the Emmons survey. On the Emmons map the flat surface of Pennsylvania Mountain may be divided roughly into three parts. The lower third is covered with Weber grits; the middle third, with Carboniferous limestone; and the upper third, with Lower Silurian or Ordovician; while the porphyry is not supposed to reach the upper surface at all. On account of this discrepancy between the formations as mapped by the Emmons survey, and as observed in the field, much attention was devoted to this mountain, and the formations were mapped with great care. Neither Carboniferous nor Lower Silurian beds could be found on the upper two-thirds of the mountain, except that, just before reaching the London fault, a very small patch of Lower Silurian appears as it bends down toward the fault plane. It is very plain that this formation did at one time cover the entire mountain, but, except where the beds were folded down in connection with the great S-fold that preceded the faulting, erosion has carried away every vestige of them. It is probable that the discovery of this Lower Silurian limestone just west of the summit of the mountain and close to the London fault led Emmons to conclude that it must cover the upper part of the flat. The dip of the Cambrian, and of the Archean floor on which it lies, is such that, except for the numerous faults that cross Pennsylvania Mountain, the upper half of the mountain would be composed of Archean rocks. Instead of the Archean, we have the Cambrian, due to the repeated faulting down of the formations on the west side of the faults.

On the south side, Pennsylvania Mountain, just beyond the bounds of the map, falls away precipitously toward the Big Sacramento Gulch, in precisely the same manner as toward the Mosquito Gulch on the north; and the geological formations on the two sides of the mountain are essentially the same.

BALD HILL—

Toward the base, Pennsylvania Mountain shows a marked variation from what is seen on the closely similar Loveland Mountain on the other side of the gulch, in that the even eastern slope is interrupted a short distance below where the Weber grits come in by a gentle rise of about 300 feet. This higher ground forms a rounded, bare-topped summit that goes under the name of Bald Hill. The summit of this hill, and also the saddle to the west, consist of Weber grits, except where these beds are covered by glacial drift.

On the steep northern slope of Bald Hill occurs a heavy intruded sheet of Lincoln porphyry, with a thickness of not less than 400 feet. This porphyry covers the hillside from the Hock Hocking mine up to a level about 300 feet below the summit. It is also well exposed along the irrigating ditch that passes the above-mentioned mine, for a distance of about half a mile. The London porphyry here as elsewhere disintegrates readily where exposed to the weather, and falls into rough gravel that resembles the disintegration gravel of coarse granites. The extent of this porphyry intrusion is not known, as both ends of the northeast-to-southwest-striking sheet are covered by heavy deposits of glacial drift. It appears to lie conformable to the blue limestone on the west, but must wedge out rapidly to the southwest. This is assumed for the reason that no trace of the porphyry could be found on the saddle west of Bald Hill, in spite of some good exposures in prospecting shafts. It is quite possible that the greater elevation of Bald Hill is due to the arching of the Weber grits by the intruded porphyry that may have a laccolithic form. As no well-defined outcrop of the Weber grits could be found, this hypothesis could not be proven.

On Bald Hill we have an opportunity to determine the depth of the Mosquito Gulch glacier. The entire summit of this hill is strewn with glacial boulders of such a character as to indicate that they were derived from along the side of Mosquito Gulch. These boulders included quartzite, porphyry, porphyrite, gneiss, schist, granite and Weber grits. The glacial boulders are not found on the Pennsylvania flat, except on the northeastern part at or about the level of Bald Hill; nor are they found on the west side of Pennsylvania Creek that flows past the southern base of Bald Hill. It is evident from the facts just stated that the Mosquito glacier must at one time have covered the entire summit of Bald Hill.

The glacial drift has not been mapped over the summit of Bald Hill, as it is not thick enough to obscure completely the character of the rocks beneath. A short distance to the east of the summit, however, the drift becomes very heavy, and from this point clear to the Platte River, at the extreme southeastern boundary of the map, underlying grits or porphyry could be found in only two or three very small spots.

The numerous cabins that dot the surface of the saddle west of Bald Hill and of the lower slopes of the Pennsylvania flat testify to the extensive prospecting that at one time characterized this region.

Loveland Flat—

The description just given for the structure of the Pennsylvania flat fits in a general way remarkably well that of the easterly-sloping surface of Loveland Mountain. This mountain is, however, considerably narrower and longer than Pennsylvania Mountain. The greater length, with a slope of about equal steepness, results in the mountain rising to an elevation some 600 feet higher than that of Pennsylvania Mountain. For a mile along the upper reaches this mountain is simply a narrow ridge, that falls off with great abruptness to the Mosquito Gulch on one side and to the Buckskin Gulch on the other.

In spite of the general resemblance in the geological and topographical structure of these two mountains, in detail they are greatly different. In this case the Ordovician or Lower Silurian white limestone extends over the entire length of the mountain, being interrupted along the middle of the slope by a sheet of porphyry. This means that the slope of the surface is almost exactly that of the strata when measured in the direction of the axis of the mountain. This does not mean that the true dip of the strata is that of the mountain slope; for the dip of the strata is on an average to the east, and that of the mountain flat about southeast. The average slope of the mountain, measured from the highest point to the bottom of the valley near Park City, is 10°. Both strike and dip of the strata vary greatly, as will be seen by a study of the geological map, on which strike and dips are indicated by a straight line at right angles to an arrow. The straight line is drawn in the direction of the strike; the arrow, with the accompanying figure, indicates the direction and amount of the dip. These dips, it will be seen, vary from 40° to 15°, the average being probably 20° or a little less. As a matter of fact, at one place on the cliff section just east of the so-called Mosquito Gulch fold-fault the strata are practically horizontal, and for a short distance actually have a westerly dip.

Emmons calls attention to an interesting feature in connection with the varying dip of the strata on Loveland Mountain. He says*:

> Loveland Hill affords an excellent illustration of the often-observed fact that the deeper transverse valleys often follow the line of a minor or lateral anticlinal fold, while the intermediate hills or more elevated region, which has been relatively less eroded, is the locus of a minor synclinal fold.
>
> On the broad, flat back of this hill or spur, whose slope corresponds very nearly with the easterly dip of the sedimentary beds, is a shallow ravine draining into Mosquito gulch, towards which there is a very perceptible dip of the beds from either side; in other words, the strata dip eastward, and at the same time dip north and south towards the bottom of this valley.

Referring to this same ravine to which Emmons in the above-quoted passage calls attention, we have here an example of nearly accomplished stream robbery. At the point where the fold-fault is made to end, a very narrow crest is left between this ravine and the precipitous slope that faces Mosquito Gulch on the south. The comparatively rapid retreat of the cliff face,

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*Leadville Monograph, p. 130.

due to the rapid erosion on the Mosquito Creek side, has encroached on this minor ravine until it has all but succeeded in capturing its drainage.

Minor faults are doubtless of common occurrence on Loveland Mountain, similar to those mentioned as occurring on Pennsylvania Mountain. In most cases, however, these are difficult of detection, except occasionally in the cliff section. There is one fault of much greater extent to be seen on the Buckskin side of the mountain, cutting through the sedimentary formations and well down into the Archean. This is located about opposite the middle of the mountain, just west of a large pegmatite mass in the Archean. The fault plane is nearly vertical and has a curved strike, being nearly N-S on the flat and N-E on the cliff. The throw is upward on the east. The actual amount of vertical slip is 236 feet. This was measured by means of a hand level between the Archean contacts on the two sides of the fault plane. Emmons' map is in error in showing this fault with an upthrow on the west side.

Another parallel-running fault of much less veritcal throw, but with a throw in the opposite direction, is seen on this same cliff 2,500 feet farther east. These faults, as well as two others that are located on the cliff section just above Buckskin Joe, will be further referred to in connection with the description of the fold-fault that crosses this mountain and continues across Mosquito Gulch and over Pennsylvania Mountain.

The distribution of the Carboniferous and Cambrian, as well as of the porphyry, on the flat surface of Loveland Mountain is in part due to fluctuations in the dip and strike of the strata; in part also to the occurrence of faults. The mapping of these formations is very difficult, on account of very heavy wash derived from higher parts of the mountain slope. The general position of the large porphyry sheet that runs diagonally across the surface of the mountain from west to east indicates that this sheet lies rather irregularly in the white limestone of the Ordovician. The occurrence of an extensive porphyry sheet in the Ordovician in the Alma district is sufficiently exceptional to be striking. From the map it will be seen that this sheet is connected with the lowest of the porphyry sheets seen in the cliff section of the Cambrian quartzite on the Mosquito side. The dike connecting these two sheets was traced by two of the student assistants, who, though without much experience, are careful workers. The writer has every confidenec in the accuracy of their observation.

The cliff section of Loveland Mountain discloses within the Cambrian quartzite no less than four sheets of igneous rock toward the east end of the mountain. One of these is a porphyrite—the same sheet that has been traced in the cliff section on both sides of Mosquito Gulch, and that continues across to the opposite sides of both Pennsylvania and Loveland Mountains. This porphyrite sheet is the third from the bottom. Below this are two porphyries of identical appearance. Above it is a much darker-colored porphyry. All the porphyries have been identified as quartz monzonite porphyry. Their thickness is not great—seldom over twenty-five feet, and often much less than this. To the east of the fold-fault all four of these porphyry sheets have been mapped. The upper sheet appears to be of small extent. It was not observed west of the fold-fault. The lowest of the four sheets does not extend to the west beyond the point where it turns upward in the form of a dike, connecting the two sheets in the Cambrian below and the Ordovician above. The next-to-the-bottom sheet appears to extend clear around the upper end of Loveland Mountain, and finally disappears in the cliff section on the Buckskin side, at an elevation of 12,750 feet. The lower porphyry sheet on the Buckskin side is probably connected with the lowest of the four sheets on the Mosquito side, but the connection could not be traced on the surface. The porphyrite sheet continues in the cliff section on the Mosquito side up to an elevation of 13,300 feet, and then disappears. The same sheet on the Buckskin side disappears at an elevation of 12,500 feet.

THE MOSQUITO GULCH FOLD-FAULT

Reference has already been made several times to a fold-fault that crosses Mosquito Gulch and runs up onto both Pennsylvania and Loveland Mountains. This fold-fault appears to have escaped the attention of the Emmons survey. At least, the extent and character of this very interesting fault evidently escaped their attention. A reference, however, to this fault is made in the Leadville monograph, on page 131, and a diagrammatic sketch of the same is presented in Plate XIV. Of this fault Emmons says:

> The fault which was observed on either side of Buckskin Gulch is not found on this cliff wall [south side of Loveland], but near the mouth of the canon is a more remarkable fault, whose direction is at right angles to the one above mentioned. Seen from the other side of the canon, the strata

> seem to slope rapidly eastward until they abut against the western side of a little knoll of granite, which projects out into the valley at this point and deflects the stream to the southward. When one actually climbs the cliff, however, it is found that there is a reduplication of the lower part of the beds; that a faulting has sheared or split off a portion of the strata on a southeast line, nearly parallel with the face of the cliff; and that the piece thus separated has apparently fallen down at its eastern end to the base of the cliffs, while at its western end it still maintains its connection with the regular line of outcrops.

The above-quoted description is quite accurate, as far as it goes. There is apparently a very marked dropping down of a portion of the cliff section and a reduplication of the series. A photograph of this section on the south face of Loveland Mountain is presented in Plate XVI, B. On the right-hand side of this plate the reduplicated series is brought out in the light-colored beds of the Lower Cambrian. If, however, one follows the lower series of outcrops to the extreme right or eastern end near the base of the knoll to which Emmons calls attention, he will find that the easterly-dipping quartzite beds, together with the intercalated porphyry sheets, bend sharply upward to a westward dip and then to a nearly vertical position. Further folding of these strata to an overturned position cannot be seen at this point on account of erosion and heavy covering with talus.

A careful study of the higher-lying upper series toward the western exposed portion discloses a most interesting section. Along an easterly-dipping plane all the strata in succession are folded sharply down to the west and back again on themselves in a completely overturned position. For instance, the very con-

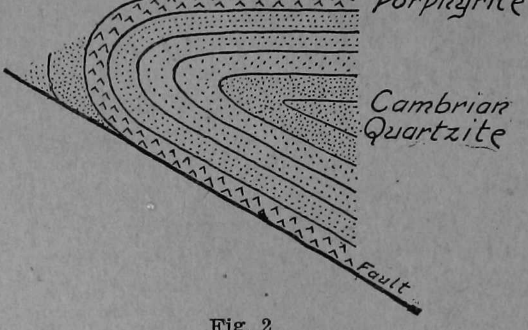


Fig. 2

FIGURE 2—Detail of the Mosquito Gulch fold-fault on Loveland Mountain, showing a porphyry sheet with Cambrian quartzite beds folded against the fault.

spicuous porphyrite sheet is folded back on itself in a complete fold, with the underlying quartzite beds folded with it. (See Fig. 2.) Again, one of the porphyry beds is folded back on itself still more sharply, so that for a distance of perhaps fifty feet the lower part of the folded sheet is very close to the upper part. (See Fig. 3.) Of course, shearing is much in evidence in connection with folding of so intense a character.

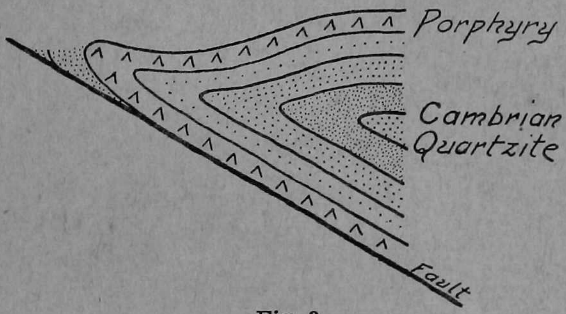


Fig. 3

FIGURE 3—Detail of the Mosquito Gulch fold-fault on Loveland Mountain, showing the porphyrite sheet and Cambrian quartzite beds folded down against the fault.

We have here, then, a case of intense folding, which has brought about the development of a marked recumbent fold, until the strata have been ruptured and torn apart in an overthrust fault. There is no way to determine how much of the displacement is due to folding and how much to faulting. Apparently most of the displacement is to be attributed to the latter.

It is impossible to trace the actual fault plane clear to the top of the cliff on this mountain, but the sharp folding of the strata may be followed all the way to the highest exposed Ordovician limestone beds on the edge of the mountain. It is more than possible, too, that the fault and folding divide near the top similarly to that described later as occurring on the opposite side of the valley.

Now, turning to the south side of the valley, an exactly similar condition may be made out on the Pennsylvania cliff section. Again we have an easterly-dipping fault plane with the strata folded sharply down against the fault on the eastern or higher side, and evidences of a similar upturning of the strata against the fault on the western or lower side. As on the Loveland side, the faulting and sharp folding of the strata were traced

Plate XV—The eastern part of Pennsylvania Mountain, showing the reduplication of the Cambrian quartzite strata due to the Mosquito Gulch fold-fault. The letter *c* is seen in two places on the cliff. This is the same Cambrian bed which has been separated by the fault. The two branches of the fault reach the cliff at *f* and *f*. (See pp. 50, 125, 127.)


f
f
c
a

clear to the top of the cliff. On this side, however, there appears to be greater complexity introduced by a double folding and faulting, as shown in one of the sections on Plate III. This section represents a somewhat idealized reproduction of the conditions observed toward the top of the cliff. The dimensions are not exact, and the strata are represented as thicker than they really are.

On Plate XV may be seen the Cambrian quartzite beds, showing a reduplication of the series through this fault. The letter "c" marks the location of a prominent quartzite bed that is to be seen on each side of the fault plane. The letter "f," shown at two points, indicates the places where the divided fault reaches the top of the cliff. These same formations, as they occur just west of the fault, are seen to better effect on Plate XVI, A.

At the top of the cliff the fault appears to disappear; but it was readily found farther to the south, crossing the flat near the center, where is a flat gulch, called Pennsylvania Gulch. (See the geological map on Plate II.) The fault is indicated by the sharp unconformity developed. To the east of the fault is to be seen easterly-dipping Cambrian quartzite, with one sheet of porphyrite at the top and two porphyry sheets lower down, geologically speaking. Against the fault at the bottom of the gulch appears a very small area of Archean gneiss. To the west of the fault the Cambrian quartzite, with intruded porphyry and porphyrite, again appears. Farther to the west the fault line was traced to the edge of the mountain on the Sacramento side, and was observed starting down toward the bottom of Sacramento Gulch. How much farther to the south this fault continues was not determined for lack of time.

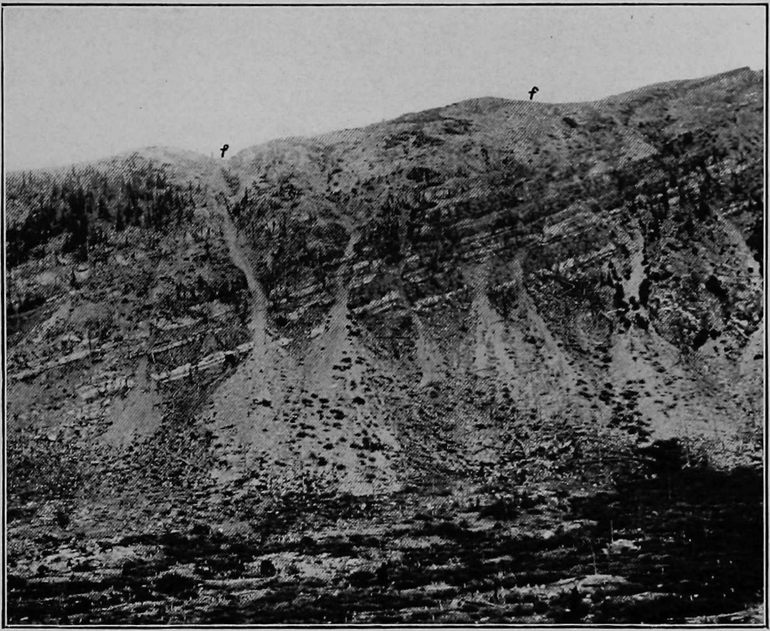
The upthrow of this fault is on the east side. The total vertical displacement amounts to 460 feet. This was determined by F. B. Saxton and R. F. Smith, two student members of the party, by measuring the difference in elevation of the well marked porphyrite sheet on opposite sides of the fault.

The dip of this fold-fault cannot be determined by direct measurement, as there are no exposures of sufficient length at right angles to the strike. Because of the strong easterly dip, the trace of the fault plane—that is, the line where the fault plane touches the surface—is not straight. Where it crosses Pennsylvania Gulch it bends far to the east. The bend in the center of Pennsylvania Mountain cannot, however, be accounted for in this manner. This probably represents an actual bend in

PLATE XVI—A. Section of the cliff of Pennsylvania Mountain in Mosquito Gulch, showing the Cambrian quartzite below and the Ordovician limestone above, looking south. Taken just west of the Mosquito Gulch fold-fault. The two branches of the fault reach the cliff at *f* and *f*. (See p. 125.)

B. Section of the cliff of Loveland Mountain in Mosquito Gulch, showing the Mosquito Gulch fold-fault, looking north. The letter *c* appears in two places that represent the bottom bed of the Cambrian quartzite. The fault reaches the top of the cliff at *f*. (See p. 122.)

Colorado State Geological Survey—Bulletin No. 3, Plate XVI, A



B

the fault plane. If the exact location of the trace of the fault plane in the bottom of Mosquito Gulch were definitely known, it would be an easy matter to determine the dip from the amount of divergence of the plane from a straight line in crossing the gulch, and from the difference in elevation of the gulch and the points where the fault crosses the two mountains. As there were no exposures in the bottom of the gulch, the trace of the fault plane as it crosses the gulch had to be approximated. On the assumption that it is correctly located, the dip is about 23°. From exposures on the Pennsylvania cliff it would seem that the dip is more than this.

The name "Mosquito Gulch fold-fault" was selected because of the character of the fault, and because of the beautifully exposed development of the folding on both sides of Mosquito Gulch.

An effort was made to trace this fold-fault across the summit of Loveland Mountain, but without success. Beyond the point where the fault is made to end at the top of the cliff the fault should be seen in the ravine in case it continues in the direction in which it appears to be going, but no indication of such faulting could be found. To judge from the map, it would appear that this fault is the same as the one described above, appearing on the Buckskin Gulch side with an upthrow on the east side of 236 feet. But this is not likely, because of the apparent absence of any fault in the bottom of the ravine in line with this Buckskin cliff fault. Furthermore, this fault is not accompanied by folding.

Just above Buckskin Joe, on the east end of the Buckskin cliff, are two nearly parallel-running fold-faults shown on the map. These two faults are plainly developed and show a remarkable similarity to the double fold-fault described as occurring on the Pennsylvania cliff, and shown in Plate XV. In putting them on the map, it was necessary to exaggerate the size of the fold, as it does not show so plainly on a plan as on a vertical section. Because of the resemblance of these two fold-faults to those on Pennsylvania Mountain, it was conceived that this really represented the continuation of the Mosquito Gulch fold-fault. But an effort to trace the fault across Loveland Mountain did not succeed.

LOWER MOSQUITO GULCH—

In the above descriptions of Loveland and Pennsylvania Mountains, and of the Mosquito Gulch fold-fault, most of the geological features of lower Mosquito Gulch have been fairly completely presented. Except where covered with glacial drift, the rocks of lower Mosquito Gulch below the sedimentary caps are Archean schists and gneisses, similar to those already described. Many of the features of the cliffs on each side of the gulch can best be seen from the gulch below. The intercalated porphyry sheets, as thus viewed from below, are occasionally seen to change their horizon, and to pass to higher or lower beds. An example of this is mentioned by Emmons on page 132 of the Leadville monograph, and a sketch shown in Plate XIV. This is taken just east of the fold-fault on the steep cliff of Loveland Mountain. It shows one of these sheets apparently wedging out in two directions, the thin wedges overlapping each other and separated by a bed of quartzite.*

On the upper end of Loveland Mountain two white porphyry dikes are to be seen cutting up vertically from the underlying Archean through the Cambrian quartzites and the included porphyries and porphyrite, and ending on the flat top above. On the opposite side of the gulch, west of the fold-fault, a dike of porphyrite passes up diagonally through the Cambrian quartzites and through the sheets of porphyry, and connects with the porphyrite sheet above, which, at this point, appears at two horizons for a short distance. From the above observations it follows that the relative age of the porphyries is: first, quartz monzonite porphyry; second, porphyrite; third, white porphyry.

GLACIAL FEATURES—

In the general description of glacial phenomena given in Chapter III, mention was made of the great glacial moraine-ridge that starts on Loveland Mountain about opposite Park City, at an elevation of some 600 feet above Mosquito Gulch, and continues, with constantly decreasing height, to the junction of Mosquito Creek with the Platte River. This moraine was formed by the joint action of the Mosquito and Buckskin glaciers. It does not indicate the extreme height to which the ice went on the sides of Loveland Mountain. Glacial boulders are to be

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* An evident slip has been made in this sketch and in the accompanying description; for these overlapping wedges of porphyry at this point are to be seen, not in the highest, but in the next-to-the-highest sheet, and the lapping should be reversed. That is, the upper wedge should be shown to the east, not to the west.

seen on the east end of Loveland Mountain several hundred feet higher than the upper end of this moraine. On the Pennsylvania side they have been noted at about the same or greater elevation, namely, 11,400 feet. The entire lower portion of the Mosquito valley is deeply buried in glacial drift, as evidenced by the boulder deposit that everywhere forms the valley bottom and sides. That this gravel is of glacial origin may be seen in the characteristic appearance of the surface, with its numerous sunken kettle-holes, sometimes empty and sometimes filled with water.

On the south side of Mosquito Gulch, along the gently sloping ridge that extends from Bald Hill down to the Platte valley, the lateral moraine of the Mosquito glacier assumes the shape of parallel-running ridges with intervening troughs. These, while very pronounced, are not on a scale large enough to show in the contours of the map.

Geologic Sections—

On Plate III are to be found four sections that give the geology of Pennsylvania and Loveland Mountains, and of the region between them. Section C-C cuts across the upper end of Loveland Mountain in a direction somewhat north of east. Section D-D shows the structure of London Mountain and of the middle part of Loveland in a general east-west direction. Section E-E gives a view of the geology of Pennsylvania and the London fault along an east-west line. Finally, Section F-F cuts across both mountains and the intervening Mosquito Gulch in a north-south direction.

BUCKSKIN GULCH

General Description—

Buckskin Creek rises on the main Mosquito Range west of Mount Bross, and drains the country lying between the range and Mount Bross, and between Mount Bross on the north and Loveland Mountain on the south. Like Pennsylvania Gulch, it has cut deeply into the Archean formation between two easterly-sloping mountain masses that carry a cap of sedimentaries on their comparatively flat eastern slope. Because of the similarity of the formations and of the structure to those already described in Pennsylvania Gulch. it will hardly be necessary to enter into a detailed description of this territory.

UPPER END OF GULCH—

The upper part of Buckskin Gulch is almost entirely confined to Archean rocks and to intrusive igneous rocks. The gulch ends in a magnificent amphitheater that lies between Buckskin Mountain and Mount Democrat, on the summit of the Mosquito Range, on the west, and Mount Bross on the east. Of these peaks, Bross and Democrat rise to over 14,000 feet, and Buckskin to within 200 feet of that amount. This amphitheater forms a great glacial cirque, with extremely narrow and sharp ridges on the west and southwest.

The principal rocks of this basin are the Archean schists and gneisses of the district. These are, however, cut by a great variety of intrusive rocks, to which attention was drawn in Chapter III. Toward the upper end of the valley is an irregular mass of granite, that measures about three-quarters of a mile across, and that extends from the summit of Mount Democrat down to the more level floor of the amphitheater. The lower part of this granite is covered with glacial drift, so that the full extent of the intrusion cannot be seen. Below the granite area are to be found the granite-like mass of Lincoln porphyry and the irregular dikes of diorite, of which full descriptions have been given in Chapter III.

In addition to the foregoing intrusive rocks, this amphitheater, like that at the head of South Mosquito Gulch, contains a great number of dikes representing quartz monzonite porphyry, white porphyry and porphyrite. This is particularly true of the sharp, steep ridge that divides Buckskin and North Mosquito amphitheaters. In addition to the numerous dikes that are shown on this ridge, there are many others that could not be mapped because of the small scale of the map, and still many others that are not exposed because of heavy wash. Evidences of the former presence of glaciers in this valley are seen in the beautiful glacial lakes. One of these, to which the name of "Kite-shaped Lake" has been given, is so named because of its remarkable resemblance to a kite. This is very pronounced when looked down upon from the heights on either side. The resemblance is heightened by the stream that flows from the lower end and that furnishes the tail.

On the summit of Mount Democrat, at the head of Buckskin Gulch, is a very small patch of Cambrian quartzite lying on the granite. This little mass of quartzite represents a mere remnant of erosion left from a once continuous quartzite formation that extended across from the quartzite on Mount Cameron. This shows that the sedimentary formations, which are nearly level on the summit of Mount Cameron, continued level as far as the present summit of Mount Democrat, as the quartzite on the two mountains lies at almost the same elevation. On the top of Buckskin Peak is to be seen a similar feature. Here the mountain summit contains merely loose fragments of Cambrian quartzite—the last flickering remnants of a once continuous cap. These fragments on the summit of Buckskin Peak are only a little lower than the small cap on Mount Democrat and a little higher than the Cambrian quartzite on the upper end of Loveland Mountain. This again shows the continuation of a practically level bed of this quartzite that once spanned the entire amphitheater.

LOVELAND SLOPE—

The cap of sedimentaries and porphyry sheets that forms the top of Loveland Mountain presents an appearance on the Buckskin side much like that on the south side of the mountain. The nearly straight line of this cap on the south side is here relieved by a conspicuous bay near the upper end. This forms a well-accentuated hanging valley, with a comparatively level floor that was at one time the bottom of a small glacial amphitheater. At the narrowest part of the gulch, where the sedimentary cap approaches the level of the valley, is the marked fault, referred to above. On the west side of this fault is an unusually large mass of pegmatite that measures 1,800 by 600 feet. A landslide at this point has brought down some tremendous blocks of pegmatite, and left them piled in a chaotic mass at the bottom of the valley.

MOUNT BROSS SLOPE—

On the east and northeast side of Buckskin Gulch the cap of sedimentaries and of igneous rocks is much thicker than on the western or Loveland side. This is because the Ordovician white limestone and the blue limestone of the Carboniferous is added to that of the Cambrian. Also, the porphyry sheets are thicker on the Bross side of the valley. The Archean rocks do not, therefore, rise so high on this side as on the other. On this side of the valley occur intrusive masses and dikes of quartz monzonite porphyry, white porphyry, diorite and Lincoln porphyry, all lying in the Archean formation.

About midway along this slope is to be seen an interesting amphitheater, or broad gulch, to which Emmons gives the name "Red Amphitheater." This is a semicircular break in the wall of sedimentary rocks a thousand feet or more above the valley bottom, and mostly filled with rock debris of various shades of red and yellow. The red color is due to a thin film of iron oxide —a mere stain on the surface of the fragments. The writer was unable to investigate this amphitheater, but Emmons speaks of the marbelizing and of the development of serpentine within the limestones on account of contact with the porphyry intrusions.

Small landslides are to be seen in three places on the Mount Bross slope.

Opposite the large pegmatite dike mentioned above as occurring on the Loveland side are to be seen three unusually large pegmatite dikes on this side of the valley. They are very conspicuous features and extend up to, or nearly to, the Cambrian quartzite.

The Emmons map shows a rather conspicuous fault with upthrow on the west side of the cliff section at the place where these pegmatite dikes occur. It is placed directly after the large fault on the Loveland side, and is spoken of as being a continuation of that fault. The writer was not able to locate any fault at this point, although careful search was made for it.

QUARTERNARY DEPOSITS—

The quarternary deposits of the Buckskin Gulch consist of glacial drift and a few landslides, to which reference has already been made. The drift covers the valley bottom continuously nearly to the head. Elsewhere along the sides of the valley the drift is usually not so thick as to completely cloak the underlying formations. In the lower part of the valley the glacial drift unites with that of the Platte and of the Mosquito glacier to cover the entire country, except for a very narrow streak along the bottom of the gulch immediately above the town of Alma, where the stream has succeeded in cutting through the drift and in exposing the underlying Weber grits. The highest point to which the glacial moraine attains on the Loveland side of the valley at the east end of the mountain is 11,300 feet.

GEOLOGIC SECTIONS—

East-west sections across Buckskin Gulch are represented on Plate II on Sections B-B, C-C and D-D; and a north-south direction on Section F-F.

MOUNTS LINCOLN, CAMERON AND BROSS

GENERAL DESCRIPTION—

The highest part of the territory embraced in this survey is that covered by these three summits. They really form one massif that stands out separated from the main range by the deeply eroded valleys of the Platte River and Buckskin Gulch, and is partially connected by the saddle between Mounts Lincoln and Democrat. The three peaks that form the highest part of this high mountain massive lie close together, the most distant, Lincoln and Bross, being not over a mile and a half apart; Cameron forming virtually a second summit on Mount Lincoln. Lincoln and Cameron are over 14,200 feet, and Bross only a hundred feet lower. A great, deeply cut valley, with steep, mountainous sides, called Cameron Amphitheater, deeply dissects this massive on the east side and nearly cuts it in two. This valley lies between Bross and Lincoln, and has cut back so far that only a very narrow ridge is left connecting Bross with the two other summits. Nearly the whole of this mountain mass—except the eastern foothills, covered mostly with glacial drift—lie above timber line. On the north and west, and on the sides of Cameron Amphitheater, the excessively steep slopes and the heavy covering of rock debris render geologizing extremely difficult. The more gentle eastern slope, on the other hand, is much more readily accessible and, except for the equally heavy covering of wash, not particularly difficult to map.

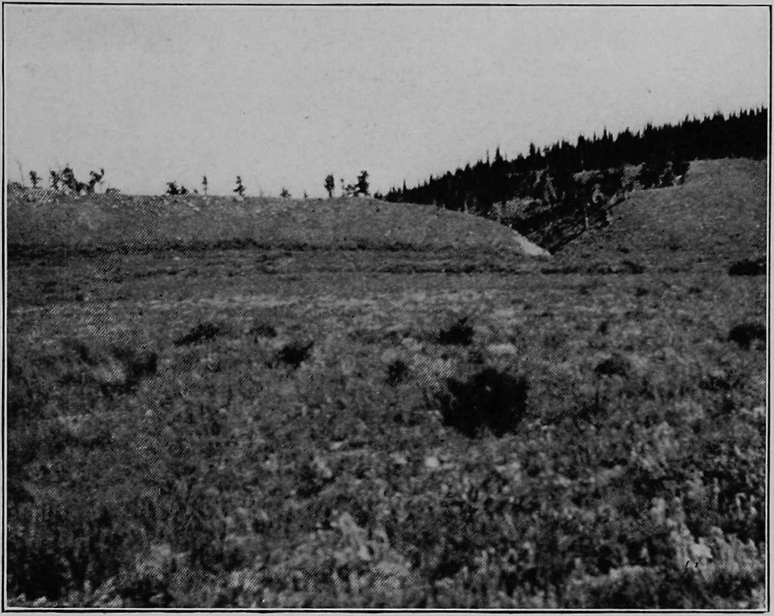
The Emmons survey appears to have devoted more time to the study of this portion of the district than was the case with the more southern parts, and very excellent descriptions of the formations and of the topographic features are to be found in the Emmons monograph. Many changes, however, will be found in the map accompanying this present report, so that a description of such features is necessary. In general, the reader may be safely referred to the description given by Emmons as covering the ground in a satisfactory manner.

ARCHEAN—

The Archean formation everywhere encircles this mountain massif on the west and north, and is to be seen forming the bottoms and sides of several amphitheaters or valleys that cut into the massif on the east side. The principal indentation by the Archean on the east side is found in the deep-cut Cameron Amphitheater. The Archean occupying the floor of this valley is

Plate XVII—A. View of the top of the west lateral moraine of the Platte River glacier forming a dam across Dolly Varden Gulch at Mineral Park on Mount Bross. The stream has cut through the moraine and drained the meadow. (See p. 141.)

B. Pine trees distorted by the winds at timber line on Windy Ridge, east slope of Mount Bross.



B

over a mile and a half long, and about half a mile wide. Around the sides of the valley the Paleozoic sedimentaries form a cap similar to the caps on the summits of Pennsylvania and Loveland Mountains. Owing, however, to a steepening in the dip of these sedimentary rocks near the lower part of the eastern slope, they dip down beneath the level of the amphitheater floor and cut off the Archean at about 12,000 feet elevation; for this reason the Archean area is entirely isolated from the main mass of the Archean. On a much smaller scale the same is true of the gulch that drains the eastern slope of Mount Bross. Here, too, is a small, isolated Archean exposure in the bottom of the valley, that is cut off on the lower side by glacial drift and by the Weber grits, which here have been deposited apparently directly on the Archean.

In a third very narrow gulch, the Dolly Varden Gulch, that runs in a southeasterly direction from the summit of Mount Bross, the small stream has cut down through the Carboniferous, Ordovician and Cambrian formations, and has exposed for about a thousand feet a narrow strip of Archean rocks in the bottom.

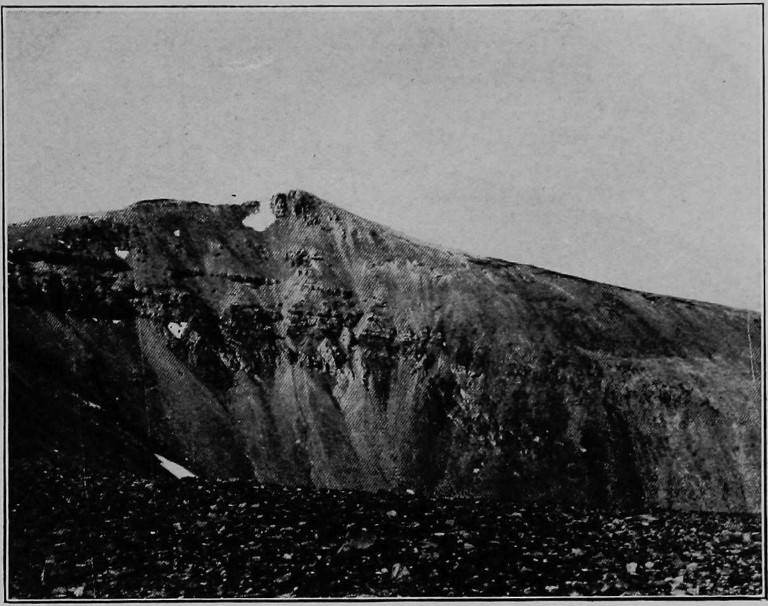
CAMBRIAN—

The Cambrian quartzites almost completely encircle in an irregular, indented line the entire mountain massif. The porphyry sheets that form so conspicuous a feature of the Cambrian around the edges of Pennsylvania and Loveland Mountains are mostly absent here. The ring of Cambrian beds on the east side of the mountain is seen to be at a much lower level than it is on the west side, thus indicating an easterly dip. This dip, however, fluctuates considerably. On the highest parts of the mountain massif the dip is nearly horizontal, as is the case with the overlying sedimentary beds. Toward the east the dip becomes steeper, until it reaches 15° to 20°. On the north side of Cameron Amphitheater is a magnificent cliff section, or rather two such sections—one at the upper end beneath the summit of Mount Lincoln, the other nearer the eastern end. Along this whole side the Cambrian beds contain an intercalated sheet of porphyry. Other porphyries also may be seen in these cliff sections in the form of dikes, sometimes cutting this sheet, sometimes cut by it. (Plate XVIII, A, shows the western, B, the eastern, cliff under Mount Lincoln.) On the west side of Cameron a thick sheet of porphyry also appears in the Cambrian. It is not known how far this sheet extends, and the steep slope and heavy wash prevented fol-

PLATE XVIII—A. View of the cliff below the summit of Mount Lincoln and at the upper end of Cameron Amphitheater. The rock at the peak is Lincoln porphyry. The cliff is mainly Cambrian quartzite, with intruded porphyry sheets. (See p. 135.)

B. The easternmost cliff on the north side of Cameron Amphitheater. The lower part of the cliff is composed of Cambrian quartzite, the upper part of Ordovician limestone and of Carboniferous "blue limestone." (See p. 135.)

Colorado State Geological Survey—Bulletin No. 3, Plate XVIII, A



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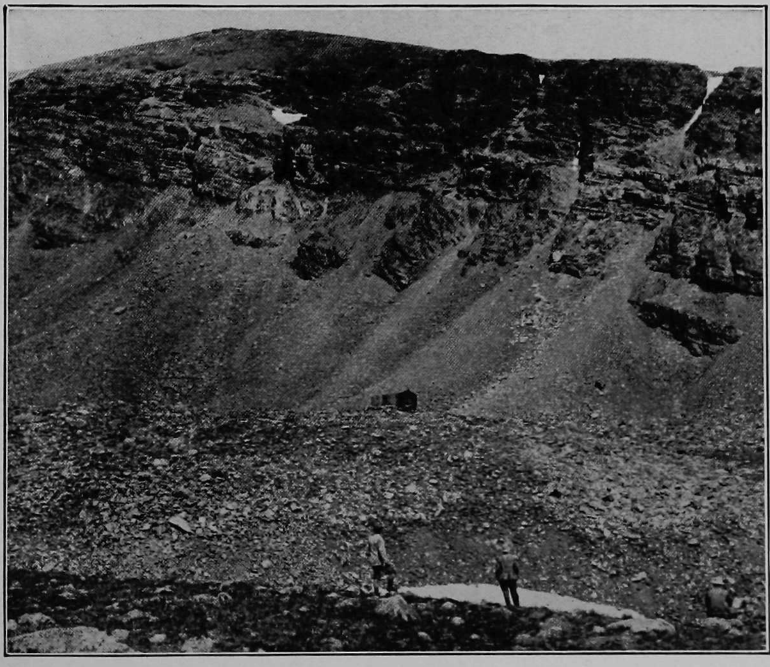


lowing it for any great distance. Another sheet of apparently small extent is to be seen in the Cambrian west of the south peak of Mount Bross. Finally, on the Platte valley side, on the eastern slope of Mount Lincoln, a number of very narrow dikes and sheets cut the Cambrian beds.

ORDOVICIAN—

The white limestone of the Ordovician encircles the mountain massif somewhat similarly to the Cambrian. It is, however, somewhat more inclined to spread out and form wider areas on the flatter parts of the mountain. For instance, below Cameron Amphitheater, to the east of the Cambrian strip, is a wide exposure of this rock. The "parting quartzite" that forms the top of the Ordovician fluctuates considerably over the area covered by this mountain massif. As already stated in Chapter III, it is entirely missing along the cliff section below the summit of Mount Lincoln. Also, it is missing on the cliff on the south side of the Archean area in the small amphitheater east of the summit of Mount Bross. Whether it is missing in the intermediate district has not been determined. It apparently thickens toward the south. The Ordovician limestone does not appear to carry ore in this region, as it does on Loveland Mountain and on Pennsylvania Mountain.

BLUE LIMESTONE—

The blue or Leadville limestone of the Carboniferous covers considerably more area than does any other formation. It appears on the surface over large parts of the higher as well as lower parts of Lincoln and Bross. It appears to be more closely associated with the large intrusive masses and sheets of igneous rocks than is the case with the other sedimentary formations. This limestone is very difficult to distinguish from the white limestone beneath it. As stated elsewhere, it becomes very coarse-grained and changes to a white color in many places, especially in the vicinity of mineral veins, and probably in the vicinity of large porphyry intrusions. These peculiarities are very pronounced in many places in this particular portion of the Alma district. It seems peculiarly liable to brecciation. This is well seen on the ridge between Cameron and Lincoln. Not infrequently dike-like or vein-like masses of quartz are to be seen in this limestone, and serve to distinguish it from the white limestone. One particularly pronounced case is to be found in Dolly Varden Gulch, at about 11,600 feet elevation. In the southern and southeastern parts of Mount Bross appears the largest continuous area of the blue limestone. Over the greater portion of this area, however, the limestone formation could not be detected without the assistance of prospect shafts. From about the 12,100-foot level up to the Lincoln porphyry sheet above, a horizontal distance of some half a mile and a vertical distance of 600 feet, the whole surface is so deeply covered with the porphyry float as completely to cover and obscure the underlying limestone. This is undoubtedly due to the comparative ease with which the limestone float fragments may be destroyed by weathering or by solution, and to the resistance offered by the porphyry. This instance well illustrates the difficulties under which the geologist works in mapping a region where the forces of disintegration are very active.

WEBER GRITS—

The Weber grits are extensively developed along the lower parts of this mountain mass, but here they are mostly buried in glacial drift and appear only in small, isolated spots. On the lower southeastern slopes of Mount Bross, however, this formation sends two spurs some distance up over the blue limestone. These grits also form, in connection with intruded masses of Lincoln porphyries, the highest parts of Lincoln and Bross. As already stated, the dip of the sedimentaries on the summit of these two mountains is nearly horizontal; consequently these grits appear both on the east and on the west sides of Lincoln and Bross. Ordinarily the Weber grits appear to lie conformably on the underlying blue limestone. One exception to this appears in the gulch that slopes east from the summit of Mount Bross. Here, as already stated, the Archean is limited below by the Weber grits. In other words, the Weber grits lie directly on the Archean. Although the relationships of the sedimentary formations at this point are somewhat uncertain, the Weber series appears to lie unconformably over the Cambrian, Ordovician and Carboniferous blue limestone at this place. This unconformity seems very unlikely, considering the marked conformity as a general rule; but there seemed to be no other way to interpret the formation as exposed.

PORPHYRIES—

As will readily be seen by the map, the Lincoln porphyry plays a very large role in the geological structure of Mount Bross. Although the name was given because of its occurrence on the summit of Mount Lincoln, the area of this rock on that mountain is very small. On the other hand, it covers a large extent of territory on the summit and along the south ridge of Mount Bross, and on the lower southeast flank of that mountain. In Dolly Varden Gulch it is seen cutting through the Cambrian and Ordovician as a dike. It appears to occur as irregular laccolithic sheets that do not keep to any one horizon, but are found most commonly at the contact between the blue limestone and the Weber grits. The large, isolated masses seen on the lower slopes of Mount Bross, and continuing down to the Platte River valley, are very likely more or less directly connected, and may be parts of one, or perhaps two, intrusions. On the west slope of Mount Bross, to the west of the tongue of Lincoln porphyry that extends along the ridge to the south of the summit, there are several sheets of porphyry, much finer-grained than the Lincoln porphyry, that are too numerous and thin to be shown on a map of small scale. These are confined largely or entirely to the Weber grits.

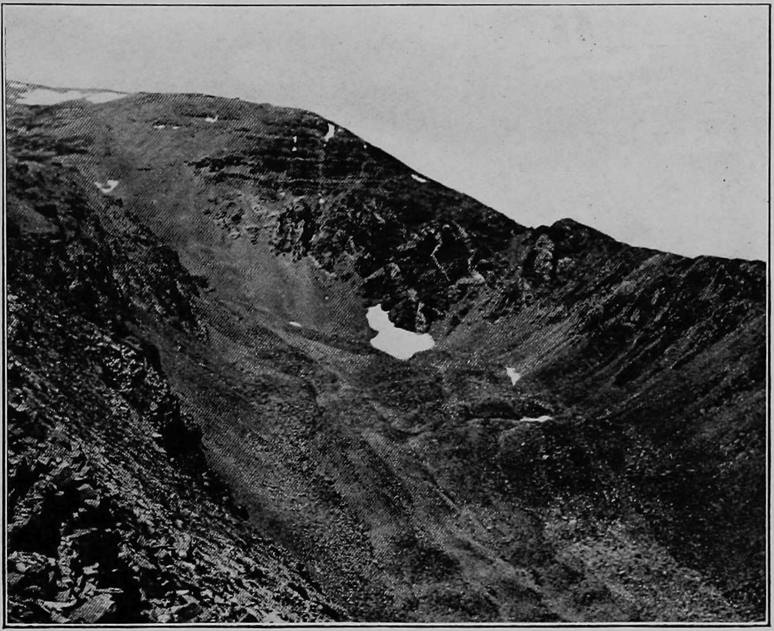
Porphyries of different type from the Lincoln porphyry are not abundant on Mount Bross. On the other hand, Mount Lincoln, and especially the eastern ridge of that mountain, is cut with numerous porphyries of greatly varying type, including quartz monzonite porphyry, white porphyry and porphyrite. Of these, the white porphyry seems to be the youngest, as two dikes are seen cutting through the quartz monzonite porphyry.

QUARTERNARY—

Glacial Drift.—The great mountain massif of these three mountain summits was one of the greatest centers of glacial activity in the Alma district. The Platte glacier was partly fed by ice from the northern and western slope of Mount Lincoln. A large stream of ice occupied the whole of the Cameron Amphitheater, but it apparently did not joint the main stream of ice coming down the Platte valley, as the rocks immediately below this amphitheater are not covered completely with glacial drift. A small glacier seems to have formed in the gulch to the east of Mount Bross and to have joined the Platte valley stream. There was no glacier, however in Dolly Varden Gulch. In the short, narrow and very deep valley, called Lincoln Amphitheater, on the east slope of the mountain of that name, there was a very vigorous glacier that left clear evidence of its action in well-preserved glacial striæ on the rocky walls to the north. (See Plate XX for a photographic reproduction of these striæ on a

PLATE XIX—A. View of the rock stream in Lincoln Amphitheater. The rock stream covers the bottom of the glacial valley. Talus has partly obscured it on the sides. At the head of the valley is the steep cliff from which the rock stream came. At the bottom is Archean with pegmatite dikes; at the top, Cambrian, Ordovician and Carboniferous strata. (See pp. 46, 62, 141.)

B. The lower end of the rock stream shown in A, looking toward the south. (See pp. 62 and 141.)



B

banded gneiss that forms the north wall of this amphitheater.) The morainal deposit that covers the lower part of this mountain massif on the west side of the Platte valley was left there by the Platte glacier, reinforced by tributary streams from the sources just mentioned. Where the glacier passed the mouth of Dolly Varden Gulch, it blocked up the gulch and left a very sharply developed lateral moraine athwart the course of the stream. This damming of the valley by a lateral moraine later caused the partial silting up of the valley immediately behind the dam, and the formation of a roundish mountain meadow that goes under the name of Mineral Park. Later the stream of Dolly Varden Gulch succeeded in cutting its way through the morainal dam. Plate XVII, A, shows this morainal dam and the new gulch cut through it by the stream.

The above-mentioned Lincoln Amphitheater presents an admirable illustration of a hanging valley, 800 feet above the level of the main Platte valley. This hanging valley was filled with a local glacier that was not powerful enough to cut downward to any great extent; consequently it remained suspended, as it were, while the great Platte glacier was scouring out the valley to its present level. The difference between the level of the Platte River at Montgomery and that of the floor of this hanging valley—800 feet—is a measure of the down-cutting of the Platte glacier. (See Plate IV, frontispiece, which is a photograph of the Mount Lincoln massif, and which shows this hanging valley with the floor covered with a rock stream.)

Landslides and Rock Streams.—There are no landslides of consequence on the east or north side of these mountains. On the west side, well down toward the Buckskin valley floor, three such slides have been mapped. In Lincoln Amphitheater there is a very interesting example of a rock stream, to which attention has already been drawn in Chapter III. At the head of the valley, where the contours are crowded close together, is a bare, ragged and excessively steep mountain slope, composed of black-looking Archean schists and gneisses, gashed with light-colored streaks of pegmatite. Higher up are seen the Cambrian and other sedimentary rocks. As the rock stream rushed down from this already steep slope, it gained sufficient headway to carry the stream for over half a mile, where the lower end rests just at the edge of a precipitous declivity. At this lower end this rock stream is about 100 feet thick. The end and side are as steep as the angle of repose will allow. Plate XIX shows two photographs of this rock stream, the upper figure giving a full view looking endwise. At the head of the valley may be seen the white gashes produced by the pegmatites. The sides of the stream are somewhat obscured by talus from the over-steep glaciated sides of the valley. This photograph also brings out the steep sides of a glaciated valley that doubtless had a marked U-shape before the floor was covered by the rock stream. The lower figure shows the lower end of the rock stream looking from the north.

GEOLOGIC SECTIONS—

The sections shown in Plate III that apply to this mountain massif are A-A, B-B, C-C and F-F. The first three are east-west, the last-named a north-south section. In Sections A-A and B-B the change from a flat to a steeper dip of the sedimentary formations midway down the east slope of Lincoln and Bross is clearly brought out. It is this change of dip that accounts for the isolated exposures of the Archean in Cameron Amphitheater and in the gulch to the east of Mount Bross. Section F-F gives a good idea of the extreme steepness of Mount Lincoln and of the great drop from the summit to the bottom of the Platte valley. These sections are drawn with the same vertical and horizontal scale.

THE PLATTE VALLEY

ABOVE MONTGOMERY—

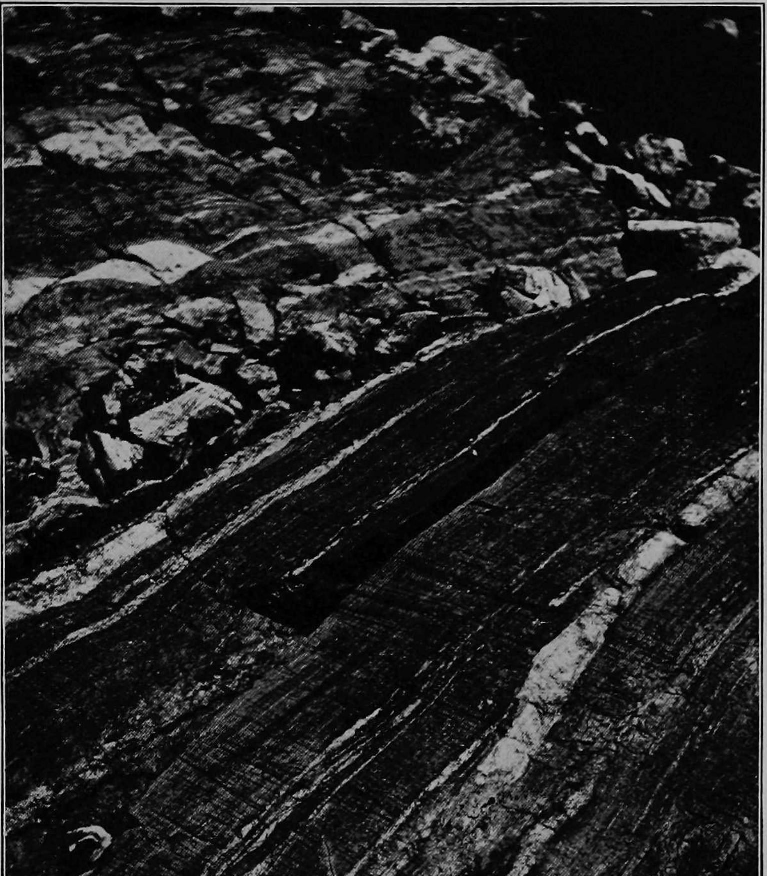
The Platte valley can well be divided into two parts, based on difference in geological structure and rock formations. This division is made at the edge of the Archean formation at the old mining town of Montgomery. The upper part of the Platte valley forms a magnificent semicircular sweep around the Mount Lincoln massif. The head of the valley is to be found directly west of Mount Lincoln. From here the stream flows north; then gradually, in a remarkably uniform circle, swings around the mountain, until it flows to the south about two miles below Montgomery. As above stated, the valley above Montgomery is composed entirely of Archean rocks. At the upper part of the valley, in the region of the great glacial cirques, granite forms most of the rock surface. This is a fine-grained two-mica granite, and has been fully described in Chapter III. The gneisses and schists and, to a lesser extent, the granites are cut by a large number of dikes, some of which attain considerable size. These consist of quartz monzonite porphyry, porphyrite and white porphyry. Where dikes of different character cut each other, the white porphyry appears to be the youngest. As one approaches Montgomery from above, the Paleozoic sedimentary rocks gradually approach to the valley level. The lowest of these, the Cambrian, is seen to contain a sheet of porphyry. This is particularly pronounced on the north side of the valley on the south slope of North Star Mountain. On the Lincoln side the corresponding sheet appears high up on the south wall of Lincoln Amphitheater.

Glacial features are very strongly in evidence immediately above Montgomery. In the first place, the valley has a marked U-shape, so characteristic of glacier-worn valleys. This seems to be particularly pronounced on the Lincoln side, where the side of the mountain is very steep. On this same side the lower part of the rocky mountain-side is pronouncedly smoothed by glacial action, and presents a strong contrast to the higher parts of the same mountain slope where the surface is rugged and deeply furrowed by aerial action. Also, on the bottom of the valley there are to be seen good examples of roches moutonnées, with the rounded knolls polished and deeply grooved by the glacier. From the height to which these glacial markings go, the ice must have been over a thousand feet thick, so that the small glacier occupying the hanging valley of the Lincoln Amphitheater joined the Platte glacier at or above the level of this amphitheater. At the head of the Platte valley, on the north side, are two beautiful examples of rock-rimmed glacial lakes, occupying the scooped-out hollows in the rocky floor. These are the Upper and Lower Wheeler Lakes.

BELOW MONTGOMERY—

The valley from Montgomery down is covered deeply with glacial drift, and this in turn, close to the stream, is covered with a narrow strip of alluvial wash. About a third of a mile below Montgomery the river has cut a path through a thin covering of drift some distance into the rock formations beneath. Both Cambrian quartzite and Ordovician white limestone are exposed at this place. From this place down the valley, after passing over a narrow strip of Carboniferous limestone that is covered with drift, the entire valley floor doubtless lies on the Weber grits. These, however, are exposed only occasionally in small patches. That these grits contain dikes and sheets of porphyries is shown by the occasional appearance of a small outcrop of this rock. The above-described condition holds for both sides of the valley. On the east side there is at least one strong

PLATE XX—Banded gneiss with glacial striæ. Taken on the north side of Lincoln Amphitheater, near the lower end of the rock stream. (See pp. 37 and 137.



sheet of porphyry that bears a close resemblance to the Lincoln porphyry, and that might, perhaps, have been so mapped; but the feldspar phenocrysts are much smaller than is the case with the more typically developed rock. The presence of this strong sheet is inferred from the occurrence of frequent outcrops along a certain horizon in the grits. The sheet is not mapped as such, because of the heavy covering of glacial drift.

On this same side of the valley there were also found outcrops of a fine-grained porphyry without any visible phenocrysts. While this porphyry bore no external resemblance to the other porphyries of the district, it proved to be a quartz monzonite porphyry.

In the extreme northeastern corner of the map, at Hoosier Pass and beyond, the Weber grits are exposed free from glacial covering, and a large mass of porphyry occupies the lower slope of Silverheels Mountain. This last-mentioned rock also proved to be a quartz monzonite porphyry, not dissimilar to most of the others described from this district.

Another large area of Weber grits is to be seen on the southern end of the ridge, to the east of the Platte valley above Alma.

Opposite the town of Alma the glacial drift is very thick. It shows on the surface the characteristic hummocky surface of glacial ground moraines, with occasional deep kettle-holes. It is of interest to note that this glacial gravel, that has no apparent stratification, has been extensively worked as placer ground.

GEOLOGIC SECTIONS—

The following geologic sections on Plate III apply to the Platte valley: A-A, B-B, C-C, D-D, E-E. These are all east-west sections across the entire territory mapped.

CHAPTER V

HISTORY OF THE MINING INDUSTRY IN THE ALMA MINING DISTRICT

BY ARTHUR J. HOSKIN

EARLY PLACER WORKINGS

This district came into existence in 1861, and it hence dates back to the pioneer days of the state. It was then that prospectors were roaming this wild, rough part of the Rockies, searching for gold in the alluvials. Much has been written concerning the finding of this yellow metal in the various regions of what is now Colorado, and it is generally conceded that there were discoveries being made in rapid succession from east to west across the mountainous country. Finds were reported almost simultaneously at Gregory Gulch and at Jackson's Bar, these two localities being subsequently named, respectively, Black Hawk and Idaho Springs. It is said that the overflow of prospectors from the present counties of Clear Creek and Gilpin spread westward, and that this accounted for the settlement of all the other pioneer mining districts in Colorado.

The whole domain now included in the State of Colorado was commonly spoken of in those days as the "Pike's Peak Region," there being little idea in the minds of the eastern citizens as to the real geography of the West, except that it contained this famous mountain. The hardy prospectors who worked their way overland to the Front Range and foothills of the Rockies soon paved the way for more and more of these people, and the overflow above mentioned began. Soon the first range of mountains had been explored, and the beautiful South Park country came in for its share of investigation. The gulches along the western side of the park soon demonstrated their valuable contents, and the search continued over the next ranges—the Mosquito Range and the Continental Divide or Sawatch Range. The discoveries of gold in the western portions of Colorado followed as a natural consequence in due season. The discoveries of placer gold at Tarryall, Fairplay, Alma, Breckenridge and California Gulch (Leadville) occurred during this general free-for-all prospecting indulged in by persons from eastern states, and it is a noteworthy fact that many of the greatest finds were made by men who had never before had any experience in such lines.

It is stated that the discoveries thus made in Colorado were by men who were working their way overland to the California fields, which had come into prominence a decade before. The gulches of Colorado afforded splendid opportunity to the pioneers for experimenting in this new line of occupation. California Gulch was given its name for the simple reason that the discoverers of the abundance of gold in the bed of this stream were satisfied to discontinue their journey to the western coast; for they had found an El Dorado.

Although this report is intended to cover only what is generally termed the Alma district, it seems desirable to approach the history of this particular district through a brief explanation of the settlement of a very close neighbor, the Fairplay district. The first actual mining in the entire area now commonly known as South Park was in Tarryall Creek, a few miles from Como. This locality was first occupied by prospectors originally from Wisconsin, but who worked their way over the mountains from Gilpin County. It seems that they met with a certain measure of success at Tarryall, which name was given the camp from the decision of these weary men to stop here and rest awhile, before proceeding farther westward. To us, living as we are under such changed general conditions, it is difficult to understand how the news of the success of these few men spread as it did to the outside world; for there were absolutely no means of communication or of transportation except on foot or through the use of plodding animals. But the news did spread very soon, and the population of the gulch was quickly augmented by later arrivals, who were promptly disappointed at finding all of the desirable alluvial ground taken up by the first contingent of prospectors, who refused to share with these newcomers. The story goes that the reception was quite contrary to the greetings for which the West subsequently became famous, and the unwelcome men left, determined that they would share fairly with any other prospectors, should they prove successful in finding another desirable field for placering. They soon found their luck in the gravels of the South Platte River, where it issues from the mountains into the prairie country on the west edge of South Park; and their camp was named, in token of their resolve, Fairplay. These discoverers are credited with living up to their promises. This town of Fairplay is now the county seat of Park County. There has not been a great amount of lode mining that can be considered as tributary to Fairplay, which has always been known as a placer-mining district. Hydraulicking has been conducted here for many years, during the summer months. Vast beds of gravel, which are very probably of sufficient value to be minable, exist for a number of miles above and below the town of Fairplay. Lode mining is carried on to some extent in the Mosquito Range to the west of Fairplay, and this town is the natural distributing center for supplies to this industry; but the mines thus operated do not lie within the area covered by the Alma report and will not be described, although one or two of them are noteworthy.

The very first operations within the area reported on herein were naturally those of hydraulicking, and occurred almost contemporaneously with those at Fairplay. The pioneer prospectors worked up-stream from their first discoveries, and this brought them to the present site of the town of Alma, which is along the South Platte River and about six miles above Fairplay. Gold was found not only in the gravels of this river's bed, but also in the beds of all the small gulches feeding into the Platte River.

Directly at the present site of the town of Alma some of the earliest operations in this district took place. These consisted of panning, cradling and sluicing in the alluvials along the Platte River. Subsequently very extensive hydraulicking was carried on in this same locality. However, it does not appear that any settlement worthy of the name was made here until years after the discovery of this placer ground. It would appear that the prospectors kept working up-stream, and that the first "camp" established was that of Montgomery, some six miles above Alma. In a book written by Mr. O. J. Hollister, and published in 1867 under the title, "The Mines of Colorado," may be found the following mention of this town: "Overshadowing the picturesque little village of Montgomery stands Mount Lincoln, this mighty monument of the Almighty's handiwork." It may be remarked here that Mount Lincoln, then including the three peaks now known as Bross, Cameron and Lincoln, was named in honor of President Lincoln, whose assassination occurred contemporaneously with the settlement of this region. Montgomery was the first town to receive mention in the reports made by Horatio C. Burchard, former director of the United States Mint. As early as 1882 his annual report states that this town "is deserted," thus leaving the inference that it had seen flourishing times prior to that date. However, in Burchard's very next report (1883) he mentions a revival of activity at Montgomery. Subsequent history explains numerous but brief periods of revival, and it now appears that the old town is in one of its deserted stages.

In 1882 the Alma Placer Mining Company owned 640 acres of alluvial ground adjacent to and southeast of the town of Alma. During the summer months of that year twenty-two men were steadily employed at hydraulicking in pits having an average depth through the gravel of sixty feet. One four-inch and one six-inch nozzle were used, and the material was washed through sluices aggregating 3,000 feet in length. It is further reported that a portable derrick, capable of handling boulders of a maximum weight of ten tons, was part of the equipment of this then rather extensive placer mine. The town of Alma had been established at this time.

One very notable location of placering in the very early days was in Buckskin Gulch, about one and one-half miles above its junction with the Platte River. A certain Joseph Higginbottom, bearing the nickname of Buckskin Joe, was the first prospector in this gulch and gave it his name. It is said that he found gold here in 1860, but there seems good reason to doubt this date. His discovery was probably in 1861. While "gulch mining" was carried on in all of the stream-beds of this region, the operations in Buckskin Gulch are significant in the fact that they were responsible for the very first lode mining in this part of Colorado. At the point of the best finds of gold in this gulch by Buckskin Joe, it happened that the bed-rock itself was found to be unusually rich in gold, and was presumably responsible for much of the enrichment of the stream-bed below that point. Investigation proved the existence of large masses of ore within this rock, and lode-mining claims were immediately laid off and "quartz mining" was instituted. A rush followed these discoveries, and in 1861 the townsite of Buckskin Joe was laid out. A post-office was established here, under the name of Laurette, to receive the occasional, belated lots of missives from the outside world.

LODE CLAIMS—PRIMITIVE MINING

The first lode claim—that covering the ore-body mentioned above—was named the Phillips. The rapid success of this mine was such, it has been reliably reported, that about $300,000 was recovered from it within the first two years of its discovery. The Excelsior and Orphan Boy mines were discovered soon after the Phillips. Arastras were the first devices used in the treatment of the ores, which were thoroughly oxidized and carried the gold in a free or easily recoverable state. Some primitive stamp mills were next introduced, but their use was of short duration, for the bodies or shoots of ore, although very rich and of easy treatment in the oxidized portions, proved to be of limited extent, and materials that could be handled profitably with the crude facilities at hand were soon exhausted. The town of Buckskin Joe had grown to something over a thousand inhabitants within a year, and had been made the county seat of this one of the original nine counties of the Territory of Colorado, which was created in 1861. But it is said that the exodus was much quicker than the settlement; for, within the year 1863, the town became quite deserted, and the county seat was transferred to Fairplay, where it still remains. There has never been a rehabitation of Buckskin Joe. One can now find only a few rotted logs and piles of stones to mark the sites of the many cabins that once were so plentiful in this gulch.

The town of Alma came into existence some twelve years after the settlement of Montgomery and Buckskin Joe, or about 1873. The operation of various individual mining companies was responsible for the starting of several mining hamlets here and there throughout the district, these rapidly built and transitory settlements being generally referred to among mining men as "camps." Among the camps of this district there were Park City, Dudley, Mosquito, and Quartzville. All that remains of Mosquito and Quartzville is dilapidated foundations and the ruins of stone fireplaces of the log cabins that have long since disappeared either by decay or for firewood. Two or three miserable buildings usually stand as specters of each of these deserted villages.

Dudley was built as the headquarters of a single mining company—the Moose. Quartzville sprang into being chiefly through the activity of this same company, which owned and located the famous Moose mine well up on the top of Mount Bross.

The discovery of silver in this district was in this Moose mine, which was quickly developed after its discovery in 1871. The Dolly Varden mine was located very soon after the Moose mine, and not far from it. The district seemed immediately to turn its principal attention to silver mining, and there was thus inaugurated a third era in the mining history of the district. So remarkable were the finds in these first two silver mines that numerous other good silver discoveries were soon made. According to reliable government reports made at that time, the production of silver from the mines of Mounts Bross and Lincoln, by the close of 1878, was about $3,000,000, the Moose mine itself being credited with one-third of this amount. During the same five or six years the Dolly Varden mine produced approximately $300,000 in silver. The Russia mine, on Mount Lincoln, was producing ore that was reported as averaging $500 per ton. Of course, in our present consideration of these figures, we must bear in mind the fact that metallic silver maintained a much higher market value then than it has of recent years.

Without entering into a description of the Moose mine at this time, it is given mention here because, as stated above, it was the operation of this property that caused the settlement of the towns of Dudley and Quartzville. The mine being situated at the lofty elevation of over 13,700 feet, on the bleak northern exposure of a perfectly bald, steep mountain, where there is little or no water obtainable, it was impracticable to establish a mining camp near by. The miners therefore built their cabins at an altitude 2,000 feet lower, in a pretty gulch where there was plenty of water and firewood. This was Quartzville. It also was the home of miners and prospectors who were working other properties, some of which were right in the camp. We may still find remains of primitive milling and mining plants for handling the oxidized ores that were readily obtained and that yielded their gold contents. The miners who worked in the Moose, it is said, were unable to reach the scene of their labors earlier than ten o'clock for the day shift, and, when they did reach the mine, they were so fatigued by their hard climb that they were able to do very little effective manual labor. Despite such adverse natural conditions, the plan was in force for a number of years. However, with the exhaustion of the known, rich bodies of ore, the operation of the mine became intermittent. Its activity fluctuated for years, until the year 1893, when the demonetization of silver effectually closed the productiveness of the property.

The town of Quartzville was at a disadvantage in the fact that the wagon-road reaching the place from the main centers of civilization was necessarily one of difficult construction and repair. The camp rapidly declined when the operations of the silver mines ceased; for it could not retain any claim as a center for general mining activity. It is claimed by persons who lived in Quartzville during its best days that there were at least one thousand inhabitants.

Dudley was built up, as said, to be the headquarters for the Moose mine. Here were erected the local office, assay office, sampling works, and, during the later life of the mine, a one-furnace reverberatory smeltery. A hotel and numerous homes and stores made this little town a lively one until the final closing down of the mine. Recently the Moose owners have rebuilt the office building and equipped it with a modern assay outfit, but no actual renewal of mining has occurred.

The second time that Montgomery had life was in consequence of the search for and the treatment of ores from the schistose formation of the upper Platte region. Many fissures in the schist of Mount Lincoln and North Star Mountain were developed, and several very pretentious mills were erected along the river, where there is always an abundance of good water for milling purposes. Among the mines that formerly contributed to the business and population of Montgomery were the Present Help, Occidental, Orion, D. H. Hill, Wilson, Taylor, Nova Zembla, Kansas and Tippecanoe. Some of these were silver mines in the sedimentaries of upper Mount Lincoln, but others were of the gold-bearing, fissure type in the schists on both sides of the Platte River above Montgomery. While it does not appear that any of these gold mines in the schist proved of much permanence, it is a fact that most of them did produce very rich ores close to the surface. One such mine, the Sovereign, is credited with having made a profit of $7,000 in thirty days, treating its output in a little, inefficient, primitive mill at Montgomery.

The veins above mentioned are of the true variety, in that they pass through various geological formations. Several mines were opened in the fissures where the walls were Cambrian quartzite, and among those that proved notable was the Atlantic, on North Star Mountain. In this claim there was worked, during the early days, a two-foot vein from which the ore averaged $35 per ton, according to report.

But the veins in schist failed to live up to appearances, and there was a gradual shutting down of mining—and hence of milling—operations. Stamp-mills were the prevailing type of plant. Later in the camp's history there was erected a thirty-ton cyanide leaching-mill, and this still remains in fine preservation. It contains ten stamps, amalgamation plates, two Wilfley tables, and other apparatus for dressing the ore before leaching. Both steam and water were used as power for driving the machinery. The erection of all of these mills was quite unwarranted; for they were all built prematurely, or before the true conditions of these attractive-looking veins had been demonstrated. They now stand as awkward monuments to this folly.

Park City was a camp established in connection with operations at the Orphan Boy mine, in Mosquito Gulch. It now presents the best appearance of all the former active little towns in the district, and contains a handful of inhabitants at this writing.

In addition to the camps that have been of sufficient import in the development of the region to be remembered by name, there have been many tiny settlements that sprang up in the immediate vicinity of particular mines, when such mines were so situated that hamlets could be established.

The town of Alma, now the main center of business in the region covered by this report, did not come into existence, as already explained, until early in the seventies. The town is not on a railroad line, the station bearing the name of Alma being about one mile south of the town at the terminal of this branch of the Colorado & Southern Railway. The station is shown in the southeast corner of the map. It is about five miles northwest from Fairplay.

Years ago, during the active days of operation of the great London mine, an extension of this narrow-gauge railroad line was built from the Alma station to the London mill, which is about seven miles up the North Fork of Mosquito Creek. With a change in the site of the main opening of this mine, the railroad was abandoned, and it has been going into decay for years.

Alma is credited with a population of 300; and this is probably correct, if we consider this population as including all persons who obtain mail through this post-office. Although the area of the district is over fifty square miles, there are very few persons in the hills, and the activities of mining are also few.

Beside the smeltery at Dudley, mentioned above, there was a similar plant erected at Alma, in very early days, for the local treatment of custom ores. This constituted a branch of the business interests that owned the first smeltery in the state (at Black Hawk), and to which the earliest ores of this district were shipped by wagon. The wagon haul from this district to Black Hawk was often by oxen, and the cost necessarily very high. The two plants were subsequently closed down and consolidated into one large smeltery at Argo, near Denver. The company owning these plants was the Boston and Colorado Smelting Company. The Alma plant must have treated a considerable tonnage, if we may judge from the remaining piles of slag. From time to time, in later years, shipments of this slag have been made to more modern smelteries, in the expectation of recovering metals which were presumed to have been lost in smelting by the pioneer metallurgists; but it is a natural inference that the discontinuance of such shipments bears testimony to a higher grade of metallurgical practice than was attributed to these pioneers.

The owners of the Fanny Barrett mine, on Loveland Mountain, erected a small smelting plant at Alma in 1880-81. The operation of this plant was of short duration, and the ore treated was probably only that from the company's own mine.

In the summer of 1910 there was blown in a modern smeltery at Alma station. This was built upon the site of a mill built years before by the London Mining Company, after it had abandoned its older mill, already mentioned. This new smeltery, built under the supervision of Mr. John Irving, is equipped with very good boilers, engines, blower, blast furnace, dust-settling chamber, steel stack, ore-bins, electric elevator, water-tanks, electric generators, and every device for operating. There are also a boarding-house, office and the manager's residence comprising parts of the property. The owners of this plant had expected to mine enough of its own ores to keep the furnace supplied; but in this expectation they were mistaken, for the plant was unable to keep in operation more than a few days at a time, and finally it closed down in the fall of the same year. The works presumably did effective work, and, with some minor alterations, it would be in good condition for resumption, should, at any time, the local production of ore warrant. The plant is designed to do matte smelting only.

Mention of the use of the primitive arastra has been made. A visitor to the district will be interested in noting how numerous these contrivances were at one time; for along the beds of the various gulches—particularly along Buckskin and Mosquito Gulches—the relics of many of these simple metallurgical devices still remain in varying stages of destruction from exposure to the elements. A stranger is also impressed with numerous relics of placering; for, here and there, in the gulches may be found rockers, long toms, penstocks, flumes, sluices, and ditches that have long since served their purpose.

As is the case in nearly all the earlier mining regions of the West, there may here be found a number of deserted mills (in addition to those already mentioned) that perhaps served their intended usefulness, or, more likely, were prematurely built in the anticipation of ore supply, or were found suitable for the treatment of only the oxidized ores, or those ores that were first encountered. We must give credit to the early operators of the district for being serious in their efforts, even if we, in the light of more modern economic notions, can criticise them for their undue optimism.

MINING UNDER DIFFICULTIES

Most of the mines of this district that have made notable productions are situated at lofty altitudes and at considerable distances from the town of Alma. Access to them is by long, steep roads, or merely trails. The whole area is high, there being no portion of it lower than the Alma station, which has an altitude of 10,238 feet. The altitude at the town itself is about 10,300 feet. The area covered in this report is bounded on the west by the crest of the Mosquito, or Park, Range, which is also the line between Park and Lake Counties. Along the north margin of the Alma district (but partially without the limits of the maps) is a lofty range of mountains forming a chain in the main Continental Divide. Within the district are several mountains that rank among the loftiest in the whole Rocky Mountain system; as, for instance, Mount Lincoln, 14,276 feet high; Mount Bross, 14,164 feet high; and Mount Cameron, lying between and contiguous to these other two peaks and having an intermediate altitude. From these peaks one may obtain views over mountain ranges in all directions, and may see the plains of eastern Colorado and Wyoming, as well as the mountains and valleys of Utah.

It happens, from a geological standpoint, that the best mining conditions are high up on and covering the crests of these great mountains. The climate of the district is naturally cold, and, although the amount of moisture that is precipitated annually is not excessive when compared with some other mountainous regions, snowstorms may be expected at any time of the year. The winters are long. The summer season, during which prospecting, road-building, ore-hauling, and the erection of mining plants may be carried on, is consequently short. Such an adverse natural condition has, of course, proved a serious hindrance to the development of the district.

In a few instances, aerial tramways were built to handle ores down mountain-sides. Disused plants of this character still may be seen—some in dilapidated conditions—at the Paris, the Winnie, and the London mines. One or two other mines formerly conveyed ores from the mine mouths down to their respective mills, built along water-courses, by aerial tramways. All of these tramways were built during the days when these contrivances were being evolved, so that they now appear ridiculously crude and inadequate when compared with modern aerial lines.

The prospectors of this area have always been more or less seriously hampered by a lack of rational knowledge of the geology. This drawback was accentuated by the peculiar complexity of the prevailing, typical formations, which feature is brought out in other chapters. This complexity, taken in conjunction with the further peculiar circumstance that some of the very different rocks present a striking similarity, may be taken to account for a vast amount of hard prospect work done in formations that, from the scientific viewpoint, offered no warrant. Much time, effort and cash has thus been really wasted; but the expenditure was made in good faith by all concerned.

This district has been experiencing a pronounced depression for a number of years past. After the flush of the early-day placering and the shallow lode mining for gold, as already explained, the region took on a phase of activity in the mining of silver ores. The grade of these silver ores fluctuated, and the price of the metal in the market also rose and fell; but the operation of these mines never became unprofitable until the pronounced drop in the price of the white metal in 1893. In that year mining for silver in Colorado took a slump, and this was especially true of this district.

Meanwhile the miners of the district had been skimming the cream from the gold mines, and had reached the deeper zones in which the ores were not only of lower grade, but were also found to be not amenable to the local, cheap methods of treatment then in use. Capital that had been acquired as profits in the previous working of the district's mines had been dissipated, and no funds were available for the necessary improvements in both mining and treatment methods. Inevitably mining operations ceased almost completely.

It would, perhaps, have been possible to continue many of the mines in operation, if they had been previously worked with the same regard to systematic advance development that characterizes operations in our more recent mining districts. However, the prevailing practice here had been to find ore for immediate extraction only, and to remove it from the ground almost completely before giving thought to prospecting for, and the blocking out of, more ore-shoots. While such a practice would not be tolerated nowadays, no criticism was offered to the plan in those days; so, when the hard times came, the mine-owners had nothing to sustain them while doing further prospecting and development.

Much complaint has been heard from the miners of this district regarding unfair treatment at the hands of ore-purchasing and ore-treatment companies of the state. While it is undoubtedly true that there has been some cause for such charges in the past, the conditions of the metallurgical industry of Colorado have been so materially altered that, were the mines of this district to resume actively, there would not now be the oppression that was notorious years ago.

FUTURE OUTLOOK

If the reader gains the impression from the preceding narration that this region is worked out and is not worthy of further mining investigations, the writer desires to reassure him by stating some arguments for just the reverse opinion:

First—It must be remembered that the most easily mined ore-bodies only have been extracted. The ores undoubtedly continue to depth and can still be mined.

Second—The country, though fairly well taken up by locations, yet offers much vacant area to prospectors. Further, most of this available ground is quite virgin.

Third—The natural geological and mineralogical conditions are favorable to profuse creation of ores. The conditions have been propitious for the deposition of a wide range of ores and minerals.

Fourth—The present-day prospector may be guided by the science that has been deduced from past experiences of prospectors everywhere, instead of by the haphazard practices and notions that prevailed formerly.

Fifth—There have been important changes and improvements in metallurgy since the last noteworthy operations in this district, and these have been along lines that will directly benefit the miner of these ores.

Sixth—The district has made a splendid production, and this goes far toward the assurance that the ground can yield more of its hidden wealth.

PREHISTORIC MINING

Although we have no history of any mining having prevailed in this area prior to 1861, some of the early miners were surprised at finding excavations that must have been created by human effort and presumably in the search for valuable metals. These excavations were high up in the sedimentary cliffs along the Mount Bross side of Buckskin Gulch. Inasmuch as these same openings were followed by the white pioneers and led into good, rich bodies of ore, the inference is strong that prehistoric mining was done in these places. Whether the original, primitive miners were Indians or their predecessors remains problematical.

"HIGH-GRADING"

The writer has made numerous inquiries into the practice of "high-grading" during the days of mining rich ores in this district. The impression gained is that pilfering of rich ore specimens, such a salient feature in nearly every later rich mining camp, did not prevail in the Alma district, or, if the theft did take place, it must have been comparatively small and never created any trouble between operators and miners.

EARLY MINING CUSTOMS

Attention is called to some curiosities on the map in the shapes of mining lode claims. When mining began in this region, locators were governed merely by local customs, which were, of course, of their own making. Hence, different prospectors would conceive different notions as to what would rightfully constitute a desirable lode claim, and they would accordingly stake out their pieces of ground with differing lengths and widths. It is to the credit of these early prospectors throughout the West that they were generally far from greedy; for they usually laid off their claims in sizes below the maximum that was subsequently (1872) permitted by federal laws. To judge from the very slender claims filed upon by several of the very early locators in this district, these men had no intention of holding any surface except enough to cover the apex or outcrop of each ore-body. The locators, it would appear, were basing their rights upon precedent established in the California fields. They did not realize the inadequacy of the rules when applied to the conditions here. Instead of having pronounced fissure ore-bodies, most of the Alma ore-bodies were of irregular shapes and sizes, and were confined to sedimentary beds that were more nearly flat than steep. Obviously, a long, narrow claim could not be expected to cover and hold such types of ore-bodies. When ore-shoots were found following a given stratum, the early prospector would lay off his claim in such a fashion as to cover the exposure of this particular layer; as, for instance, around a steep mountain-side or on the face of a cliff. Upon the map several examples of these crooked, fifty-foot claims may be found. Some of these claims are high up on Mount Bross and Mount Lincoln, and have a close relationship to certain sedimentary horizons.

It must have been the practice of the Land Office in those days to permit the issuance of patents to what may be termed "disjointed" claims, as in the cases of Survey No. 38, De Mary lode, and Survey No. 39, Honeycomb, both now parts of the large property commonly known as the Orphan Boy Group. Whether or not these claims were laid off in this shape to avoid conflict with prior claims having a transverse direction does not appear. These two claims and Survey No. 37, Orphan Boy lode, were patented simultaneously and were the first in the district to receive federal deeds. (See detailed map of the Orphan Boy mine, Plate XXVII.)

Here and there may be noticed claims taken up prior to the laws of 1872 which made it compulsory to lay off the two end-lines of each claim perfectly parallel. This is not a feature of the fifty-foot claims alone, there being numerous 300-foot claims exhibiting the same non-parallelism of their end-lines; as, for instance, Survey No. 167, Ivanhoe lode.

With the creation of the counties forming the Territory of Colorado, each county was permitted to formulate and enforce its own local laws in regard to mining claims and rights, in so far as such regulations did not conflict with existing national statutes. It thus happened that Summit County chose to limit the widths of claims to a maximum of 75 feet on each side of the lode-line, whereas Park County decided in favor of 150 feet on each side of the defined lode-line. In other words, claims were permitted to be 300 feet wide in the Alma district, but only half that width just over the range on the Breckenridge side. When a locator chanced to have a vein crossing this county line, he was obliged to lay off some very peculiarly shaped claims, to conform with the laws. Were the limits of the maps herewith extended a little farther north, so as to include the crest of the Continental Divide, several of these curious shapes would appear. (See description of Atlantic-Pacific mines.)

As another instance of the peculiar forms in which mineral claims were permitted to be surveyed during that early period when mining laws were in their evolution, the case of Mineral Claim No. 40, Excelsior Lode, may be cited. This will be found

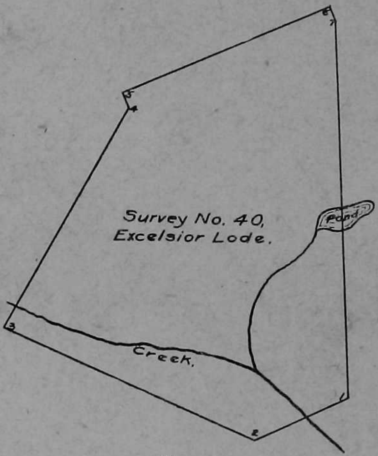


Fig. 4

FIGURE 4—Survey No. 40, Excelsior Lode. A mining claim of odd shape.

on the map in Sections 3 and 4, Township 9 South, Range 78 West. The shape of the claim resembles an irregularly shaped placer claim (such as were formerly permissibly located), but there will be observed at the north end of the claim three boundaries of a fifty-foot lode claim. The following verbatim extracts from the approved notes of the official (patent) survey, on file in the office of the surveyor-general, furnish an interesting exhibit:

Monday, September 27th 1869

The Excelsior Lode is situated above timber line on the Southerly slope of a spur of Mountain running in a South Easterly direction from the Range, dividing the waters of the Platte and Arkansas Rivers at an elevation of about 11000 feet above the sea, and 1000 feet above the South Park at Fairplay, and has been traced for a distance of one thousand feet. The vein dips to the North West at an angle of 8°—from the horizon for a depth of two hundred feet where it becomes nearly vertical. This lode has been extensively worked by its present owners for years past. A portion of the lode the greater part of the surface ground claimed was purchased by the present claimants at a cost of $26,000.00.

The nature and cost of improvements are [among other items]: 300 fathoms Stopeing, $6000.00. Quartz Mill 100 x 45 feet, Lean-to 100 x 40 feet, Boiler house 60 x 20 feet, 1 Labratery $500, 6 Arastras on creek $1800, 2 large Steam Boilers & 100 horsepower engine $25000, 1 Hodge & Christie Rock Breaker, 2 Setts Cornish Rollers, 2-20 foot diameter Arastras, 6 Tyrol Pans.

Most of the work done on the mine for the past two years has been done to open it with a view to the more convenient working, also to prove the value of the mine.

There has but a small quantity of ore been found below a depth of 200 feet. The nature of ore for 250 feet in depth is decomposed quartz with traces of galena, below it gradually changes to Iron and Copper pirates. The average yield of the ore in an arastra has been about Ten dollars in gold per Ton. The ore has mostly been worked by this process in connection with a Rock Breaker and Cornish Rollers.

Assays show considerable silver and copper in the ore but it has never been worked for these metals. The mine has been worked and drained from the shafts with Whim and Buckets. * * * The buildings are all substantial frames with shingle roofs.

From the Companies Books I ascertain that they have expended altogether for purchase of mine, Milling and Arastra claims,—and for buildings, Machinery and other improvements—the sum of Three hundred thousand Dollars.

S. A. SAFFORD,
Dept. U. S. Surveyor.

The notes also contain the name of the stream flowing in this gulch as Fairchilds Creek, thus showing that some of the geographic features had not as yet assumed definite names; for this gulch now carries the name of Buckskin Gulch.

The Phillips mine has been mentioned. This body of ore was covered by numerous claims, and a curious idea of patent rights is brought out in the official survey notes of Mineral Claim No. 55, approved July 1, 1872, which state that the claim consists—

of six hundred lineal feet the same being Mining claims Numbers 1-2-3-4-5 & 6—SouthWest of the discovery claim by one hundred and forty feet in width on the

Phillips Lode

being a gold, silver and copper bearing vein of rock in place.

The Phillips Lode was one of the first discovered and is one of the best known in Buckskin Joe District as being remarkably rich and productive in free gold ore, from the surface to a depth of from twenty to sixty feet, this claim being among the best and most productive portions of the lode, producing decomposed quartz—copper and iron pirates.

The finer portions of the ore were generally treated by puddling & sluicing and the coarser by stamp mills, saveing only the gold.

The lode was worked most extensively from the year 1860 to 1864 exhausting most of the surface ores, since which time it has been but little worked.

This claim has been worked its entire length by continuous excavations of from twenty to eighty feet in width and from ten to sixty feet in depth, the average width of excavation being forty feet, which width is assumed as the width of the crevice the same being undefined at the bottom of the excavation.

Another mineral claim was filed on this same deposit as No. 143, Phillips Lode. In this survey the open cut is given as "120 feet long, 40 feet to 20 feet wide by 20 feet to 10 feet deep situate on the southwest end of claim."

CHAPTER VI

PROMINENT MINES IN THE ALMA DISTRICT

BY ARTHUR J. HOSKIN

LONDON MINE

The London mine, on London Mountain between the two branches of Mosquito Gulch, was opened during the early seventies, but it did not become a producer of any note until early in the eighties. In 1882 this mine had over 3,000 feet of levels and raises, and had begun mining from five large stopes. In 1883, according to the "Fairplay Flume," the development had exceeded 4,500 linear feet, of which more than one-half mile was in ore. This ore is said to have maintained a grade during that year as follows: 3 to 4 ounces of gold, 6 to 12 ounces of silver, and 1 to 3 per cent copper.

A narrow-gauge railroad had been built during 1881-82, as an extension from the then Denver & South Park Railroad from its station known as London Junction (now known as Alma), seven miles up North Mosquito Gulch to the first mill and the loading-bins of the London mine. These bins were several hundred feet lower in elevation than the portal of the mine, and an aerial wire-rope tramway—the first one in Colorado—was constructed to transport the ore down this intervening horizontal distance of about 3,300 feet. At the same time, a second stamping and concentrating mill was erected at London Junction by the associated London Companies.

This mill was started up in 1883, and during the first seven months of its operation it treated an average of 850 tons per month—certainly a remarkable tonnage for such pioneer times. During this same period of seven months the mill recovered gold bullion amounting in value to $124,000, and made 240 tons of concentrates that averaged close to $60 per ton gross. These concentrates and fifteen cars of high-grade ore were shipped by rail to the smelteries at Black Hawk and Denver.

The costs of mining the ore and of tramming it to the bins at the portal of the mine amounted to $3.60 per ton, and it cost about 20 cents per ton to handle the ore down the aerial tramway to the railroad loading-bins. The overall costs of mining, transportation to the mill, and milling were figured at $7.50 per ton. So, taken all together, the mine was doing very well indeed. But about this time the owners were attacked by litigation—a frequent sequel to the initial success of mines—and the entire property was forced to close down in 1884, pending adjustments of ownership.

The property now owned by the London Mining Company is really a consolidation of a number of groups of claims originally held by a number of distinct, but closely related, companies, in which there appears to have been a considerable proportion of common ownership. The adjustment of certain disputes about holdings resulted in the organization of the present London Mining Company, which holds a large group covering all of the desirable ground along the vein for about four miles. This group comprises five lode claims originally held by the parent company, three lode claims of the Vienna Mining Company, three lode claims of the Rome Mining Company, and seven lode claims of the Berlin Mining Company. There are also about 100 acres of mill sites and placer ground, as well as three other lode claims on Loveland Mountain a considerable distance from, and having no connection with, the London vein or the company's main operations. This consolidated London Mining Company was incorporated in New York, among the first officers being George R. Blanchard, president; H. S. Comstock, secretary; and John T. Herrick, of Fairplay, general manager.

The main opening or portal of the London mine was formerly along the Mosquito Pass wagon-road on the north side of London Mountain, and about one and one-quarter miles from the pass. Reference to the contour map will show that this mountain stands somewhat alone, with other high peaks surrounding it. The mine has always been worked through adits, the topography being particularly favorable therefor. The elevation of the first London adit (now called the North London) is 12,280 feet. Some twenty years after the beginning of operations in this property, owing to the approaching exhaustion of the ore-bodies along and above the initial adit, the company established a new mining plant around on the opposite side of the mountain and drove a new adit at an elevation of 11,970 feet. This has since been the chief mine mouth and is called the South London.

The plant at the South London encloses the portal of the adit. The main building houses three departments; viz., the boilers, the blacksmith shop, and the compressors. Since the property is above timber line, wood for fuel is unobtainable, and the boilers are fired with bituminous coal that costs nearly $20 per ton delivered in the bins at the mine, it being hauled seven miles by wagons up a hard road. There are two Imperial Type, Rand, cross-compound compressors, but only one of them has been required to supply drilling air for a number of years. Extending from the dump adjacent to this large building, a trestle extends out to an independent structure that constitutes the ore-bins. The capacity of the bins is 750 tons. This amount of storage was provided in order to take care of the interruptions that are inevitable in the hauling of the ore by wagons to the railroad station, through severe weather or blockaded roads. During one of the most active seasons of this mine, a few winters ago, it was found necessary to store several months' output of ore in a great heap on the ground beside the ore-house.

There are commodious boarding- and bunk-houses, an office building, and stables.

The characteristic fluctuations in the thickness of the London vein were strikingly exemplified when the mine was opened up from the South plant. The adit was driven as a cross-cut, and, despite the careful calculations as to where the vein should be encountered, it could not be found. Presuming the vein to have assumed a new strike or dip, the adit was pushed blindly ahead until finally a superintendent assumed the responsibility of driving a branch from the cross-cut, and this eventually found the vein. A drift was then made along the vein to the cross-cut which had penetrated the vein at a pinching out.

The two adits were first connected by a large raise that was necessary to create a natural system of ventilation. Since 1892, when the South plant started, the ore-bodies between the two main adits have been practically exhausted. In February, 1912, an exhaustive examination of the property was made by a prominent mining engineer, who recommended the development of a large block of virgin ground above the upper level and toward the northern end of the property. It is not known, at this writing, what the owners will decide to do.

During recent years the property has been under lease to the London Mine and Reduction Company. This company is made up of the parent company, which controls one-half of the leasing company stock, and of John M. Kuhn and John H. Singleton, both of Alma, who together hold the remaining half-interest. At the present time the ownership of the main London Mining Company is vested in three estates; viz., the Story, the Packard and the Jewett. Mr. Kuhn, one of the lessees, was for years the superintendent of the mine for the owners.

The mining has all been done by the ordinary overhead stoping methods. Wherever the value of the vein warranted, chutes have been built at frequent intervals along the levels, and stoping has proceeded upward. Owing to the narrowness of the veins, it has been necessary to break a considerable amount of the country or wall rock during drifting and stoping. However, the stopes have been carried as narrow as was consistent with efficient labor. These old stopes may be seen to vary in width from two and a half to four feet. The practice of resue or stripping has been followed, and some of the country rock, usually on the hanging-wall side, has been first drilled, shot and removed. This waste material has been disposed of as filling for the same or other stopes, the surplus being shoveled into some of the cribbed mill-holes built up through the stopes from the chutes along the levels below. Certain of these mill-holes have been reserved as man-ways and air-ways. After a stretch of the vein has been uncovered by this stripping, short holes drilled into the hard quartz of the ore would serve for the light charges of explosives that would break this material down onto canvass sheets spread out for the purpose. Very often the ore could be worked down by hand tools, without any shooting. All the sorting of ore has been done in the stopes, the selected portions being shoveled into some of the mill-holes not then being used for handling waste. At times it may have been necessary for the miners to carry the ore rather long distances along a stope in order to deposit it in an ore-chute intended for ore, and this "packing" was done using sacks and boxes as receptacles. The same chutes have been used alternately for handling waste and ore, and since they are built of round pole timber, laid up crib-fashion, the practice is open to criticism; for not only was it necessary carefully to sweep or brush all of these timbers whenever a mill-hole was to be used for waste after it had contained ore, but there must have been a considerable loss of the richer and finer ore through the openings in the sides.

Persons not familiar with the precise conditions confronting managers and superintendents of mines are prone to offer criticism of those cases in which costs have appeared to run high, but it is well for us to bear in mind that the people in charge of property are often obliged to submit to excessive costs in order to operate at all. In the case of the London mine, we must appreciate the unfavorable natural conditions, due chiefly to altitude and climate, before we assume that the expenses of mining have been unduly high there. This property has proved a wonderful producer and has made splendid profits.

In the earlier years of the London mine there were American miners, chiefly, in the district, but since the decline in activity which occurred a decade or more ago, most of the intelligent miners have removed to other mining districts. The demands, at times, for men to work isolated properties like the London mine has brought into the district some of the more ignorant European laborers, such as the low-class Austrians, Hungarians and Italians. The employment of such inefficient laborers to do metal-mining has increased the costs of ore production, thereby adding another handicap to the operation of the alpine mines of this region. At the London mine, during the years 1910 and 1911, the following scale of wages was maintained for eight-hour shifts: miners, $3; machine men, $3.50; stationary engineers, blacksmiths and foremen, $4. This same scale of wages prevails throughout the district.

This mine has proved a wonderful producer and is credited with a splendid return of profits to the owners; but since the affairs of the company are maintained very privately, figures cannot be given. The mine has now reached a stage that requires a large expenditure to develop the vein at greater depth. This kind of a project would be perfectly feasible; however, owing to disagreements between the owning and the leasing companies as to which company should be rightfully responsible for this outlay, the whole scheme of further development appears to be indefinitely postponed. It is hoped that the near future will bring about a reconciliation of these factions and that there will be a realization of the recommendations that have been made by engineers relative to this new development.

ORPHAN BOY MINE

This gold mine lies, as already stated, near Park City, or about two and one-fourth miles west of Alma. The property belongs to the Kennebec Mining Company, but it generally goes by the name of the initial claim in the large group. The Orphan Boy claim was the very first in the entire Leadville land district to make application for a patent survey, and hence it bears the initial official survey number, 37.

The group is made up of twenty-three patented claims of various sizes and shapes, together covering a compact property of 133 acres. This area is on the eastern slope of Loveland Mountain and includes the outcrops of numerous sedimentary measures. The early discoveries were of outcropping veins in limestone and quartzite. These veins yielded rich ore wherever they had walls of these rocks, but they proved valueless in other measures. A number of openings in these "surface" ore-bodies were operated in the early days. A large production is said to have been made from these veins through shallow shafts and adits, but no trustworthy records were kept at the time. There were workings in the Orphan Boy, De Mary, Good Samaritan, Honeycomb, Senate and Evening Star veins, each of which is credited with yielding rich shoots of gold ore. Most of the gold in the ores of this property is closely associated with pyrite and chalcopyrite. The ore stands concentration very well, even by the primitive methods, but, as a rule, the sulphides are so compacted naturally that artificial concentration is unnecessary.

After exhausting the easily discoverable ore-shoots near the surface, and finding difficulty in combating the flows of water at depths, the owners established a central mining plant lower down the mountain and drove a cross-cut adit to tap the recognized ore-bearing formations at greater depths than they had been worked from above. The several known veins have all been found in this tunnel, and fine shoots of ore have been taken from them. Composing the surface equipment for this mine, there are the tunnel-house or shop, at the portal; an ore-house, with bins of seventy-five tons' capacity; power-house, containing two boilers, a six-drill Rand, Imperial compressor, a three-drill Norwalk compressor, large air-receiver, and feed-water heaters; boarding-house; and assay office. Several hundred feet inside the adit there is a second large receiver in the air-line preceding the branching of the lines.

This adit being driven northwest, or at right angles to the strike of the strata and in the reverse direction to the true dip of these measures, its advance was in the nature of cross-cutting, and the face was brought continually into lower zones. When the tunnel reached the ore-bearing horizon, or so-called "Orphan Boy contact," the main bore was diverted to the northeast, so as to follow almost on the strike of the beds and thus remain with the proper formation for ore. However, cross-cutting was continued straight ahead (northwesterly) from this point of deflection for about 100 feet beyond the "contact;" but, nothing of value being disclosed in the substrata, horizontal driving was discontinued and a vertical upraise was driven to catch the contact again. From the collar of this raise an incline was driven northwesterly directly up and along the true dip of the quartzite. This penetrated several of the veins that had been opened from the surface. One of these, the Honeycomb vein (being really a fault plane), had displaced the measures relatively, and another raise, vertically twenty feet, was necessary to again push the incline along the proper floor. Between the two vertical raises, used as chutes for ore and waste, a jig-back tram was installed to lower broken material. At the head of this tram is a twenty-five-horsepower, duplex, hoisting engine to serve as a brake. The engine is piped to use compressed air when hoisting supplies into the mine. Ordinarily the lowering of a loaded car of dirt hoisted an empty car.

The "contact" was again followed in the same manner, by another incline started from the top of the second chute, and this was driven for about 750 feet. The geological description of this mine, elsewhere, explains the failure of this last stretch of the incline to develop ore-bodies.

The principal production of the mine has been from the workings below the second, or Honeycomb, chute. Careful record has been kept of all shipments made from here since 1891. Operations have been somewhat intermittent. Nothing was done during 1904 and 1905, nor has any work been done here since 1908. However, during the period beginning with 1891, and extending to date, there have been 8,949 tons of ore shipped to Denver smelteries. After deducting the smelting charges, returns from all of the shipments show a net average value per ton of $20.70. This ore was taken from various veins, and the shipments varied in value per ton between $5.88 to $36.55. The largest shipments made during the period averaged, in value per ton, very closely to the general average given for this same period. The Orphan Boy vein has probably proved the most productive of this system. Most of the old stopes are still open and easily inspected. One of them, along the Orphan Boy vein, has a length of over 300 feet.

The veins in the Orphan Boy system have approximately parallel, northeast strikes, and are presumed to be continuous with the veins disclosed in the workings of the Phillips mine, in Buckskin Gulch. Using local terms, these two mines are said to be in "the same contact." The veins stand quite erect, whereas the beds dip southeasterly.

The track of the old railroad to the London mine passes the power-house, and coal was formerly delivered to, and ore shipped from, the mine over this railway. This line has gone into decay, but the mine is readily accessible by good wagon-roads. As stated, practically nothing has been done about the mine since 1908. At that time funds were needed for more development and for desirable improvements; but former profits had all been declared and distributed, and the stockholders were facing the general financial depression then prevalent. Efforts are being made by the president of the company, Mr. James Moynahan, of Alma, to resume operations, and the residents of the district are optimistic about the results of such mining, if it be undertaken.

HOCK HOCKING MINE

The center of the Hock Hocking mine property is about one and one-half miles southwest of Park City, along the main wagon-road up Pennsylvania Mountain. The property comprises a group of thirteen claims lying upon the eastern, sloping flank of this mountain, and the name of the group is derived from the name of one of the claims. The Hock Hocking and Weston claims were located in 1879 and became the nucleus of this group. The two initial claims were worked continuously for the first four or five years, during which period oxidized ores only were sought.

Most of the ore mined during the early days of this mine was found in masses replacing Lower Silurian limestone. These large ore-bodies were really adventitious discoveries, for the locators had taken their claims up along two promising veins that yielded well in rich oxidized ore close to the surface. These masses were discovered as contiguous to, and southwest of, the intersection of the veins. This ore was often oxides of iron and manganese mixed with carbonate of lead. Its chief value was in silver, which was found in beautiful native forms. This ore is reported to have been of high grade, but the writer cannot verify such statements, since he has not been able to consult records.

The main fissures were true in the sense that they crossed all the formations; but the mineralization of these fissures was confined to a particular bed of Lower Silurian limestone between beds of quartzite. There was just one ore-shoot ever mined outside of this lime, and that was in the so-called "parting quartzite," overlying the usual ore-bearing bed. The development of the veins—and hence the mine—proceeded through four discovery shafts that were well up above the present plant. There was little or no difference between the ores taken respectively from the veins and the masses. In fact, the ore-shoots were continuous from the veins. One such shoot, of small extent, branching off from the vein, is reputed to have netted $17,000 in silver bullion.

The two initial claims were located and held for a time by different men. The very nature of the ore's occurrence soon engendered strife. The veins seemed to possess equal responsibility in the genesis of the mineralization. Hence it was not long before litigation tied the hands of these owners, and the mines (for there were two mines recognized at that time) were closed down, and remained so until 1893, when a compromise was effected in the incorporation of the Hock Hocking Mining Company, to own the consolidated interests. This compromise took place, unfortunately, at the low ebb of silver mining. The previous operations here had practically exhausted the rich, native-silver ore-shoots. Consequently the new company faced the necessity of mining the lower-grade and more refractory sulphide ore, which was minable only at an increased cost per ton. With insufficient investment by the owners, superintendents found it impossible to operate systematically, and the operations were of a desultory nature until 1900, when the company established its main plant at its present site and began driving the long adit that now penetrates the mountain some 500 feet lower than the collars of the old shafts. This enterprise was launched in the hope of affording automatic drainage and of opening the ground at greater depth.

The plant at the adit's mouth is not extensive, but it has been sufficient. The small shop and power-house building contains an eighty-horsepower Erie City boiler, a three-drill Rand, straight-line compressor, a three-by-ten-foot air-receiver, feed-pumps, water-tanks, and a complete blacksmithing equipment.

The first 2,000 feet of the adit were driven through very wet and hard country rock, so that the progress was slow and expensive. Two years were required to reach the objective ore-bearing zone, and even then the shoots were not to be found. It was not until the fall of 1905 that the development and exploitation had been sufficient to create any ore production. To take care of this output, a large ore-bin was built on the side of the mountain along the wagon-road. There are buildings used as office, assay office, boarding-house, bunk-house and stable.

It does not appear that the mine has had any notable prosperity since its early days; but this statement must not be construed as implying that the ground is exhausted. On the other hand, the presumption is strong that more and rational development will disclose good shoots of ore similar to those excavated years ago. A study of the geological chapters of this report will show the peculiar intricacy of the formations here that have rendered systematic development problematical.

Most of the early workings have caved in, but Mr. Radford, the last superintendent, states that there were about 7,000 feet of levels and 200 feet of winzes above the level of the adit.

In 1907 several of the principal stockholders organized a subsidiary company to carry on future development and mining under a lease contract. These lessees forming the Nyack Leasing Company, as it is called, were C. B. Kountz, G. W. Logan, Samuel Cohen, M. Overhalser, William Hill and M. S. Bailey. The name of the company is that of another of the lode claims of the group. The lease granted to the subsidiary company extends until the spring of 1920.

Mr. Radford sunk a winze 195 feet from the adit level along a fissure. In a drift at the bottom of this winze was found a limited showing of sulphide ore having a calcite gangue, but this has not been developed.

The last work done in this property was in the winter of 1910-11.

KENTUCKY BELLE MINE.

This mine comprises a fairly large and compact group of lode claims that have not been patented. This is an instance of the safety of holding good mining ground and of operating it when it is held only by location rights. This district is one in which such possessory rights are recognized, and no locator is interfered with in the operation of his ground, providing he has made reasonable effort to conform with the mining laws. The Kentucky Belle tract is at the head of Buckskin Amphitheater, the plant and buildings being upon the slope of a ridge connecting Democrat Mountain and Mount Cameron. The ground extends over this ridge into the Platte Amphitheater.

The mine is opened by an adit that follows along the vein. The only piece of machinery observed at this plant was a small gasoline engine, belt-connected to a blower that acted as an exhauster of the mine's air. All work of mining has been done by hand.

This property was held, for a time, under lease and bond by the Colorado Gold Mining and Smelting Company that built the smeltery at the Alma station. The mine was operated during the summer season of 1910 by this company in an effort to supply ore for its furnace. However, the low grade of the ore, taken into conjunction with the difficulty and high cost of getting the mine's product to the smelteries, caused the closing down of the property in the fall of 1910, since which time it has lain idle. This mine has had high operating costs because of its remoteness from sources of supply. Being at a very high elevation, the climate is objectionable, labor is scarce, and difficulty has been experienced in getting effective results from the employes. This mine also requires much timber, which of course must be hauled up-hill, since the property is above timber line.

The so-called vein of this mine is really a modification of the eastern side of a porphyry dike that stands nearly erect and strikes N. 26° W., cutting through the ridge mentioned above. The dike has granite walls, and the ore is found between this granite for a foot-wall and a crevice, nearly parallel to this foot-wall, in the dike. The distance between these two bounding walls of this "vein" varies from nothing up to four feet. This latter width has been maintained as the average for most of the stopes that have been worked. The foot-wall dips 85° southwest.

The adit or working level is driven in the porphyry along this contact, for the reason that it is soft, whereas the granite is unusually hard and "tight." This soft nature of the porphyry, due to partial decomposition, makes stoping very treacherous, the hanging wall requiring constant support to prevent sloughing. The dike is filled with parallel shear-planes that render the rock scaly in large slabs. Stoping has been done by the usual, old-time, overhead methods. As the ground is rather wet as well as soft, it cannot be worked by shrinkage or rill methods of stoping; for the dirt will pack solid again, if any downward pressure is exerted upon it.

The gangue of the ore is the porphyry itself. The chief mineral is pyrite, which appears to have withstood the oxidation agencies that altered the gangue. In some of the surface exposures and workings of this vein the iron sulphide has oxidized and the ore is iron-stained porphyry. The value of the ore lies in gold, which appears to be intimately associated with the pyrite. When the sulphide has been oxidized, gold is lacking in the material, and as the percentage of pyrite varies, the content of gold fluctuates likewise, according to the statement of the superintendent, Mr. A. K. McDonald, who was in charge during the season of 1910. The product would therefore present the desirability of concentration before shipment. The average grade of ore taken from the mine has been between $8 and $10 per ton. If this could be concentrated close to the mine—say, eight tons into one—it is probable that a very efficient saving of the gold value would result, and a shipping product could be obtained that would well stand the heavy hauling and freight charges. Still better would appear to be the scheme of treating this ore by cyanidation right at the mine.

The best production that was possible was gauged by the ability to get the output hauled away by wagons. This limited the production to about twenty tons per day, this being the capacity of four five-ton wagons. The roads cannot be maintained in good condition for the hauling of heavy loads, and one trip per day is all that can be expected. The charge for this hauling to Alma is $3 per ton.

PARIS MINE

Mention has been made of some prehistoric mine workings on the cliffs of the southern end of Mount Bross, overlooking Buckskin Gulch. The Paris is one of the mines that developed this same vicinity. With scarcely any mining equipment, and with hand methods exclusively, this mine was worked through adits and is credited with having produced some very remarkably rich, oxidized gold ore. The geology is explained elsewhere. After working the mine for years, hauling its output down the mountain in wagons, in 1894 a mill was built below in Buckskin Gulch and an aerial tramway installed to connect the two plants. The tramway is of one span, 1,750 feet long. Its upper end is

750 feet higher than the mill terminal. It has two buckets traveling in opposite directions on separate cables, each bucket holding about 1,100 pounds of ore per trip.

The mill contains bins, a gyratory crusher, four batteries (twenty stamps) of Fraser & Chalmers stamp mills, amalgamation plates, Pierce amalgamators, and a vanner for each battery.

During the summer of 1910 this property was under lease to Denver parties. Again, during the season of 1911, it was leased to other Denver parties. The mine is now lying idle for lack of capital and interest to perform some needed exploratory work. Figures for the total production of this property are not available.

MOOSE MINE

The following data relative to the Moose mine are in addition to those already given in Chapter V.

The point of discovery of ore was immediately covered by a narrow, crooked claim called the Moose. Here the ore outcropped, and excavation proved that it existed as a great, irregular-shaped mass in blue limestone. The regulation form of lode claim could not be fitted to such a formation. The claim was accordingly surveyed to include the outcrop of the particular limestone bed as it swerved about the bleak contours of Mount Bross. This location of the original Moose claim was quickly followed by the location of more claims, comprising a solid group belonging to the one Moose company. From time to time additional ground has been obtained by the location and patenting of later claims, until, at the present time, the area included in the so-called Moose Group amounts to hundreds of acres.

There was a very notable production by open or surface mining from such of these ore-bodies as outcropped. This ore was very rich as well as abundant. The value of the Moose ore has always been in silver, which was never found here in the free or metallic state, but always as the sulphide, argentite. As the superficial bodies were exhausted, work was pushed underground, and numerous adits and shafts were bored in a rather blind search for more ore-shoots. Lack of comprehension of the geological conditions and the proper mining methods to be pursued was responsible for a great amount of ineffectual deadwork. The stratified rocks—limestones and quartzites—so shade or blend into one another that they are frequently distinguishable only with difficulty. To further aggravate such troubles, it happens that these sedimentary rocks are penetrated with flows of porphyries having fine-grained textures as well as colors that closely resemble the outward properties of the stratified formations. Naturally, such a state of affairs was perplexing to the pioneer prospectors and miners, and we must therefore be lenient in our criticisms about their earnest efforts. The climax of their troubles was presented in the complete termination of the ore-bodies and the ore-bearing horizon by a strong, steep fault, beyond whose plane nothing of value has yet been discovered.

The openings driven in the search for new ore-shoots were often very crooked, and, to the modern engineer, it does not seem that there could have been any system followed in this development. But the miners had no means of knowing where these ore-shoots were likely to be found, except that they were all confined to the blue limestone. Sometimes passages were driven close to and upon two or more sides of a splendid mass of ore, but the actual disclosure of this ore-shoot would remain for subsequent operators or lessees. In such a fashion there were excavated miles of underground passages—horizontal, inclined and vertical—exclusive of stopes. All of this work was performed by hand methods, and, since the rocks are of exceedingly fine texture and unusual hardness, the cost of such work was unavoidably great.

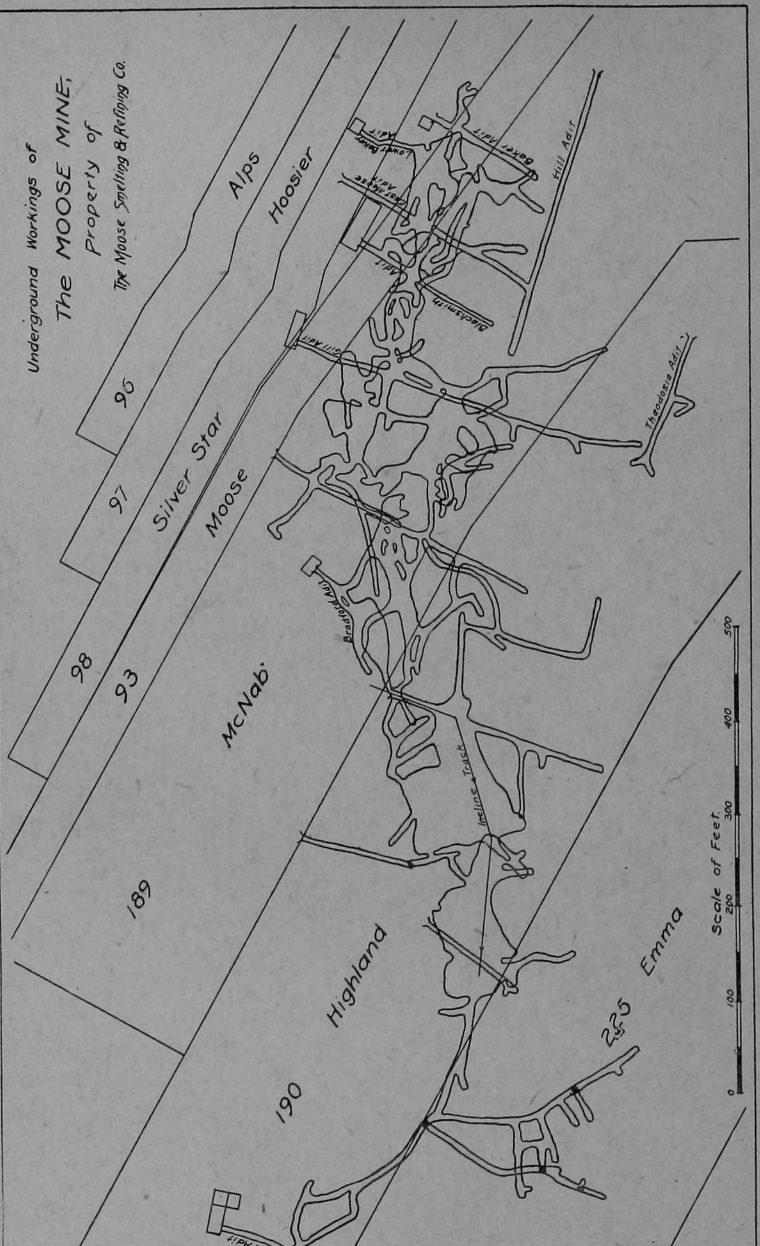
It does not appear that there was ever inaugurated a systematic development or blocking-out of ore in advance of actual stoping operations. As a consequence, the production of the mine was always very erratic and not conducive to mining economy. During one of the later periods of the mine's activity a primitive type of diamond drill was used, from surface and underground set-ups, in searching for the elusive bodies of ore and in endeavoring to elucidate the geological complexity. It did not, however, accomplish its mission.

The true production of this property cannot be ascertained, as records were not seriously considered nor preserved by the early operators. Men who have had intimate knowledge of this mine's operations variously estimate the gross production as between $5,000,000 and $15,000,000. The higher figure is undoubtedly unreliable, and we shall probably be closer to facts if we assume that the production has been around the first figure stated. During the later part of the bonanza period this mine was purchased, at an unwarranted figure, by Ludlow Patton, of New York City. His investment was very ill-timed; for the mine was able to operate only a short time after the transfer of ownership.

It is reported that the management by early operators was exceedingly reckless. Excessive "overhead" charges at the New York offices proved considerably greater than the legitimate payrolls at the mine. Besides, poor judgment was exercised in various directions, as, for example, in the unwarranted installation of inadequate metallurgical apparatus and machinery in the smeltery at Dudley, previously mentioned. Here, as explained, was the local or western office of the mine. This office and the mine were connected by a telegraph line, for which operators were employed. The single reverberatory furnace at this "smelter" was run but a short time, as is evidenced by the small size of the slag-dump. At a subsequent time there was an attempt at so remodeling as to make this a chlorination plant, but the plans failed of culmination. Nearly all of the Moose ore was treated in the custom smelteries at Black Hawk, Omaha and Denver.

As is true of all mines that have produced more than ordinary grades of ore, so with the Moose—marvelous tales are told regarding the richness of its product during early days. It is easily believed that all of the ore shipped from this mine must have been of reasonably high grade to have stood the heavy costs of mining, hauling, freight and treatment. The ore carried a fairly large percentage of barite that was subject to a heavy penalty by the smelting companies, and this raised the treatment costs to unusual figures. The testimony of a former superintendent is to the effect that his shipping ore varied in silver content between 100 and 700 ounces per ton. He also tells of a single breast of ore averaging close to 700 ounces per ton in silver, at which fifteen pairs of miners worked "double-jacks" simultaneously.

A visitor to this mine is impressed with the almost perfect preservation of the old workings. Great cavities of very irregular shapes, frequently with scarcely a stick of timber in them, may now be found with as sound walls as they had years ago, when first excavated. The major dimensions of these stopes lie in the direction of the dip of the measures. The mineralization created ore-shoots that sometimes took on very peculiar forms. Some of these chambers are twenty or more feet high, and spanned by sound roofs of limestone. Considering the location of this property, it was indeed fortunate that timbers were not generally needed in mining. In one or two instances stoping was carried on by one set of miners who stood upon a natural shelf of limestone that acted as a roof above another crew of

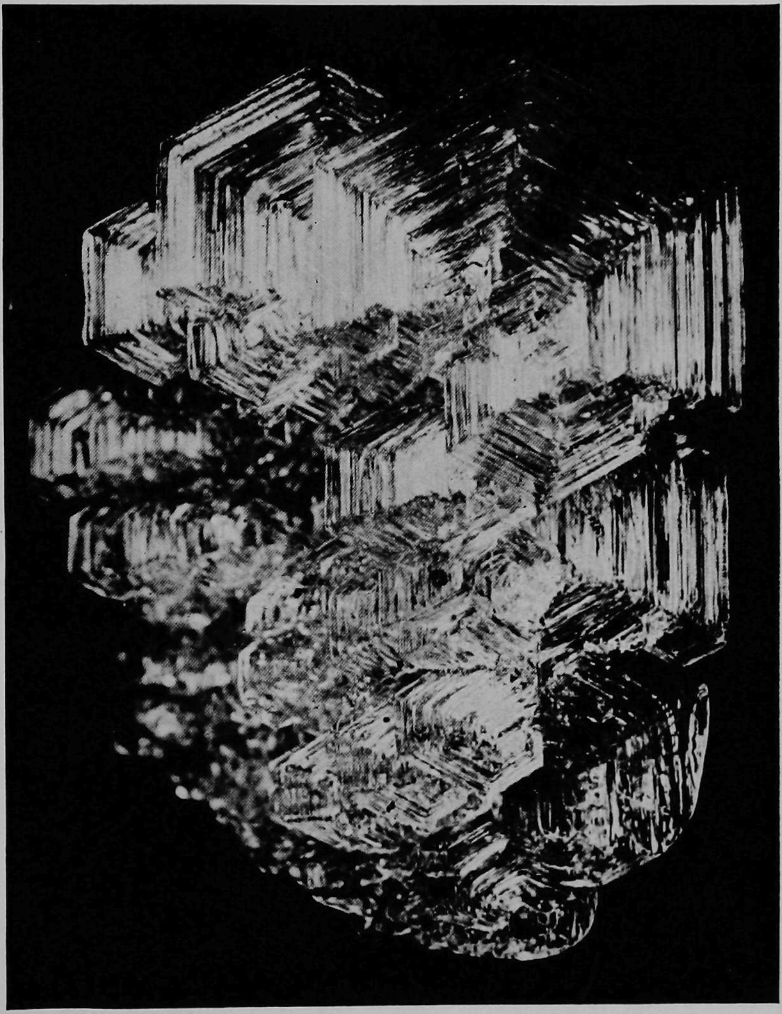


Colorado State Geological Survey—Bulletin No. 3, Plate XXI miners who were simultaneously engaged in stoping ore from a breast directly below. These ledges are still intact. The chief use for timbers in this mine was for the support of walls and roof in penetrating the slide-rock when starting adits and shafts. Thereafter wood was useful in constructing tracks, chutes and bins in the mines. The ore from one set of stopes was transported to the surface up an incline equipped with track and skip, the motive power therefor being supplied by a horse-whim. From some stopes adjacent to this long incline the hoisting was obviated by the ingenious scheme of driving "jack trains" into the workings, there to be loaded with their burdens, which were borne or "packed" down to Alma. Owing to the very cold weather that prevails here most of the time, much of the screening, sorting and sacking of ore was done underground, some of the bins and screens still remaining where they were last used.

The mine is a dry one. Although there is a large precipitation of snow and rain on this mountain, the water is disposed of chiefly by surface run-off during the short summer season. Some snow-banks are perpetual. The mine does not collect water, for the reason that the continually low temperature at this elevation keeps the moisture already in the ground permanently congealed. The rocks are thus rendered impervious to seepage water. The only collection of water to be found in the mine at the present time is along the inclines, which have allowed water to follow in from their mouths, and this has frozen solid. Even this ice is in limited amounts. A very interesting phenomenon is exhibited in these old mine workings in the wonderful growth of frost crystals which now adorn the walls and roofs of most of the passages and stopes. These crystals are of unusual size and of most interesting forms. They are strictly frost in the sense that the water composing them was derived from the atmosphere and did not come by penetration of the rocks. Individual crystals three inches or more across are not uncommon, while the growth of successive layers of these beautiful structures has assumed a thickness of a foot or two. An old stope thus completely lined with these marvelous brilliants, that reflect millions of rays from the visitor's lamp or candle, reminds one of the fairyland castles of juvenile fiction. A group of these frost crystals is shown in Plate XXII.

The mine has splendid natural ventilation by reason of the many openings from the surface. Some of these openings proved superfluous and have been shut off. Another interesting natural

Plate XXII—Group of frost crystals, about two-thirds natural size, taken from the roof of an old stope in the Moose mine on Mount Bross. The largest of these crystals measures three and one-fourth inches across.



phenonenom to be observed here is the wonderful preservation of wood. Timbers that were placed in chutes, bins, or as occasional props, years ago, appear now as though but set a day or two ago, the surface presenting a perfectly fresh appearance. Upon inspection, it is found that the timber is absolutely sound all through. In one place the writer noted some sawdust that had lain a very long time, and was still yellow and bright. This condition is due to the fact that the wood has been kept continuously in a dry, cool atmosphere, and the exclusion of light has contributed to the preservation.

The Moose property has lain inactive for years, practically the only work that has been done recently being limited amounts of deadwork during the summer and fall of 1911. Careful geological investigation and the exploratory work done recently, as mentioned above, have located the ore-bearing blue limestone horizon beyond the fault that has always formed a natural obstruction to mining. The ownership is now vested in the Moose Smelting and Refining Company, whose principal office is in New York.

DOLLY VARDEN MINE

This mine was discovered, in 1873, by Cy. Hall and G. W. Brunk. It is interesting to note that these two prospectors are still owners of the property, they having taken as partners but two other persons during all the intervening years. The first mining was done in open pits, where rich silver ores were excavated from limestone, in a manner somewhat similar to that at the Moose mine. The Dolly Varden, in fact, has many features in common with the Moose and is a close neighbor, the present holdings of the two companies being contiguous. The first two claims of the Dolly Varden group were the Hiawatha and the Dolly Varden. These have been supplemented by thirteen other lode claims, and all are patented, covering an area of about 160 acres.

Extensive mining was done until 1884, and the production was really large. One superintendent tells the writer that it was close to $3,000,000 up to that time. The many large dumps, adits, pits and caved-in places on the property testify to the fact that much work was done. Quite a good many men must have been employed here, there being still a few remnants of the boarding- and bunk-houses used during this flourishing period. The property is in a very bleak location, somewhat similar to that of the Moose, but having a different exposure.

The mine then lay idle until 1910, except for an occasional bit of desultory work by lessees. The property has been recently under lease, and a limited amount of development work has been done. Some bodies of ore have been disclosed, but the property needs extensive development.

ATLANTIC-PACIFIC MINES

These two mines constitute a single property. Two lode claims of the company lie on North Star Mountain (near the northeast corner of the map), and the crest of the Continental Divide lies along their common end-line. The names of these two claims refer to the respective watersheds upon which they lie. Each claim has been separately operated, but for the past few years no work has been done upon the Atlantic claim. Reference to the map will show the lofty elevation of these mines, and some notion may be conceived as to the expense incurred in conducting mine operations.

These mines were opened up along a fissure that traversed all the formations, but which was found to be responsible for ore-shoots only within the Cambrian quartzite. Adits were driven into the mountain following this "contact" (as the miners term it), and the chief production has been from the stoping of large masses of gold ore in and adjacent to the vein. Some of these stopes are of large extent, with the main dimensions parallel to the bedding planes, and, as one compensation to the miner, scarcely any timbering has been necessary, for the country rock has been found remarkably secure.

Two grades of ore have been considered—the oxidized and the sulphide. As a general statement, the ore-shoots above the porphyry sheet within the quartzite have been oxidized, while those shoots beneath this same sheet have been in the original sulphide condition. Both sorts of ore carry good value, if they are given careful sorting before shipment. All the mines' outputs have been hauled by wagons over rough roads to Alma, where the ore has been shipped by rail to Denver smelteries. An exception to this practice took place for a short time during the summer of 1910, when the smelting plant of the Colorado Gold Mining and Smelting Company was in blast. An officer of the company is responsible for the statement that fifteen cars of both oxides and sulphides shipped to Denver, during the fall of

1911, showed a gross average value per ton of about $74. It is the writer's impression, gained from numerous inquiries about the district, that such a high grade was attained by unusually close sorting of the ore, and that the mean of past shipments from this property will probably be in the neighborhood of $40 per ton for the oxides, and about $10 to $12 per ton for the sulphides.

The mines have never been developed in a systematic fashion, and the periods of successful operation have been brief. The company holds a third claim, by the name of Silver Lake, but this has not received development and is outside the territory covered by this report.

CHAPTER VII

PRESENT-DAY PLACER OPERATIONS

INTRODUCTION

In Chapter V it was shown that this entire mining region came into being as a result of successes met by the pioneers who sought the yellow metal in the alluvials along the various stream-beds. A brief outline of the accomplishments of some of these men was given, but it will be well to return now to a discussion of placering, in order to explain to what extent this sort of mining has become a feature of the district.

Within the borders of our map of the Alma district there has not, of late years, been any notable activity in placering. While there are undoubtedly many enriched alluvial deposits within the area covered by the topographic and geologic reports herewith, such deposits have generally been such coarse gravels and boulders that ordinary methods of placering could not be applied with profit. Also, in some instances where such work has been attempted, the bed-rocks were found so rough as to render systematic hydraulicking or sluicing impossible. All such areas will, undoubtedly, be ultimately handled, but their exploitation has thus far been unremunerative.

It is reported by various persons informed on the subject that there are very good enrichments of the alluvials and decomposed portions of some of the mountain-tops in this area. For instance, it is doubtless true that the placer claims on Pennsylvania Mountain, in Sections 16, 17 and 20 (along the southern border of the map), contain considerable gold. The ground within these claims is chiefly disintegrated rocks of the vicinity. Most of the rock fragments are not rounded nor water-worn, but are angular and more commonly spoken of as slide-rock. This sort of debris has accumulated to a depth of several feet on portions of the mountain where the slopes are not steep. Filling the interstices are sand and mud, and these materials, when laboriously separated from the rocks and washed, have yielded fair quantities of gold. The working of these properties has never been for more than brief periods and by very arduous methods. Water in such places is scarce, so that any washing of the dirt on the ground must be done during a very short time in the summer, when neighboring snow-banks are melting. In some instances small quantities of the dirt have been packed down the mountain to Mosquito Creek and there washed. These placers—if they may be so styled—present opportunities to mining engineers who have the ability to overcome such natural obstacles.

The mining-claim map shows a number of placer claims to the south and west of Alma. These were surveyed and patented to secure areas of glacial and alluvial materials that constitute the ridge between Buckskin and Mosquito Gulches, and the valleys of these two streams. Prospectors probably succeeded in proving their claims gold-bearing, but it is doubtful if any scheme, at present known and used, could effect an economic recovery of the gold contents. The claims may cover valuable lodes or deposits of ore in place beneath the moraines and alluvials, and these may some day prove valuable, while the improvements in methods and devices for handling placer ground may reach such perfection that these deposits will yet be forced to give up their contents.

There are a number of patented placer claims along the beds of the various streams above Alma, but their operation, by methods of the past, did not meet with success. This is particularly true of Mosquito Gulch and the upper Platte valley.

And yet, despite these various discouraging facts, Alma maintains its reputation as one of the placer-mining "camps" of Colorado; for, within short distances of town and relying upon it to a great measure as a source of supplies, there are the properties of a few companies that have, regularly or intermittently, conducted placering for years past. It is believed that these operations are of such import that they should be briefly described.

SNOWSTORM PLACER

The map shows that almost the entire bed of the Platte River is covered by placer claims. These claims were taken up by many persons, at different times, with the idea of being ultimately worked by placering methods. The operation of nearly all of these claims has been attempted, as already mentioned, by the application of primitive, arduous, expensive methods of former decades. The majority of them—especially those in the northern portion of the valley—were found to present such serious obstacles in the handling of large boulders and in rough bed-rock that neither sluicing nor hydraulicking was successful. Accordingly, the ground in most of these properties, though patented, is still virgin.

In 1902 a company, known as the Snowstorm Hydraulic Company, was organized to acquire and control the placer ground along the Platte River and to institute operations upon a systematic basis. This company soon succeeded in buying up or in optioning practically all the placer claims along the river as far up as the hamlet of Montgomery. It constructed a complete system of ditches to collect water from each of the principal streams of this district—viz., Platte River, Buckskin Gulch, Mosquito Creek and Beaver Creek (not shown on the map, it being the first stream to the east of Platte River)—and to convey the combined flows by one large canal to the main point of its operations about midway between Alma and Fairplay (southeast of the map).

About two miles north of Alma this company constructed a dam across the river and created a small storage reservoir. Several ditches of the company are shown upon the map. The two ditches taking water from Mosquito and Buckskin Creeks unite south of town, their contents being conducted across the Platte valley by a large steel pipe-line laid as an inverted siphon, the water thus reaching the main canal and thence the placer mine. The company appropriated practically all the water in this area. Hence, other companies or individuals are unable to secure water rights sufficient for any placer operations, except above the headgates of this company.

The name of the company was changed, in 1908, to the Platte River Placer Company, and offices are now maintained in New York, Denver, and at the mine. The stock is held principally in New York. Mr. W. J. MacConnell is very efficiently managing the affairs of the company, and it is generally understood that the mine has, for a number of years, been making satisfactory returns to the stockholders.

Operations are possible here for but a few weeks during the summer time. Work cannot usually begin before the latter part of May and generally terminates the latter part of September. Hydraulicking is the method employed. The available supply of water being of restricted duration, work is pushed hard during the operating season. Part of the time, work is carried on both day and night, but toward the close of the season, as the water supply wanes and the nights become too cold for out-of-door work, washing is done during the day shift only.

Two giants with seven-inch nozzles and one giant with a six-inch nozzle are used to tear down the banks and to handle the dirt in the two large working pits. The sand and gravel are washed into wooden sluices, thirty-six inches wide, laid upon a four-inch grade; i. e., four inches to twelve feet. The first few boxes at the head end of each sluice are paved with wooden blocks, but thereafter there are no blocks nor any riffles except ordinary forty-pound railroad rails placed longitudinally the entire length of the sluices. The sluices from the two pits unite as a somewhat larger sluice for the remaining several hundreds of feet to the tailing dump.

The natural slope of the bed-rock has been such that the main sluice could be maintained upon a good grade for the rapid disposal of the tailing. The heavy rails with which the floor is paved are for the double purpose of protecting the sluice and of acting as skids for the rapid movement of the larger boulders. These boulders, under the impulse of a liberal flow of water and the favorable grade, rush through this long sluice in a manner that causes very little trouble in their disposal. Before reaching the dump along the Platte River, the sluice passes through a short tunnel and a deep, open cut beneath the Colorado & Southern Railway track. At the foot of the main sluice is stationed another seven-inch giant to throw the tails to one side and to spread them.

The alluvials within the area now being operated are much finer and more easily mined than are those some miles above this mine. At present the materials handled consist of gravel, of sizes varying up to boulders that require handling by derricks or manual labor, mixed with sand and a reddish soil. The pay-streaks are said to follow along channels that are not easily accounted for, but it has been noted that the best dirt is the reddish soil which has probably resulted from the decomposition of rocks originally containing iron minerals.

At one time the pit was equipped with a crane mounted on wheels and traveling on rails, but this was dispensed with years ago.

The gold recovered is in all sizes from mere colors to good-sized nuggets. The bullion, as sold to the United States Mint at Denver, is said to average about 950 fine.

No attempt has been made by the writer to ascertain the total or annual productions of this mine, for the reason that the company's affairs are not given publicity. It is, however, a natural conclusion that the mine is maintaining a good production; for the operations are pushed with increasing vigor each succeeding year.

CINCINNATI PLACER

Every visitor to the Alma district is interested in learning about the operations that resulted in the turning over and washing of vast quantities of gravel along the bed of the Platte River just above the town of Fairplay and below the railroad and wagon-road to Alma.

This has been a very active mine. According to the statements of long-time residents of Fairplay, the Cincinnati placer gave employment to hundreds of men at one time. At one period in the history of this mine, Chinamen worked the ground by ordinary sluicing methods, employing only physical labor. These men were permitted to work, day by day, upon the payment to the mine boss of one dollar each per day, and each man was allowed to retain all the gold dust or amalgam he recovered. This simple arrangement avoided all question concerning the honesty of these miners; but the scheme also rendered it impossible for anybody to estimate what production was made. These Asiatics were extremely secretive about their recoveries, and it is not known what percentage of their bullion and dust ever found its way into the mints, where its source could have been ascertained.

During a later period a very expensive ditch- and pipe-line was constructed to operate a large hydraulic elevator of the Evans type at the lower end of this property, close to the town of Fairplay. About 8,000 feet of thirty-inch steel pipe was installed, but the elevator was never a success.

Nothing has been done upon this ground for years, in the way of mining. The banks of the Platte within this property are high, and the materials are such that it is thought a modern dredge could readily handle them. Most of the boulders in this placer—which contains a long stretch of the river's channel and banks—are of small size. There were, however, numerous very large, rounded boulders encountered by the Chinamen that, to the present visitor, appear impossible of movement by ordinary human effort; and yet these rocks were frequently moved considerable distances both horizontally and vertically.

BEAVER CREEK PLACERING

Beaver Creek is a stream flowing approximately south and a mile or more to the east of the eastern edge of our map. It heads in a depression between two prominent mountains, known as Mount Silverheels and Scout Mountain. This particular area has never been given scientific investigation and has no worthy geological maps. It should, however, be given attention, since there are undoubtedly deposits of valuable minerals and ores. Beaver Creek, Tarryall Gulch and other streams whose sources are within this area have all produced gold from the alluvials, and prospectors have often found evidences of other metals, among them being platinum.

Beaver Creek flows into the Platte River just below the town of Fairplay. For years gulch mining has been followed in a desultory fashion along the bed of Beaver Creek. Practically the entire length of the stream is taken up by placer locations. The lower portion of the gulch is owned by the Platte River Placer Company.

At various times in the past, operations by hydraulicking have been inaugurated, and there are evidences of the washing of large quantities of gravel. At one place along the course of this gulch a short tributary comes into it from the west. Good gold values having been discovered at the confluence, certain operators, years ago, installed ditches and flumes and handled the gravel in the smaller stream. This is reported to have been very disappointing, and there was very probably an error in assuming the gold to have come from this western branch. However, the financial resources of the owners of the project had been expended, and no more work was done at this locality.

Placer pits have been dug at intervals the entire length of the gulch, but it is not believed that modern methods of churn-drilling and sampling have ever been attempted in Beaver Creek. The valley varies in width from about 300 feet, over short intervals, up to one-third of a mile. The alluvials are of many rocks. Sedimentary formations have been abundant contributors. At places, sheets of quartz-porphyry within beds of limestone have eroded, and their fragments are mixed with the sands and gravels. These porphyry fragments have, as a rule, retained rather large size, and are still in angular slabs that are quite objectionable in any sort of placer work.

As a rule in this gulch, the gravels are not deep, and it has never been deemed advisable to install dredges. One manufacturer of dredges, however, recently caused an examination of the ground to be made and proposed the installation of a dredge.

During the summer of 1910 there was installed a small hydraulicking outfit for working a tract owned by Alabama capitalists. A ditch was dug 4,000 feet long to conduct water onto the property, at a head of 120 feet, for operating two four-inch giants. Through failure in placing the sluice on bed-rock at the beginning, the project did not succeed that season, nor the next, and, for reasons quite foreign to the value of the land, there was nothing done during the summer of 1912. It is understood, however, that this ground is to be worked during the summer of 1913. There seems little doubt regarding the worth of the alluvials along this portion of the creek's channel; for, immediately above the placer property just mentioned, the Role placer has been operated for a number of years and with satisfactory results. The gravel unquestionably carries gold in paying amounts, but the operators have faced numerous obstacles, such as shortage of water for hydraulicking, the brevity of season, insufficient capital, the angular shapes of the boulders, and the rough, creviced nature of the bed-rocks.

Not far above the mouth of the gulch there has, for years past, dwelt a lone Chinaman who makes his living by simple hand methods of washing the sands and gravels near his cabin, he operating under a free lease from the Platte River Placer Company. As he never renders accounts of his clean-ups, there is no knowledge available concerning the value of the ground he handles, although it is generally conceded that he has done very well.

CHAPTER VIII

ORE DEPOSITS OF LONDON MOUNTAIN AND MOSQUITO GULCH

BY HORACE B. PATTON

INTRODUCTION

A reading of Chapter VII of this report will disclose the existence of several mines that have been in the past or still are of considerable importance within the area drained by Mosquito Gulch. One of the mines, the London, has not only been a great factor in the past in the mining industry of the Alma district, but still today is active and possesses great possibilities of future development. Its great success in the production of high-grade ore, and its close association with the great London fault that has taken its name from that of the mine, have been a constant source of inspiration for prospectors, who have taken for granted that the London fault and the London ore vein are, or should be, synonymous terms, and who have devoted their energies to prospecting the London fault. To all such a description of the nature and probable origin of the London vein and of the London fault should prove of more than passing interest.

ORE DEPOSITS ALONG THE LONDON FAULT

GEOLOGICAL FORMATIONS INVOLVED—

As already described in Chapter IV, the London fault is the result of great earth movements brought about by a horizontal thrust. This thrust has first folded and then rent asunder in a great thrust-fault the strata along a northwest-southeast line extending many miles. On the west, or rather southwest, side of the fault the formations have been depressed or thrown down by the combined influence of the fold and fault to the extent of 2,500 or 3,000 feet. As a consequence of this faulting, the Archean gneisses and schists, with their intrusions of granite and pegmatite, are found on the east side of the fault and, in contact with them on the west or opposite to the fault, the Carboniferous series.

This fault is what is known as a "strike fault;" that is, a fault whose strike corresponds with that of the stratified beds affected by the faulting. Consequently, the strike of the fault plane and the strike of the Carboniferous beds in contact with the fault are, as a rule, practically the same. Again, it happens that the Carboniferous strata of London Mountain, where the London mine is located, have been cut by several sheets of porphyry that have split the strata and lie as sheets conformable, or nearly conformable, to the bedding of the sedimentary rocks. Two of these porphyry sheets—one composed of the white porphyry, the other of a porphyry that Emmons called the "gray porphyry," and that in this report is included under the monzonite porphyries—happen to lie close to the Archean contact that marks the line of faulting. As these porphyry sheets conform very closely to the stratified Carboniferous rocks, they also run parallel to the fault plane.

As already explained in Chapter IV, the fault plane does not always strike exactly with the strata, and hence it does not strictly keep the same geological horizon. There is a certain amount of variation in the strike of the fault plane that does not always conform to the varying strike of the strata. Similarly, the two porphyry sheets do not always lie between the same beds; neither do they remain of the same thickness. For most of the distance where these porphyry sheets appear in the workings of the London mine they are close together, either in actual contact or separated by a very few feet of shale or grit. The same condition prevails on Pennsylvania Mountain, as shown in the working of the Butte mine at the foot of the mountain, in the Pennsylvania tunnel about 1,200 feet above the base, and at the place where the London fault crosses the ridge of the mountain.

Except for two short stretches near the northwestern end of the London fault, as far as the fault is shown on the map, the rock in contact with the fault plane on the west side at the surface appears to be the blue or Leadville limestone. In the two short stretches the Weber grits appear in contact with the fault plane. Lower formations must come up to the fault plane at lower levels, but they do not happen to do so at the surface.

THE LONDON MINE—

Map and Sections.—In the comparatively limited examination that the writer was able to make of the London mine—limited because of insufficient time—it was made very evident that the geological relationships were far from simple, and that only an investigation extending over many weeks would suffice to bring order out of apparent chaos. At that time the main London fault, that at the Archean contact, was nowhere exposed in the mine, and no positive data could be secured indicating even the directon of the dip of this fault plane. On Pennsylvania Mountain it was proved that the fault plane dips to the east, and it was later found, by careful study of the surface geology on the London ridge, that the fault plane dips to the east at this point also. But this point on the ridge is located 800 or 1,000 feet above the mine workings, and a dip to the east at the surface would not necessarily indicate an easterly dip at the level of the mine workings.

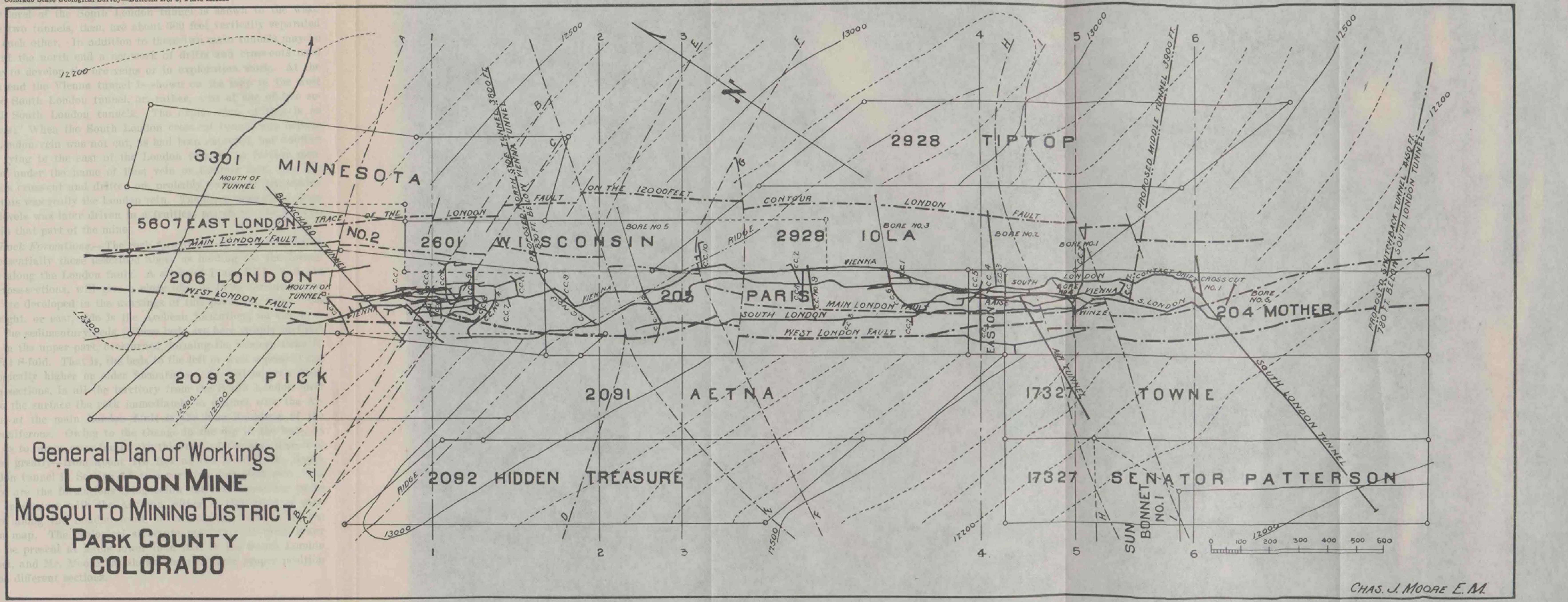
Fortunately, after the field-work had been closed, the mine management secured the services of Mr. Charles J. Moore, a mining engineer, to make a thorough investigation of the mine, with a view to further extensive development of the property. Mr. Moore has spent some two or three months in a painstaking study of the ore-bodies and of the geological conditions of the mine, and has prepared a very careful, detailed map of the ore-veins, rock formations and faults. This work was conducted under discouraging conditions, inasmuch as many of the old workings were difficult of access and even dangerous to enter. Even had the geology of the mine been carefully mapped at the time the development work was done, the problem of disentangling the complexities of the geological structure would have been considerable. That Mr. Moore has succeeded, under these conditions, in producing a detailed map of the geology of the mine is highly commendable and gratifying.

In pursuing his investigations, Mr. Moore caused six horizontal diamond-drill holes to be bored—five of them in the direction of the main London fault plane, and three of them extended until they actually passed the fault plane and entered the Archean schists. This gave important information both as to the extent and character of the formations lying to the east of the mine workings and as to the location of the great fault plane. By combining the observations of Mr. Moore underground and those of the writer partly underground, but mainly on the surface, it has been possible to work out a solution of the fault systems of the mine, and, of course, the relationship of the ore veins to the same.

Mr. Moore, with the consent of the mine management, has kindly permitted the publication in this report of map and sections of the mine prepared by himself. This generous attitude toward scientific research on the part of the mine management, and more especially on the part of the general manager, Mr. W. K. Jewett, and the superintendent, Mr. J. M. Kuhn, will be greatly appreciated by both geologists and the public, and furnishes an example that may be highly commended to others.

Plate XXIII is a plan of the mine workings, in addition to which are shown the surface contours in broken lines (taken from the map published in this report in Plate I) and the fault systems. As will appear later, there are two principal fault planes, approximately parellel to each other. The map shows the trace of these two principal planes on the surface. Likewise, the trace of the main or Archean fault plane is shown where it cuts the 12,000-foot plane—approximately the level of the South London tunnel. This trace of the fault plane on the 12,000-foot level, compared with that on the surface, shows the easterly dip of the fault. Plate XXIV presents a longitudinal section of the mine; that is, one parallel to the London vein, and at the same time parallel to the main London fault. It also shows the minor cross-faults and the stoped ground. Plate XXV presents six sections through the mine at right angles to the longitudinal section shown in Plate XXIV. The position of these six sections is marked in the two preceding plates. In this same plate are also shown the rock formations, the ore veins and the cross-faults.

Mine Workings.—The London mine has been worked principally from two cross-cut tunnels. The first one driven was the tunnel on the north face of London Mountain, called the Blanchard tunnel. This is located at an elevation of about 12,300 feet above sea-level. Later a tunnel was driven from the south side of the mountain and cut the ore-bearing formation at about 1,000 feet from the portal. This is at the 12,000-foot level and is called the South London tunnel. There were other openings made at different levels, especially at the north end, during the early days of development. Of these openings it is not necessary to speak. In general, there are two main drift-tunnels. One is at the higher level of the Blanchard cross-cut tunnel, called the Vienna tunnel. This is shown on the map to the east



General Plan of Workings
LONDON MINE
MOSQUITO MINING DISTRICT
PARK COUNTY
COLORADO

of the other, for the most part. The other drift-tunnel on the lower level of the South London tunnel is shown to the west. These two tunnels, then, are about 300 feet vertically separated from each other. In addition to these two main tunnels may be seen at the north end a net-work of drifts and cross-cuts used either to develop the ore veins or in exploration work. At the south end the Vienna tunnel is shown on the map to the west of the South London tunnel, or, rather, west of one of two so-called South London tunnels. The explanation of this is as follows: When the South London cross-cut tunnel was driven, the London vein was not cut, as had been expected, but another vein, lying to the east of the London vein, to be further mentioned under the name of East vein or Contact vein, was cut by this cross-cut and drifted on, probably under the impression that this was really the London vein. The more westerly of these two levels was later driven in a fruitless search for the London vein in that part of the mine.

Rock Formations.—The rock formations of the London mine are essentially those described above as holding for the formations along the London fault. A study of Plate XXV, with its six cross-sections, will give a clear idea of these formations as they are developed in the workings of this particular mine. On the right, or east, side is the Archean formation; on the west side, the sedimentary beds. These beds are here steeply inclined and, in the upper part, overturned, forming the western flank of a great S-fold. That is, the beds to the left or west represent the geologically higher or older formations. As will be seen from these sections, in all the territory from the South London level up to the surface the rock immediately in contact with the Archean at the main London fault is the blue limestone of the Carboniferous. Owing to the change in the dip of the beds, as well as to minor cross-faults, the thickness of the blue limestone varies greatly—from about 175 feet at the level of the South London tunnel in Section 6-6 to a very few feet elsewhere. Nowhere are the formations lying below the blue limestone to be seen in contact with the Archean, either in this mine or elsewhere along the London fault, in the district covered by the Alma map. The geological structure requires that these lower beds be present at levels lower than that of the South London tunnel, and Mr. Moore has shown them in their proper position in the different sections.

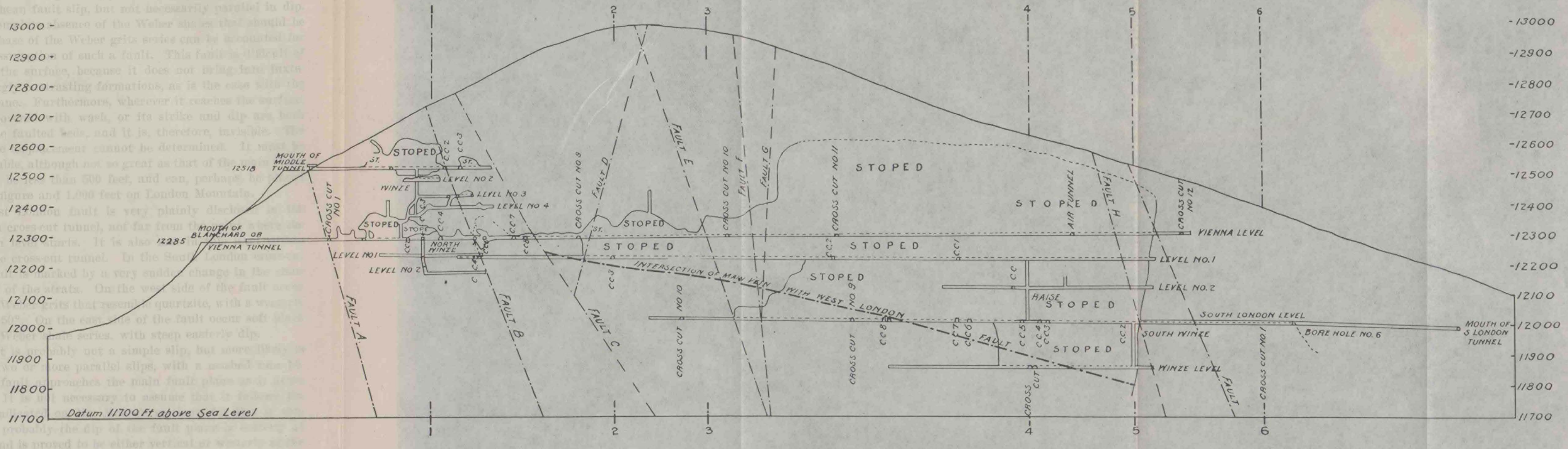
Fault Systems.—As shown in Chapter IV, the so-called London fault is not a simple fault slip, but a fault zone several hundred feet wide and marked by at least two pronounced fault planes that have an approximately parallel strike, but that may differ considerably in their dip. In the London mine these two pronounced fault slips are very strongly developed. But there are other much less pronounced faults that run more or less at right angles to the strike of the two main faults and that belong to an entirely different system. The faults, therefore, will be discussed under the following heads

The Main London Fault.
The West London Fault.
Minor Faults.
  (1) With steep dips.
  (2) With flat dips.

The Main London Fault.—Undoubtedly the great slip is the one at the Archean contact. Although there is no way available for determining the amount of this slip, it cannot be less than 1,000 feet, and may easily be twice that amount. That the fault movement in a vertical direction has been very great can readily be seen from the fact that only the Archean formation is to be seen on the east side of this fault plane in the vicinity of London Mountain, while on the west side the lowest beds are those of the blue limestone of the Carboniferous. That means that all the beds of the Cambrian and Ordovician, with their intercalated porphyry sheets, have been elevated on the east side of the fault and have subsequently been removed by erosion. More than this, as the fault plane follows in its dip for a long distance the dip of the sedimentary beds, much more must be added to the amount of the vertical displacement produced by this main fault.

The strong easterly dip of the fault plane is plainly brought out in the sections. This dip appears to increase as one goes from north to south. At the northern end the inclination of the fault plane is somewhat conjectural. At the southern end it was determined with very considerable accuracy by locating the Archean contact at the surface and at a point where one of the horizontal diamond-drill bores cuts this same contact at the level of the South London tunnel. None of the mine workings actually cut this main fault.

The West London Fault.—This fault is difficult to locate, and also difficult to prove. It could probably not have been worked out in the mine alone. It was first worked out on the



Longitudinal Section on the Main Vein

(Vertical Projection)

London Mine

Chas. J. Moore E.M.

surface in the study of the London fault on Pennsylvania and on London Mountains, and in the intervening Mosquito Gulch, as is described in Chapter IV. The structure of the sedimentary formations west of the Archean fault plane necessitates the presence of another fault plane approximately parallel in strike to the main Archean fault slip, but not necessarily parallel in dip. The almost complete absence of the Weber shales that should be found at the base of the Weber grits series can be accounted for only on the assumption of such a fault. This fault is difficult of detection on the surface, because it does not bring into juxtaposition strongly contrasting formations, as is the case with the main fault plane. Furthermore, wherever it reaches the surface, it is either covered with wash, or its strike and dip are both parallel to the faulted beds, and it is, therefore, invisible. The amount of the displacement cannot be determined. It must be very considerable, although not so great as that of the main fault. It can hardly be less than 500 feet, and can, perhaps, be placed between that figure and 1,000 feet on London Mountain.

This West London fault is very plainly disclosed in the South London cross-cut tunnel, not far from the point where the South London level starts. It is also met in this level within 200 feet of the cross-cut tunnel. In the South London cross-cut tunnel the fault is marked by a very sudden change in the character and dip of the strata. On the west side of the fault occur heavy beds of Weber grits that resemble quartzite, with a westerly dip of 40° or 50°. On the east side of the fault occur soft black shales of the Weber shale series, with steep easterly dip.

This fault is probably not a simple slip, but more likely is divided into two or more parallel slips, with a mashed zone between. This fault approaches the main fault plane as it nears the surface. It is not necessary to assume that it follows the curved line indicated on Mr. Moore's sections, for this is conjectural; but probably the dip of the fault plane is easterly at the surface, and is proved to be either vertical or westerly at the lower mine workings.

The direction of slip of this west fault is the same as that of the main fault, namely, up on the east side.

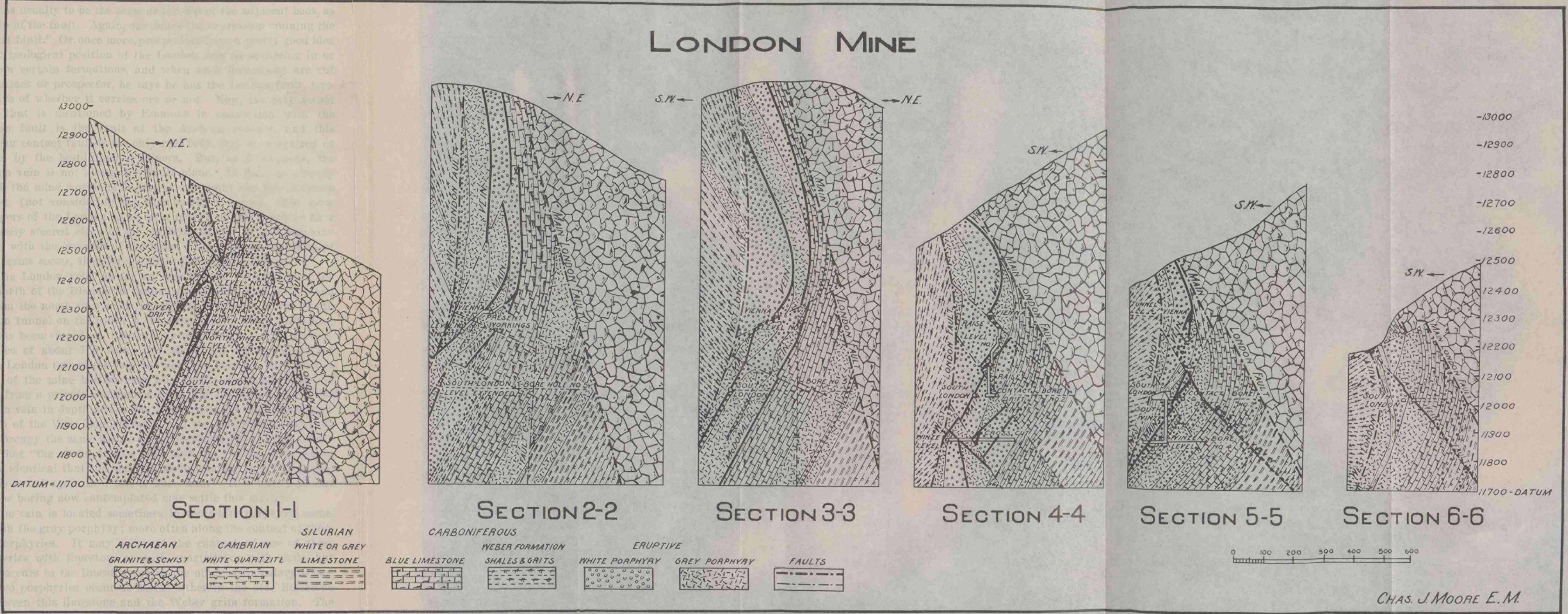
Minor Faults.—(1) The minor faults with steep dip have a strike approximately at right angles with the course of the London fault. As the London fault has a general northerly direction (actually about 30° to 35° west of north), so the steep-dipping faults have a general east-west direction. Mr. Moore shows nine of these on his map, seven of which dip from 55° to 75° southerly, one is vertical, and one dips 70° northerly. The amount of the vertical slip is not definitely known and is not very much in evidence in the mine workings. There is, however, often a very marked horizontal movement. One case of this is seen near the north end of the workings, not far from the Blanchard tunnel, where the parallel-running gray and white porphyries, with a narrow streak of shale between them, have been faulted horizontally by an amount more than equal to the width of the two porphyry sheets; namely, by ninety feet. The direction of this horizontal movement is sometimes so that the north wall moves east, sometimes west.

These cross-faults have not been seen actually to cut the main London fault, but in one case the assumption is unavoidable that the London fault has been cut and thrown by a cross-fault. This cross-fault is located on the surface in a marked gulch that runs from close to the summit of London Mountain in a southerly direction a little to the west of the portal to the South London tunnel. This is Fault I-I on the map. The south side of the London fault has been moved to the west. In this case the proved location of the Archean contact on the surface is quite out of harmony with the known conditions in the mine, except on the assumption of a fault, as above described. This also accords with the fact, observed on the surface, that the Archean contact on the south side of the above-mentioned gulch is located considerably farther down-hill than is this contact on the north side.

(2) The flat-dipping faults are only two or three in number, so far as known. They dip easterly at an angle greater or less than 45°. They are reverse faults; that is, the hanging (east) wall has gone up. The movement is not great, being in one case twenty-five feet. They seem to be local in their development. In one case a fault of this character appears to be mineralized. This is the fault just below the Vienna tunnel on Section 4-4, and may be the same as the East vein shown on Section 6-6.

The London Vein. Location and Extent.—As already stated, there is a popular conception among prospectors in the Alma district, that amounts to popular delusion, to the effect that the London vein is inseparately connected with the London fault, so much so that the two terms appear to be used more or less interchangeably. By this is meant that wherever along the line of the London fault a vein is struck that resembles the London vein, or that the discoverer thinks is the London vein, he is apt to speak of

LONDON MINE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BORE NO.
MCDONALD FAULT
RAISE
LEVEL NO.
WINZE LEVEL
CROSSCUT
TUNNEL
CONTACT BORE
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SECTION 2-2
SECTION 3-3
SECTION 4-4
SECTION 5-5
SECTION 6-6
ARCHAEAN
GRANITE & SCHIST
CAMBRIAN
WHITE QUARTZITE
SILURIAN
WHITE OR GREY LIMESTONE
CARBONIFEROUS
BLUE LIMESTONE
WEBER FORMATION
SHALES & GRITS
ERUPTIVE
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GREY PORPHYRY
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CHAS. J. MOORE E.M.

it as the London fault. He speaks of the dip of the vein, which happens usually to be the same as the dip of the adjacent beds, as the dip of the fault. Again, one hears the expression "mining the London fault." Or, once more, prospectors have a pretty good idea of the geological position of the London vein as occurring in or between certain formations, and when such formations are cut by a miner or prospector, he says he has the London fault, irrespective of whether it carries ore or not. Now, the only actual fault that is mentioned by Emmons in connection with the London fault is the fault at the Archean contact, and this Archean contact fault is the only real fault that is recognized or known by the best-informed miners. But, as it happens, the London vein is not along this fault plane. In fact, as already stated, the mine workings do not at any point cut this Archean contact (not considering the diamond-drill bores). The mine managers of the London mine, as a matter of fact, seem to have purposely steered clear of the Archean as not in any way connected with the ore vein of the mine. The popular confusion of these terms seems, therefore, a little difficult to explain.

The London vein, as far as now known, extends from 100 feet north of the Blanchard tunnel intersection with the Vienna level on the north to a point about 400 feet north of the South London tunnel on the south, a total distance of about 2,700 feet, and has been stoped at different places through a total vertical distance of about 750 feet. For about 400 feet north of the South London tunnel the vein has not been located. Mr. Moore's study of the mine has brought him to the conclusion that (to quote from a private communication) "the disappearance of the London vein in depth and at the southern end is due to the intersection of the West London fault, and the probability that both veins occupy the same fissure in the southern part of the mine;" also, that "the strike of this fault and the London vein are so nearly identical that the question as to whether the London vein will be found again in depth is uncertain." It is expected that the new boring now contemplated may settle this matter.

The vein is located sometimes in the white porphyry, sometimes in the gray porphyry; more often along the contact of these two porphyries. It may occur at the contact of one of these porphyries with limestone or with quartzite or with shale, but never occurs in the limestone or in the other sedimentary rocks. The two porphyries occur as sheets either in the blue limestone or between this limestone and the Weber grits formation. The two porphyries are usually in close contact with each other, or, when not, are separated by six inches to two feet of black shale that is often crushed to a black, coaly-looking powder. These sedimentary beds with which the two porphyry sheets are interbedded dip steeply to the west at angles that vary from almost vertical to 30°.

Character.—The London vein is a fissure vein consisting of a quartz gangue with sulphides of iron, lead and zinc carrying high values in gold and a little silver. To these metals may be added locally a little copper. The visible sulphides are pyrite, galena, sphalerite and chalcopyrite. The average values obtained from 1,700 tons of ore, according to smelter returns, were: gold, 2.66 ounces; silver, 2.4 ounces; lead, 3.1 per cent; zinc, 2.66 per cent; iron, 4.85 per cent; sulphur, 6.11 per cent; silica, 76.8 per cent.

The vein varies in width from a foot or less up to four or five feet, and may in places reach as much as ten feet. The ore is very irregularly distributed, and the vein pinches and swells, or feathers out to a mere streak. There is very little evidence of movement along the vein since the fissure was filled, nor is there evidence of great crushing of the wall rocks either before the deposition of the ore minerals or after that event. Slickensiding may be noticed at times, but only such as may be produced in a vein by very little actual movement. There are no fragments of ore or of rock encrusted with ore. The walls are mostly sharply defined, there being little or no impregnation or replacement of the country rock. While the distribution of the ore is irregular, there is no marked impoverishment of the ore with increasing depth, and therefore little to indicate a secondary enrichment at the higher levels.

This vein conforms in a general way with the strike and dip of the formations in which it lies. Its dip, therefore, changes with that of the porphyries, being more nearly vertical in the higher levels and possibly overturned before the surface is reached. In dip it does not even approximately follow that of the main London fault, as the vein dips to the west and the fault to the east. That the strike and dip of the vein may deviate more or less from that of the porphyry sheets is seen by the fact that its course may change from the gray to the white porphyry. This is further attested by the fact that the vein splits into two parallel-running veins at the north end of the mine. There do not appear to be any offshoots or feeders to this vein connecting it in any way with the London fault.

The East Vein.—This vein occurs along one of the flat-dipping minor fault planes. The strike is about parallel to that of the London vein; the dip is about 45° to the east. The dip of the vein, therefore, is not even approximately parallel to that of the sedimentary formations. It has been worked at intervals for a total distance of about 1,200 feet. The ore and gangue are similar to those of the London vein, except that the ore runs higher in lead. The vein is cut by the South London tunnel and is known to extend farther to the southwest. It seems to accompany the gray porphyry, or to occur with a hanging wall of blue limestone and a foot-wall of gray porphyry. Some good ore has been shipped from this vein. This vein was not personally examined by the writer. From Mr. Moore he learns that the East vein is undoubtedly formed within the fault fissure in which it is found, but that there is fragmentary ore included in the vein crevice—portions, apparently, of an older vein than the present one.

The McDonald Vein.—At the northern end of the mine occurs a vein to the east of the London vein and having the same strike. This is known as the McDonald vein. Its dip is vertical instead of to the west, as is the case with the London vein. Considerable ore was mined from this vein in the early days. It is possible that this vein is the same as the East vein above described. If so, the East vein would have a total length of 2,600 feet. The correctness of this supposition could probably be tested by a little prospecting.

The Blanchard Vein.—In the Blanchard tunnel—a cross-cut to the London vein from the north opening—a vein was struck about 150 feet east from the London vein that strikes N. 40° W., a little more northerly than the strike of the London vein, and that dips to the west at an angle of 45° to 60°. This vein was developed for a distance of 210 feet, but produced little ore.

Relations Between Faults and Veins.—As already stated, the London vein is not a fault vein. That is, there has been no pronounced movement along the fissure in which the vein lies, either before the deposition of the ore or after the same. Its strike happens to correspond fairly well with that of the London fault, but its dip is entirely different. It is evident that this vein fills a fissure that followed a line of least resistance, which was parallel, or approximately parallel, to the bedding planes of the sedimentaries and of the intruded porphyries. It lies between the Main London fault and the West London fault, but is not directly connected with either of these. It is cut, however, by the minor cross-faults and by the West London fault and thrown by them. This makes the London vein older than the cross-faults. But as the cross-faults also cut and throw the Main London fault, the latter must be the older of the two fault systems. This leaves a doubt as to whether the Main London fault is older or younger than the London vein. Owing to the lack of faulting along the London vein, it is not likely that the vein was formed before the London fault system was developed. Otherwise it would seem that the great earth stress that folded the strata into a great S-fold, and that finally caused their rupture and faulting to the extent of 2,000 or 3,000 feet, would have caused a movement along the vein fissure.

As to the East vein that appears to fill a minor fault fissure, the evidence available is not conclusive as to whether the ore was deposited in the fault fissure, or whether an already existing ore-body was cut by such a fissure and the ore dragged into the fissure.

Definite information is lacking, also, as to any possible connection of the McDonald and the Blanchard veins with any of the fault systems.

Origin of the Veins.—There are two striking features of the London vein that deserve to be emphasized. One is the close connection of the vein with the porphyry intrusions; the other is the fact that the vein does not cut the limestone nor replace it. As to the first feature, there is nothing unusual in the association of the ore with the porphyries. On the contrary, such an association is a very commonly recognized fact. The great majority of veins that carry the precious metals in the mining regions of the world, and especially in the mining West of America, occur either in igneous rocks more or less similar to the porphyry rocks of this district, or closely associated with such rocks. Such, for instance, is the case at Leadville. The other feature, on the other hand, is contrary to usual experience. It is generally known that, where porphyries and limestones occur in close association with each other and with ore deposits, the ore deposits favor the limestone. In Leadville we have the identical porphyry rocks, and also the identical limestone formation, that have been described as occurring at the London mine. Yet at Leadville the ore deposits are largely confined to the limestone. An explanation of the difference in the two cases is to be found in the difference in the character of the ore deposits. In the Leadville district the ores are what are known as "replacement ores." That is, the ore does not lie in a clean-cut fissure, but in irregular masses that have replaced the limestone bodily. Such replacement ores are conceived to originate by the percolation of mineral solutions through irregular, and perhaps more or less clogged, channels, so that the ore-bearing solutions dissolve their own channels through the readily soluble limestone and, at the same time, deposit a part of their mineral burden in the place of the dissolved limestone.

In the case of the London vein the circulating ore-bearing solutions found a clean-cut fissure at hand that did not happen to pass through limestone. It may well be that the porphyry walls through which the solutions passed had an effect on the solutions favorable to the precipitation of the mineral content. As to the ultimate source of the mineral solutions, it may probably be sought for in the deeper-lying regions from which the porphyries ascended. The widespread porphyry intrusions that characterize this part of the Mosquito Range must have had some common source at an unknown depth below the surface of the earth. Heated waters rising from these regions of relatively high temperature may be supposed to have brought up the mineral matter in solution, and to have deposited them on their way to the surface, either by loss of temperature and pressure, or by reaction of the wall rocks with which they were in contact, or, possibly, by mingling with solutions derived from a different source.

As to the other veins found in the London mine, information as to their character is too scant to justify any speculations. There is, however, so far as at present known, no reason to attribute a different origin to them from that of the main London vein.

Possibility of Further Development.—If the above-outlined theory as to the origin of this vein is correct, in the absence of definite proof that the original ore deposits have been enriched by descending waters, there is no reason to anticipate an impoverishment of the ore with increasing depth. The depth to which the ore has been stoped out is very moderate, and the ore-carrying vein might reasonably be expected to continue for many hundreds of feet, or until the vein strikes rock conditions materially different from those encountered in the present workings.

MINES NORTHWEST OF LONDON MOUNTAIN—

In the region northwest of London Mountain considerable prospecting work has been done along the London fault in the effort to find the continuation of the London vein. Most of this work was done many years ago, and the mine workings are now inaccessible. From the size of the dumps it is evident that the development or exploration work has been in some cases quite extensive. Most of this work has been done through tunnels driven in the very prominent limestone hill immediately southwest of the fault and about half a mile from the portal of the North London tunnel. Other work has been done in the flat to the south of this hill.

As no mine in this region from which ore has been taken was found accessible, information as to the ore deposits is confined to what could be picked up from those who have been a long time in the district. From this source it was learned that only one property north of London Mountain has produced ore similar to that of the London mine; namely, the "Hard to Beat" claim. This is located on the London mine property and is at the immediate foot of London Mountain, only a short distance from the North London mine buildings. This claim is said to have produced ore to the value of $40,000. The vein comes to the surface and shows a dip of about 20° to the southwest.

The only other mines or claims in the area northwest of London Mountain that are said to have produced ore are the New York and the Baltic. These are located at the foot of the very steep easterly face of the above-mentioned limestone hill, close to a small lake. The ore from these mines is said to have been entirely different from that of the London mine, in that it contained only silver instead of both gold and silver, and in that it lies in the blue limestone in pockets, not in a vein associated with porphyries. Close to these two mines is a tunnel, called the Oliver Twist tunnel, which is still open. This tunnel starts near the lake-level to the east of the London fault, in Archean rock. It passes through the Archean, cuts the London fault and the porphyry west of that fault, and ends in the blue limestone. No ore was found in this tunnel, but the fact that it was carried forward into the limestone to the west of the fault is evidence that an effort was made to strike the ore formation found in the New York and Baltic mines.

MINES SOUTHEAST OF LONDON MOUNTAIN—

General Description.—There are a large number of prospects in proximity to the London fault on both sides of Mosquito Gulch. Some of these have been very extensively developed, and are designated as mines irrespective of whether ore has been uncovered or not. They have all been worked through tunnels that have been driven with a view to striking the London vein. As will appear later, the Butte mine on the south side of the creek may justly claim to have found the London vein, or, at least, a vein of similar character and in the same geological position. So far as definite information could be obtained, this is true of no other property. Most of the properties are now inaccessible because of caving in, or because of bad air. Undoubtedly small ore-streaks or leads have been struck, as would naturally be expected, but no ore-body of any considerable size appears to have been struck, except in the one case above mentioned. Most of these prospecting tunnels have been driven from the west side of the fault through the Weber grits or through the porphyry sheets. These have furnished the best showing. A few have been driven from the east side of the fault in the Archean rocks. No ore appears to have been struck in the Archean. Only three of the tunnels appear to have actually cut the Main London fault at the Archean contact. These will be more particularly mentioned later.

Butte Mine.—The only mine outside of the properties of the London mine in which the London vein appears to have been struck is the Butte mine. This is located on the south side of Mosquito Creek, close to the bottom of the valley. The rock formations are exactly the same as those in the London mine. The tunnel is driven parallel to the strike of the London fault, which is practically the same as that of the sedimentary formations and of the porphyry sheets. This is S. 30° E. at the portal. The gray porphyry at this place lies to the east of the white porphyry. Ore was struck in the gray porphyry in a vein that varied from four inches to two feet. The strike of the vein was about S. 35° E., the dip 60° to 65° to the west. It should be noted that the strike of this vein is about the same as that of the porphyry sheet. The dip, however, does not at all correspond to that of the porphyry, as the latter dips at this place about 70° to the east, whereas the vein, as just noted, dips even more flatly to the west. It is evident that, at this place, the vein is not following the porphyry to the extent that it does in the London mine.

This ore-vein was drifted on for 400 feet and then played out. Altogether three cars of ore were shipped from this drift. At the time the writer visited the mine, in 1910, the drift had been continued for a distance of 1,500 beyond the ore-shoot, or a total of 1,900 feet from the tunnel portal. Most of the way this drift lay between the white porphyry on the west and the gray porphyry on the east. Between the two is to be found a black, lustrous, soft, slickensided gouge, about six inches wide. This black gouge is a crushed shale identical with that frequently met with in the London mine at the contact of the two porphyries. No ore was struck in drifting these 1,500 feet. The general manager of the Butte Mine, Mr. Charles P. Aicher, states that since 1910 he has extended the drift 500 feet farther to a point under the end of the Pennsylvania tunnel, situated some 1,000 feet higher on the same mountain, without finding any trace of ore.

Close to the mouth of the tunnel a shaft was sunk to a depth of 150 feet. Here, in a drift 800 feet long, an ore-shoot was struck that extended 150 feet along the contact between the white and the gray porphyries. This was simply a narrow ore-streak measuring four to six inches in width.

In the Butte mine the two porphyries lie to the west of the blue limestone, which measures 100 feet in thickness. The white porphyry seems to split into two sheets, as, at one point, there are two white porphyry sheets—one in contact with the Archean, the other 160 feet farther west, with 100 feet of limestone and forty feet of gray porphyry between them. The West London fault is also met in this tunnel. It lies on the west side of the gray porphyry and dips with the porphyry 70° to the east. On the west side of this fault are the Weber grits, with a westerly dip of about 65°. This information was obtained from Mr. Aicher, who also stated that, whereas the beds at the portal dip to the east about 65°, in the shaft, at a depth of 150 feet below the tunnel, the dip is 65° to the west. It is evident from this that the sedimentary formation makes a sudden bend from the normal easterly dip to a vertical just below the surface at the tunnel portal. From the surface up to the top of Pennsylvania Mountain, a vertical distance of some 1,800 feet, the main London fault dips about with the sedimentary beds which are overturned and dip to the east at 70° to 80°.

In the Butte tunnel several cross-faults are struck that show both vertical and horizontal throws. In one case a horizontal throw of twenty feet was observed, the south wall being thrown to the west.

Other Mines in Mosquito Gulch.—On the north side of Mosquito Gulch, below the wagon-road that ascends to the South London mine, are a number of mine claims and prospects in which considerable prospecting work has been done through tunnels. These are driven in the Weber grits formation to the west of the Main London fault. No ore of any consequence has been found in any of them, but considerable information is furnished as to the geological structure. The mines visited are the Genevieve, Reconstruction and London Extension. In all of these tunnels, located not far from the bottom of the valley, the sedimentary formations west of the London fault are shown with a not very steep westerly dip. This is true of the Weber beds and the intruded porphyries, and shows that these formations gradually change from an easterly to a westerly dip as they approach the fault. Another important geological feature shown in these tunnels is the presence of the Weber shales in their normal development. In the higher level of the London mine, where the formations against the London fault are more steeply inclined, the Weber shales are all but wanting, having been cut out by the West London fault. At these lower levels, some distance west of the fault, too far away to be affected by the West London fault, the shales at the bottom of the Weber grits formation are seen to be present.

The Pennsylvania Tunnel.—About 800 feet below the summit of Pennsylvania Mountain, just below the Butte that rises immediately west of the London fault, this tunnel has been driven in an easterly direction approximately at right angles to the Main London fault, until it cuts the Archean schists at 1,200 feet from the portal. The tunnel cuts through easterly-dipping Weber grits and porphyry sheets, then through steeply dipping and possibly westerly-dipping Weber shales, and finally through white porphyry which is in contact with Archean schists at the fault. The tunnel then drifts several hundred feet to the southeast, in the general direction of the fault, but zigzagging through the formations and cutting the Archean at one other point. In all of this work no trace of ore was struck. A further description of this tunnel will be found in Chapter IV, page 108.

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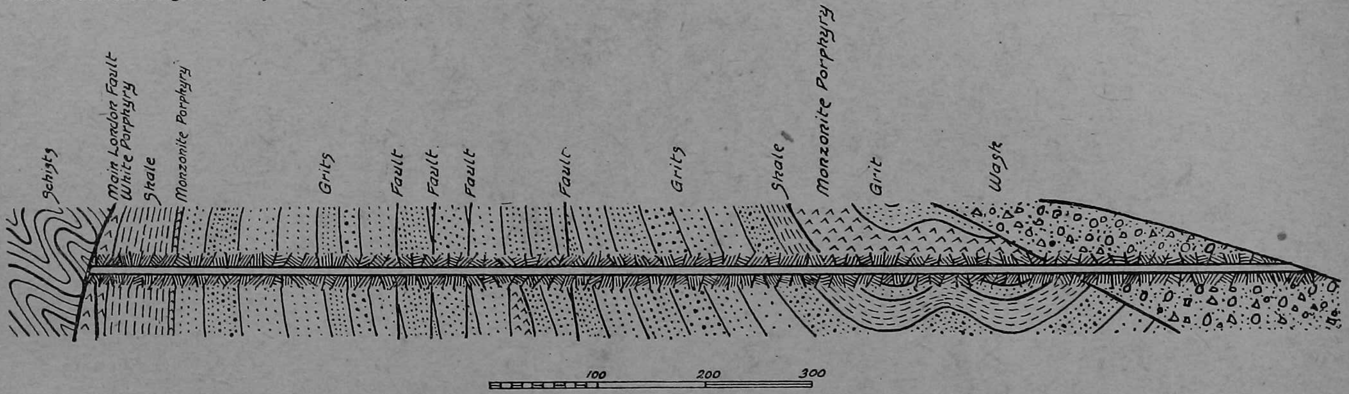

PLATE XXVI.—Section along the Pennsylvania Tunnel, looking South. One of the fault lines shown in the grits is supposed to be the west London fault.

Conclusion as to Extension of London Vein.—From the above description it will be seen that no extension of the London vein has been found to the northwest of London Mountain, in spite of extensive prospecting. In the other direction the vein has been diligently sought for both at the creek-level and higher up the mountain. In both the Butte and the Pennsylvania tunnels the prospecting seems to have been done quite thoroughly. Only in the Butte was ore found, and this quickly gave out. It would seem, therefore, that the vein does not extend north of London Mountain, nor south of it to any great extent. While it would be rash to assert that this vein does not extend beyond Mosquito Gulch, except sporadically, and that further prospecting in that direction would be fruitless, still there is little in the experience of those who have carried on this extensive prospecting to offer great hope of success.

ORE DEPOSITS ON LOVELAND MOUNTAIN

THE ORPHAN BOY MINE—

Geologic Structure.—About two-thirds of a mile west and three hundred feet above Park City, at the east foot of Loveland Mountain, is located the property of the Kennebec Mining Company, of which the Orphan Boy is the principal claim. The property, therefore, goes under the name of the Orphan Boy. As shown in Chapter IV, this part of Loveland Mountain consists of easterly-dipping Cambrian quartzites, with three, and in one place four, conformable sheets of igneous rocks. The two lower sheets are quartz monzonite porphyry, the third from the bottom a hornblende porphyrite (represented in Plate XIII, A, and in Plate XIV, A), and the fourth another quartz monzonite porphyry of darker color. Above these quartzite beds and intruded porphyries are the calcareous quartzite beds of the upper part of the Cambrian, and above these the Ordovician limestone. It is probable that the fourth porphyry sheet, which was found farther west on the cliff section, is to be found at the location of the Orphan Boy property.

Ore-Veins and Faults.—The easterly-dipping formations are cut by a number of more or less parallel-running and steeply inclined fault planes that have an average strike of N. 35° E. There are said to be about twenty of these faults. The dip varies from 60° to vertical; three dip to the west, the others to the east. The amount of vertical slip varies from a few inches to twenty feet, in one case to fifty-four feet. The upraise is sometimes on the north, sometimes on the south side of the fault.

All the veins of the mine are confined to these fault planes. According to Mr. A. E. Moynahan, for several years superintendent of the mine, the veins are not properly veins at all, but merely very narrow streaks of gouge resulting from the crushing and rubbing of the walls of the fault. The material is crushed quartz where the faults cut through quartzite, and rotted and mashed porphyry where the walls are of that rock. These crushed streaks are hardly ever over two inches in width, and very often are entirely missing. Where these faults cross a contact between quartzite below and a porphyry sheet above, there is a sudden change. At such places, called locally "contacts," the vein changes absolutely in character. At the under contact of a porphyry sheet, more especially is case of the next-to-the-bottom sheet, the vein widens out on each side of the fault to a total width of ten to twenty feet, and for a distance of five or six, or possibly eight, feet—in one case eighteen feet—below the contact. This suddenly widened portion of the fault fissure-vein is a replacement vein in quartzite. The gangue is calcite, but usually the ore is nearly solid pyrite, with small but varying amounts of galena, sphalerite and chalcopyrite. Locally the quantity of the less common ore minerals may become important. For instance, sphalerite is known to form in one place 30 per cent of the ore. While the ore is mostly confined to the quartzite, it is not strictly confined to this formation, but may extend to a slight extent into the overlying porphyry.

This replacement of the quartzite takes place beneath both of the two lowest porphyry sheets, but paying ore has thus far been found only under the second sheet. This contact is known as the "Orphan Boy contact." Under the third sheet, the hornblende porphyrite, no ore is found. According to Mr. Moynahan, there is one exceptional vein. The Evening Star vein carries ore through all the formations, and varies from three to six inches in width. It also develops into an ore-body of considerable size below the porphyrite contact, but the ore at this place is of low grade.

The above-described conditions are brought out in Fig. 5. The replacement ore-bodies generally continue along the line of the fault and at the porphyry contact with great regularity, but they differ considerably in values at different points.

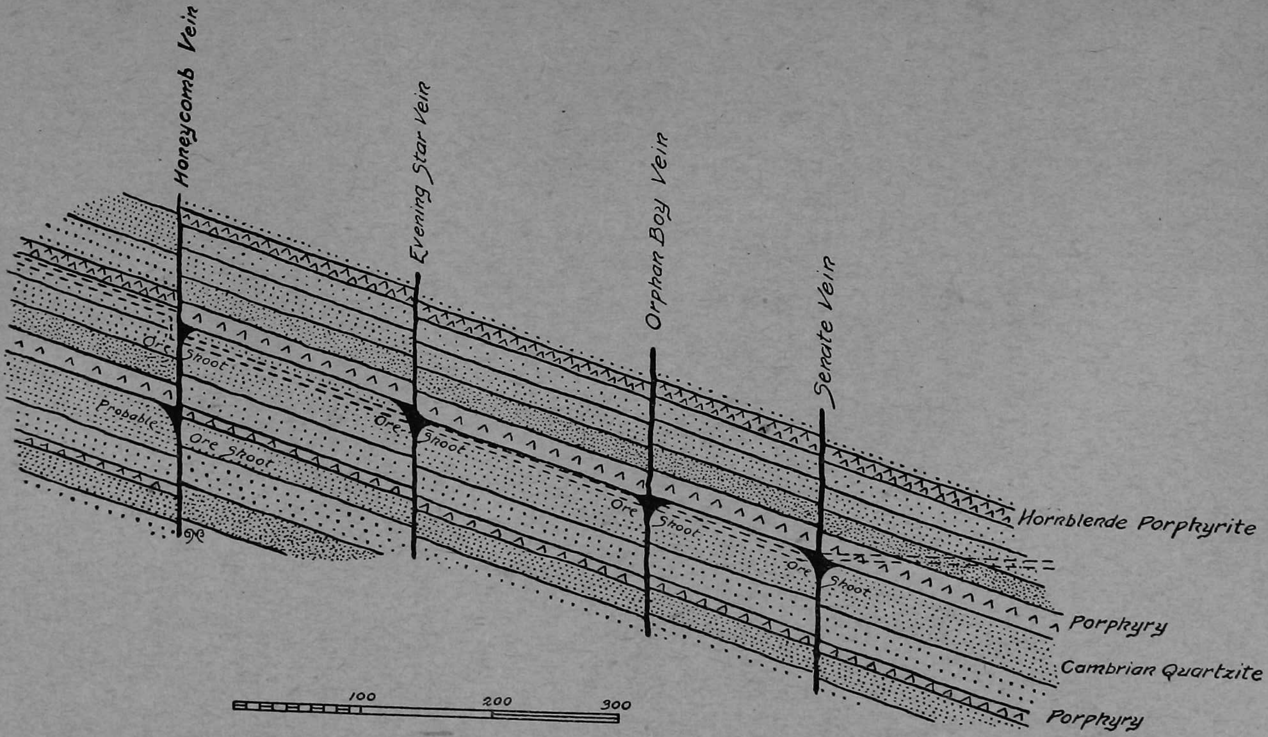

Fig. 5

Idealized Section along the Incline of the Orphan Boy Mine, showing system of veins and Ore Shoots, also the Incline in broken lines following the wrong intrusive sheet.

Of the twenty fault-veins that have thus far been struck in this property, eight are said to have produced paying ore. Those that have produced ore in considerable quantity are the Senate, Orphan Boy, Honeycomb, New Years, Evening Star, Copper and Good Samaritan veins. Of these the Orphan Boy vein is the most important. Some of these veins, or others farther to the north, are known to contain ore-bodies in the overlying white limestone. These upper workings were not accessible and their exact character is not known to the writer, except that in some cases, as might be expected, lead carbonates were found.

Ore Values.—From a certified list of smelter returns, as found in the office files of the Kennebec Mining Company, was prepared the table found below:

Vein	Tonnage	Value
Senate	1,729.366	$ 46,880.77
Orphan Boy	5,389.192	99,442.23
Honeycomb	1,150.026	20,917.69
New Years	583.074	9,417.69
Evening Star	1,425.058	29,436.79
Copper	684.860	22,697.38
Good Samaritan	38.697	321.51
Total	11,000.273	$229,113.87

This gives an average of about twenty-one dollars per ton. This does not, however, cover the entire period of working, as no smelter returns are available for the earlier years of mine working. According to Mr. Moynahan, the unaccounted-for output considerably exceeds that of the above-quoted smelter returns. The values as returned by the smelter are, with comparatively few exceptions, entirely in gold and silver. The gold runs in carload lots from .25 to .50 ounce, with a good many returns of 1 to 1.50 ounces, and occasional still higher ones. The silver returns run from 10 to 25 and 50 ounces, with some above and some lower than these figures. Ten returns from the copper vein give an average of 3 to 4 per cent copper, and about 20 per cent zinc. It is probably true, as stated by Superintendent Moynahan, that considerable bodies of low-grade ore, especially of zinc- or copper-bearing ore, have been left standing in the mine awaiting more favorable conditions for mining.

Plate XXVII shows a map of the Orphan Boy properties and indicates the positions of the above-named ore-veins.

A Misdirected Development.—Some years ago the management of the mine decided to develop the veins that were known

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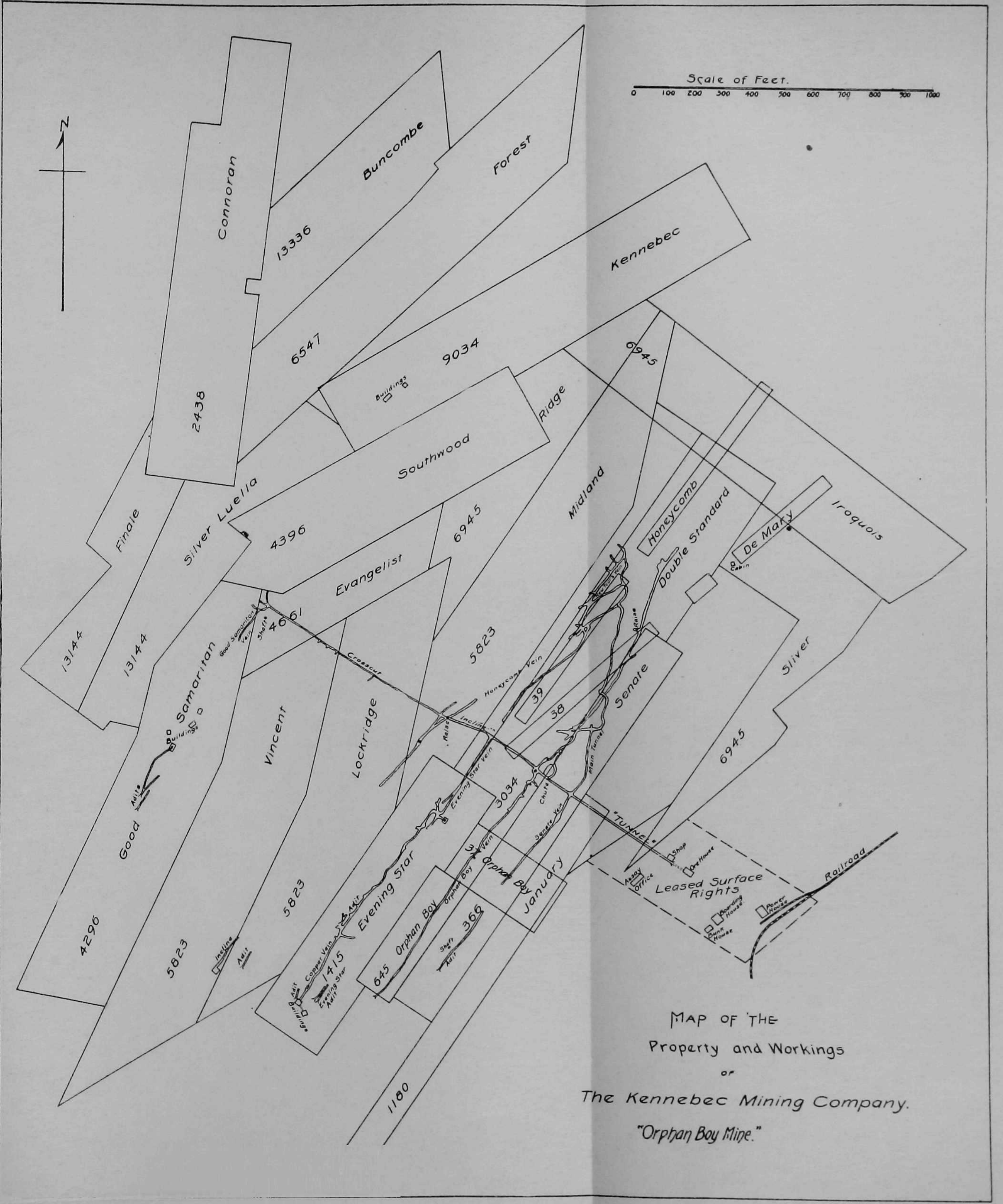

MAP OF THE
Property and Workings
OF
The Kennebec Mining Company.
"Orphan Boy Mine."

to occur in the area north of the main workings. These veins had been struck in shafts sunk into the overlying white limestone, and ore had been struck in some of these veins in the limestone. It was confidently expected that these veins would prove to develop valuable ore-bodies at the porphyry contact. Accordingly, a cross-cut 1,200 feet long was run from the Senate vein in a northwesterly direction, approximately at right angles to the strike of the veins. As the strata dip at this place about 18°, and as this cross-cut followed approximately the direction of the natural slope of the strata, this cross-cut was run on an upward incline of 18°. Where this main cross-cut crossed the Honeycomb vein it encountered a fault, and, under the supposition that the upthrow was on the farther side of the fault-vein, an upraise of sixteen feet was made and the contact again struck at this point. But the ore-body that was looked for at the contact was missing. On continuing the cross-cut, which was driven on the contact, eight veins were crossed, but no ore-bodies were found where the veins crossed the contact. At the upper end of the cross-cut a vein was encountered that contained some high-grade lead ore. This is the Good Samaritan vein, that had produced large quantities of lead carbonate in the higher workings in the Ordovician limestone. But even this vein failed to show the body of replacement sulphides that had confidently been expected.

At the request of the superintendent, the writer made an examination of the property, with a view to explaining, if possible, the absence of the ore-bodies where the veins cross the Orphan Boy contact. The explanation was readily found on examining the overlying porphyry sheet. It was found that the overlying sheet was not, as had been supposed, the quartz monzonite porphyry of which the second sheet is composed, but the hornblende porphyrite that forms the next higher sheet. As this porphyrite is known not to have ore-bodies beneath it, no further explanation was needed. Of course, those driving the cross-cut incline supposed they were following the Orphan Boy contact. It is evident that, on cutting the Honeycomb vein where the sixteen-foot upraise was made, they should have gone down to find the lost contact, as the upthrow was on the nearer side and not on the farther side of the fault-vein. The vertical distance between the Orphan Boy contact at the bottom of the second porphyry sheet and the lower contact of the porphyrite sheet above is said to be seventy feet. As this porphyrite contact was found in the upraise sixteen feet higher on the west side of the fault, it is evident that there has been a downthrow on the west side of fifty-four feet, and a winze sunk to that depth below the level of the incline should strike the Orphan Boy contact again. In the altered condition of the hornblende porphyrite along the incline, the real character of the rock had not been recognized. And yet a careful comparison of the rock of this contact with that of the Orphan Boy contact, without the necessity of resorting to thin sections of the rocks, left no doubt as to their essentially different characters. The wasted effort and expense in connection with this abortive development work resulted in the closing down of the mine on account of the exhaustion of funds and of the attendant discouragement. Here is a case where the services of a geologist, and not that of a mining engineer, were needed, and where the expenditure of a very few dollars would have saved the loss of many thousands.

Fig. 5 on page 211 shows this incline following the wrong contact to the west of the Honeycomb vein.

Genesis of the Ores.—The very peculiar position of the ore-chutes of this mine, in which, with the exception of one vein, the deposition of the ore-bodies is confined to the lower contact of a porphyry sheet with the underlying quartzite, indicates a like origin for all the veins, with the possible exception of the Evening Star vein. That the faults should prove barren at contact with the porphyrite, and ore-bearing at the other porphyry contacts, seems to point to a marked difference in the effect of these two igneous rocks on the ore-bearing solutions. As no veins occur except those in close connection with faults, we must look to the faults alone as channels for the mineral solutions. It is well known that sulphide ores are frequently precipitated by reaction between the wall-rock and the solutions carrying the ore. It would seem that the presence of the porphyry was essential to the precipitation of the ore, and that we have here a striking case of the effect of the wall-rock on the ore deposition.

It may fairly well be admitted that the solutions were traveling through the narrow fault fissures either up or down. If the ore-vein was continuous through the different formations and concentrated at certain horizons, there would be good ground for belief that there had been two periods of ore deposition—a primary period of deposition, presumably by rising waters, and a secondary period of enrichment by descending waters. In the absence of such a condition, there is not so much ground for claiming more than one process of the development of these ore-bodies. The writer is inclined to believe that these ores were deposited by descending waters, for the following reasons: (1) It is known that there are oxidized ores in the overlying white limestone, and therefore waters must have been descending from the surface during at least the later portion of the ore-forming period. (2) The ore appears to have been deposited because of some effect produced by the porphyry. For this to be effective, the waters must first pass through the porphyry. As the ore is confined to the lower contact, the waters must, then, have come from above. (3) In passing through the higher of the two porphyry sheets, the metals would be largely removed from the solutions, so that little would remain to be precipitated by the lower porphyry sheet. This would explain why the ore-chutes below the lower porphyry are not pay-ores.

And yet it is difficult to say why the metals should have been precipitated as they are. The process can hardly have been due to reduction; for in this case the porphyrite sheet would have been a more effective precipitating agent than the porphyry, as it contains a much larger amount of minerals carrying ferrous iron. One fact, however, should not be lost sight of. The ore is a replacement product of the quartzite rather than of the porphyry. The porphyry may have furnished solutions favorable to the precipitation of the metals as sulphides, but only as further acted upon by the pure silica rock.

OTHER MINES—

A number of prospect tunnels have at one time or another been driven along the contacts of the porphyry sheets with the Cambrian quartzite, where these rocks crop out along the cliff section of Loveland Mountain overlooking Mosquito Gulch. Some of these operations seem to have been quite extensive. Whether much ore has been extracted is unknown to the writer. On the eastern flat slope of Loveland Mountain there has been more extensive mining. The most important of these mines is the Shelby mine, located about 3,000 feet northwest of the tunnel portal of the Orphan Boy mine, at an altitude of 11,500 or 11,600 feet. This mine was not accessible on account of water. It is said to contain extensive bodies of oxidized ore, especially of lead carbonate in the form of replacement bodies in the Ordovician white limestone.

ORE DEPOSITS ON PENNSYLVANIA MOUNTAIN

THE HOCK HOCKING MINE—

This mine is located on the road that leads from Park City to the top of Pennsylvania Mountain, directly opposite the Orphan Boy mine, and at about the same elevation. At the time the writer visited this mine, work was being done in a winze sunk below the level of the new cross-cut tunnel, but, on account of the excessive amount of water, a study of the ore deposits was extremely difficult and was postponed for a later date. Unfortunately, circumstances prevented a second visit. This mine has, however, been described by Professor Hoskin in Chapter VI of this report, where a brief description of the ore deposits will be found. Suffice it to say that the ores of this property in the upper levels that have long since been worked out were oxidized ores of lead and silver, with a gangue containing calcite and much manganese; that they occupy fissure veins, or are limestone replacements along such veins; and that these veins cut all the formations from the Carboniferous limestone to the Cambrian, but that the ore was confined to the Ordovician limestone, except where a little was found in the "parting quartzite" at the top of the Ordovician.

These conditions are apparently somewhat similar to those that prevail on the flat slope of Loveland Mountain. That the ore does not occur in the Carboniferous limestone may be due to the fact that the ore-veins come to the surface very close to the lower contact of the Carboniferous limestone, and that probably any ores that may have originally been present have been leached out and carried down by descending waters.

That ore must have been found in the Carboniferous "blue limestone" on Pennsylvania Mountain is attested by the fact that a large number of shafts have been sunk all over the lower part of Pennsylvania Mountain in the region covered with Carboniferous limestone, and that many of these shafts show evidence of considerable development work. All of these prospects are now closed by caving in.

There has also been considerable mining done at the foot of Pennsylvania Mountain, at or near the place where the ore-veins of the Hock Hocking mine are supposed to crop out. This is at a point about 1,500 feet west of the portal of the Hock Hocking mine. There is one property that was being prospected at the time this survey was made, but no investigation was made.

CHAPTER IX

ORE DEPOSITS NORTH OF ALMA

BY G. MONTAGUE BUTLER

AREA INVOLVED

Unless otherwise indicated, the following description applies only to the ore-bodies in Buckskin Gulch and in the area lying north and northeast therefrom. The writer was able to spend but a month in the field, and, realizing the impossibility of making a detailed examination of the whole Alma district in that time, he confined his attention to the territory above described. He cannot, therefore, speak with certainty concerning the deposits south of Buckskin Gulch, although it is probable that many of the statements herein contained apply with equal truth there.

Throughout this chapter the various formations are designated by the names commonly applied to them at Leadville. This is done because of the uncertainty concerning the true geological age of several of them. The terms placed opposite each other in the table below may, however, be considered synonymous:

Lower Quartzite	Cambrian (Upper Cambrian?) Quartzite
White Lime	Lower Silurian or Ordivician Limestone
Parting Quartzite	Lower Silurian or Ordivician Quartzite
Blue Lime	Carboniferous Limestone

TYPES OF DEPOSITS NOTED

At least four types of deposits occur—all distinctly different, although doubtless related genetically. They are:

1. Veins.
2. Replacements.
3. Impregnations.
4. Placers.

These will be described and discussed in the order of decreasing frequency of occurrence, as named.

VEINS—

Veins of various kinds are not only very plentiful at many points, but, as the result of an almost total lack of soil, their outcrops are often decidedly conspicuous and easily traced. The outcrop of the Kansas-Magnolia vein shown in Plate XXVIII, A, is very noticeable from a distance of half a mile or more as a rusty streak in the cliff.

At least six types of veins are recognizable and may be thus designated:

a. Fissure Veins.
b. Fault Fissure Veins.
c. Contact Fissure Veins.
d. Gash Veins.
e. Sheeted Zones.
f. Fahlbands.

Fissure Veins.—Fissure veins are numerous in the upper part of Platte valley, particularly at, or just above, Montgomery, and in upper Buckskin Gulch. They vary from less than an inch up to four feet or more in width, and are more plentifully exposed in the Archean schists, gneisses, and granites than in the overlying sedimentaries. Not infrequently they cut through both, however, as in the case of the Kansas-Magnolia vein northwest of Montgomery, which passes vertically through the white lime and lower quartzite, and extends an unknown, but very great, distance down into the Archean rocks.

The vein-walls are frequently sharply defined and are approximately plane surfaces, but where a vein cuts the sedimentaries there are often off-shoots of ore along the bedding planes, as in the Fanny Barrett mine on Loveland Mountain. Impregnation or replacement of the wall-rocks by the vein solutions is fairly common, and large ore-bodies have been produced in this way. Such enlargements or extensions of the veins are frequently confined to certain horizons, as in the Atlantic-Pacific and Hock Hocking mines. The ore-shoots of the former are confined to the lower quartzite, and the latter was productive only in the white lime.

With rare exceptions, it is true that the fissure veins proper are filled with very low-grade ore, although rich shoots are occasionally encountered. It is, in fact, doubtful if it would usually pay to prospect the fissure veins, if it were not the case that they often lead to, and connect with, valuable ore-bodies of some of the other types later discussed.

Many of the fissure veins are—as is to be expected—roughly parallel to the schistosity when they occur in Archean schistose rocks, but the manner in which a number of them cut across the stratification planes of the overlying sedimentaries, and their departure from exact parallelism to the lamination of the schists, is sufficient to remove them from that class of deposits described as follows by S. F. Emmons, under the title "Deposits in the Archean":*

> "It was found * * * that they were invariably a simple mineralization of the country rock along some plane which admitted the percolation of water, * * * the vein materials being simply an alteration product of this rock, and not foreign material filling pre-existing fissures, as is supposed to be the case in a true fissure vein."

Near Montgomery all types of veins have an average strike of N. 20° W. (magnetic) and an average dip of 70° W.; this is also the average strike and dip of the schists. Elsewhere a decided parallelism of the veins is not so evident, although a northwest and southeast striking series is recognizable in Buckskin Gulch.

The following is a very incomplete list of properties situated on fissure veins, or combinations of fissure veins and other types of ore deposits. Doubtless many other caved and abandoned prospects, which it was impossible to examine, are of this type:

Name of Claim or Operating Company	Location	Formations Intersected
Little Nell	Loveland Mt. Facing Buckskin Gulch	Lower Quartzite
Julia	Loveland Mt. Facing Buckskin Gulch	Lower Quartzite
Jay Gould	Loveland Mt. Facing Buckskin Gulch	Archean
Rainbow	Loveland Mt. Facing Buckskin Gulch	Archean
Rock Island	Loveland Mt. Facing Buckskin Gulch	White Lime
Ernest	Loveland Mt. Facing Buckskin Gulch	White Lime
Northern Light	Loveland Mt. Facing Buckskin Gulch	Lower Quartzite
Tanner Boy	Loveland Mt. Facing Buckskin Gulch	Archean
Fanny Barrett	Loveland Mt. Facing Buckskin Gulch	Archean—Lower Quartzite
Phillips	Loveland Mt. Facing Buckskin Gulch	Lower Quartzite
Esmeralda	Mount Bross Facing Buckskin Gulch	Archean
Home Sweet Home	Mount Bross Facing Buckskin Gulch	Archean
Pulaski	Mount Bross Facing Buckskin Gulch	Archean
Excelsior	Mount Bross Facing Buckskin Gulch	Archean—Lower Quartzite —White Lime
Criterion	Mount Bross Facing Buckskin Gulch	Lower Quartzite
Greenwich	South Face of North Star Mountain	Archean
Chicago-Columbia	South Face of North Star Mountain	Archean
Davenport	South Face of North Star Mountain	Archean
Kansas-Magnolia	South Face of North Star Mountain	Archean—Lower Quartzite —White Lime
Lee Goss	South Face of North Star Mountain	Archean—Lower Quartzite —White Lime

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*U. S. Geol. Surv., Mono. 12, p. 538.

Name of Claim or Operating Company	Location	Formations Intersected
Nova Zembla	South Face of North Star Mountain	Archean
El Dora	South Face of North Star Mountain	Archean
Puritan	South Face of North Star Mountain	White Lime
Gold Chord	South Face of North Star Mountain	White Lime
Anna	South Face of North Star Mountain	Archean—Lower Quartzite
Rhinegold	South Face of North Star Mountain	Archean
Wheeler	Platte Amphitheater	Archean
Atlantic-Pacific	Crest of North Star Mountain	Archean—Lower Quartzite —White Lime
Gold Moose	Northeast Base of Mount Bross	Blue Lime—Parting Quartzite

Fault Fissure Veins.—Excepting that one or both walls are often more or less slickened, or that a brecciated structure is present, the fault fissure veins differ in no way from the type just discussed. They are relatively uncommon, however. Perhaps it would be more correct to say that those that may be identified with certainty as belonging to this type are rare.

A brecciated vein at the base of the cliff northwest of the old Green Mountain mill, and a vein on a fault 200 feet from the Wheeler bunk-house, are of this type, as is also the Iron Clad vein in Buckskin Gulch. The two first-mentioned are near the head of Platte valley.

The Enterprise vein on North Star Mountain is not a fissure vein at all; it is merely a slightly mineralized faulted and brecciated zone, such as Emmons described in the paragraph already quoted.

Contact Fissure Veins.—As used here, the term "contact fissure vein" is applied to an ore-body filling a fissure at the contact of intrusive igneous and other kinds of rocks. Such contacts are natural lines of weakness, and the shrinkage of the cooling intrusions may develop open fissures, which subsequent mineralization may transform into contact fissure veins. The vein solutions often penetrate one or both walls, and give rise to more or less extensive replacement deposits.

The Kentucky Belle vein, near the head of Buckskin Gulch, is probably in this class, although most of the mineralization is in the porphyry dike itself, instead of between the porphyry and the Archean country rock.

The Dolly Varden mine, on the east face of Mount Bross, may also belong to this class, but the workings are so caved as to make it impossible to settle this point with certainty. Emmons stated that the ore occurred along the southeast face of a nearly vertical dike of Lincoln porphyry, forty feet thick. As the deposit extended 100 feet southeastward into the blue lime, it may also be classified as a replacement deposit.

Several small contact fissure veins were noted in prospects the names of which could not be ascertained.

Gash Veins.—Enlarged, ore-filled joint-planes in the white or blue lime are not uncommon, and constitute deposits of limited extent, although frequently rich. They often connect valuable replacement deposits, but are themselves of little importance.

Sammy's Barrel, on North Star Peak, is of this class, as are several veins near the crest of Loveland Mountain above Buckskin Gulch.

Sheeted Zones.—Lines of weakness resulting from the presence of numerous closely spaced joints or fault planes occasionally occur and are usually mineralized to some extent.

Plate XXVIII, A, shows a sheeted zone (possibly the Rip Van Winkle vein) coming up from the left and joining the fahlband and quartz-filled fissure vein constituting the Kansas-Magnolia veins.

Plate XXVIII, B, represents a horizontal sheeted zone in gneiss which crops on the south side of Buckskin Gulch about half-way from the mouth to the head of the same.

Another sheeted zone occurs in the northeast-facing cliffs above Montgomery. It is about a foot wide, strikes S. 60° W. (magnetic), or nearly at right angles to the schistosity, and dips about 70° S. It contains limonite, pyrite, sphalerite, and quartz.

Fahlbands.—The term "fahlband" is here applied not only to zones of porous schist mineralized with sulphides, but also to the oxidation products of such zones. One or more small fissure veins are frequently found in the interior of the fahlband, and in this case the mineralization of the schists is doubtless brought about by solutions working outward from the small fissures.

Deposits like this are very common near Montgomery, where most of the fissure veins are parallel to the schistosity and are often enclosed in fahlbands. When such a vein is oxidized, it resembles a heavily iron-stained sheeted zone with, possibly, a few quartz stringers included, but the foliation is always parallel to the schistosity of the enclosing rock.

The Chicago-Columbia and the Kansas-Magnolia veins are important examples of this class, but neither is quite typical, as in these the fahlband is often quite subordinate to the fissure.

PLATE XXVIII—A. The Kansas Fissure Vein and Fahlband at its Junction with a Sheeted Zone, North Star Mountain. (Pick rests on an eight-inch quartz vein containing considerable pyrite.)

B. Small Sheeted Zone in Buckskin Gulch.

B

Fahlbands unaccompanied by fissure veins or veinlets are exposed in numerous small prospects, but the limited amount of development which they have undergone indicates that they are of little or no importance.

REPLACEMENTS—

While it is true that veins are much more numerous than any other type of deposit, the ore-bodies originating by metasomatic replacement of limestone or quartzite are much more important from an economic standpoint.

These deposits are apt to be rather tabular or lenticular, with the larger dimensions parallel to the bedding planes, and some of them are of great size—twenty or more feet thick, and over one hundred feet long and wide. Very irregular shapes are not unusual, however. The masses of ore are more apt to be found along the various contacts than elsewhere, i. e., at the contacts of sills of intrusive and sedimentary rocks, different kinds of sedimentaries, or sedimentary and Archean rocks. Occasionally, however, good replacement ore is found away from such contacts.

Sometimes ore-bearing veinlets connect different bodies, or they may be joined by streaks of worthless gangue. Occasionally the replacement deposits plainly owe their origin to solutions rising through veins, while in other cases the source of the solutions is not so evident.

Replacements in Limestone.—The most valuable replacement deposits are in the blue lime, and several of them are of higher grade and greater size than any other bodies of ore yet found in the district.

Why the white lime should be inferior to the blue as an ore horizon is an unsolved problem. It may be that the condition is more apparent than real. Early prospectors familiar with the Leadville district naturally confined their attentions largely to the blue or Leadville limestone, which contained the great Leadville bonanzas. Subsequent exploration has, however, revealed fine bodies of ore in the white lime at Leadville, and, since all conditions are so similar at Alma, it is logical to presume that other valuable deposits will yet be found in the white lime in the district under discussion.

The following is an incomplete list of replacement deposits in limestone, or of combinations of these and other types of deposits:

Name of Claim or Operating Company	Location	Geological Horizon
LaSalle	Loveland Mountain	White Lime at Contact with Lower Quartzite
Colorado Springs	Red Amphitheater on Mount Bross	Blue Lime just above Parting Quartzite
Dominion	Red Amphitheater on Mount Bross	Same as Colorado Springs
Dolly Varden	Northeast Face of Mount Bross	Blue Lime
Moose	Near Summit of Mount Bross	Blue Lime
Russia	East Face of Mount Lincoln	Blue Lime

Replacements in Quartzite.—Replacements in quartzite are almost, if not fully, as plentiful as are those in limestone, and some are of large size and great economic value, but the ore does not average as high-grade as in the limestone.

The quartzite ore-bodies are usually plainly connected with fissure veins, while, as has been noted, the location and character of the feeders of the limestone deposits are often uncertain.

The following mines are in deposits largely or entirely of the class under consideration:

Name of Claim or Operating Company	Location	Geological Horizon
Mountain Lion	Loveland Mountain	Lower Quartzite
Silver Exchange	Loveland Mountain	Lower Quartzite
Phillips	South Side of Lower Buckskin Gulch	Lower Quartzite
Criterion	Mount Bross Facing Buckskin Gulch	Lower Quartzite
Paris	Mount Bross Facing Buckskin Gulch	Lower Quartzite
Atlantic–Pacific	North Star Mountain	Lower Quartzite

IMPREGNATIONS—

The seepage of mineral-charged solutions into the country rock may result in the metasomatic replacement of the latter, or a deposition of mineral may take place in the pores or cavities of the country rock with little or no solvent action by the solutions. In the latter case, impregnations are formed, and these may be of considerable value.

In the Alma district commercially important deposits entirely attributable to such an origin are almost unknown, but a certain amount of impregnation has often occurred in connection with other kinds of deposits, as has been mentioned in discussing fahlbands.

In limestone, the result of such dissemination of minerals is usually invisible and is determinable only by assay; but, in unoxidized quartzite and schists, pyrite and other sulphides are often developed in large quantities. Where the crystals or grains of sulphides are large, there has doubtless been some replacement action; but this has occurred only at scattered points in the mass, and it seems best to regard the resulting ore-body as essentially an impregnation rather than a replacement. Effects of the kind just described are very noticeable in the Phillips, Criterion, Orphan Boy, and other properties.

The Star mine, on the northeastern slope of Mount Bross, is the best illustration in the area of an impregnation deposit. There the parting quartzite is mineralized from the base up as far is it has been tested (ten to fifteen feet) over an area of about five acres. The quartzite is much fractured and considerably iron-stained.

Near the northern edge of the property a sheet of porphyry, dipping 12°, S. 85° E. (magnetic), lies over the quartzite, which is of higher grade near the porphyry than elsewhere. This furnishes a suggestion as to the source of the ore.

In one place on the property the blue lime has been opened just above the porphyry sheet, and very rich ore found there.

PLACERS—

Very little placer mining has been done in the area examined, excepting below the Phillips mine in Buckskin Gulch. Data on the deposits there are not now available, but it is probable that they were well worked out before abandoned.

During the summer of 1911 a fairly successful attempt to recover placer gold was made on a small scale at Montgomery.

So far as is known to the writer, the upper part of Platte valley has never been prospected with drills, nor has the depth of bed-rock been determined. The country is so well mineralized, however, that it seems quite certain that there is gold there. At several points the valley is broad and flat over a considerable area, so dredging operations might be possible. The matter is well worthy of investigation, but lack of time made it impossible for the writer to give it the attention it merits.

CHARACTER OF THE ORE AND GANGUE

Any visitor to the district must be impressed with the wide variety of minerals found therein. Almost every mass of ore differs somewhat, mineralogically, from every other one, yet it is possible to make some statements that are generally applicable.

It might be supposed that any one class of deposits would usually contain similar ore, but this is frequently not the case, particularly where veins are concerned. It appears to be a fact—as might naturally be expected—that ore formed at the same depths, other conditions being equal, shows certain similarities, no matter in what class of deposits it occurs. Since the various formations were approximately horizontal at the time of the formation of the ore-bodies, and since the upper surface of the ground was presumably fairly level, the statement just made may be extended to read: Identity of geological horizon involves similarity of ore.

In the Archean Rocks.—In the Archean rocks, pyrite—or its alteration product, limonite—is often the only visible mineral of possible value. Not infrequently, chalcopyrite is also present, while sphalerite is comparatively rare, but is probably more plentiful here than in other horizons. Quartz is usually the only gangue mineral in the fissure veins, while oxidized fahlbands contain sericite and kaolin.

The Home Sweet Home, Tanner Boy, Queen Mary, Enterprise, and other veins in Upper Buckskin Gulch are seeming violations of the rule just laid down. They contain argentiferous galena, rhodochrosite, and, often, sphalerite. One or more of the following minerals may also be present: cuprite, enargite, bornite, azurite, malachite, fluorite. Quartz is a common gangue. Most of these veins are small, but some of them carry gold.

These lead-bearing Archean veins doubtless represent a second period of mineralization which occurred after a considerable thickness of the overlying strata had been removed by erosion. The fissure formation may have taken place during the mountain-forming movements at the end of the Cretaceous period.

In the Lower Quartzite.—In the lower quartzite, pyrite and chalcopyrite are still prominent and are apt to carry considerable gold. In fact, this is the principal gold horizon. Occasionally a little argentiferous galena or sphalerite is found, especially near the upper part. The gangue may consist of barite or calcite as well as quartz, although none of the replacement deposits in any horizon contain much gangue when they are of high grade. When oxidized, the deposits carry limonite, malachite, and azurite, and, rarely, lead carbonate or other lead minerals.

In the White Lime.—In the white lime, argentiferous galena and its alteration products—cerussite, anglesite, halogen salts of silver, etc.—predominate, but pyrite and chalcopyrite (especially the latter), or their oxidation products, are still plentiful. Sphalerite is scarce. The ore sometimes carries gold, which may be in the free condition. Free silver is not uncommon. Barite, calcite, and quartz are the usual gangue minerals.

DATA ON SAMPLES YIELDING ASSAY RETURNS HIGHER THAN $1.00 PER TON.

Name of Property	Location of Property	Location of Point Sampled	Width of Vein	Minerals Present	Au (Oz.)	Ag (Oz.)	Cu (%)	Zn (%)	Pb (%)	Value	Remarks
Nova Zembla	North Star Mountain, near Montgomery	125 feet from the mouth of adit	1 foot	Limonite, pyrite, quartz, very little sphalerite	.1	.46	.....	.....	.....	$ 2.28	An old shipper. The sample is from a foot of well-defined quartz veinlets in a two-foot fahlband.
Rip Van Winkle	North Star Mountain, near Montgomery	50 feet from mouth of drift to north	18 inches	Pyrite, quartz, limonite	1.18	2.20	.....	.....	.....	24.95	A very distinct fahlband containing one large, and several small, quartz veinlets.
Rip Van Winkle	North Star Mountain, near Montgomery	Near mouth of adit	1 foot	Limonite	.06	.18	.....	.....	.....	1.30	A small, wholly oxidized fahlband parallel to the main vein.
Lee Goss	North Star Mountain, near Montgomery	Dump	....	Limonite, quartz, pyrite, chalcopyrite	.51	1.62	.43	.....	.....	12.63	
Magnolia	North Star Mountain, near Montgomery	Near mouth of adit	2 feet	Quartz, pyrite	.12	1.48	.....	.....	.....	3.30	Was mostly worked on the other side of the mountain. Northward extension of the Kansas vein. Produced between $10,000 and $15,000.
Chicago	North Star Mountain, near Montgomery	Near mouth of adit	5 feet	Quartz, pyrite	.16	.91	.....	.....	.....	3.75	Fahlband with so many quartz veinlets as to be over half quartz.
Chicago	North Star Mountain, near Montgomery	Dump	....	Quartz, pyrite, chalcopyrite	.32	4.80	2.01	.....	.....	16.10	From large chunk of ore on top of dump. Probably as good as any found in the mine.
Wheeler (?)	North Star Mountain, near western edge of map	Mouth of adit	1 foot	Limonite, quartz	.20	1.18	.....	.....	.....	4.70	Fault fissure vein 200 feet south of Wheeler bunk-house. 300 feet west is another vein of exactly similar character which was not sampled.
Wheeler	North Star Mountain, near western edge of map	Dump	....	Pyrite, sphalerite, little chalcopyrite, quartz	.16	5.48	.....	6.00	.....	14.90	There are many tons of this ore on the dump.
Upper Rhinegold	North Star Mountain	Breast	4 feet	Quartz, pyrite	.18	3.52	.....	.....	.....	5.70	Vein was started on Archean-porphyry contact, but is deflected along a fault.
(?)	Mt. Lincoln, above dam near Montgomery	(See Remarks)	....	Limonite	.06	.50	.....	.....	.....	1.50	No vein is in sight here, but the porphyry on both sides of a fault plane is heavily iron-stained and has been prospected in one place where sampled.
Enterprise	Buckskin side of Mt. Bross	Dump	....	Tetrahedrite, galena, quartz	1.32	13.77	9.40	.....	.....	140.95	The vein in the adit averages six inches wide; it shows no ore like that stacked on the dump.
Queen Mary	Buckskin side of Loveland Mountain	Dump	....	Rhodochrosite, sphalerite, galena, pyrite, chalcopyrite, quartz	.08	5.50	.....	12.30	.....	22.10	Many tons of ore identical with the sample are on the dump.
(?)	Above last on Loveland Mountain	Breast	6 inches	Rhodochrosite, sphalerite, pyrite, quartz	.06	6.10	.....	.....	.....	4.85	
Same as last	Above last on Loveland Mountain	Near breast	2 inches (see Remarks)	Galena, sphalerite, pyrite, fluorite, quartz	.....	3.00	.....	.....	10.10	10.90	This little streak forms one side of the last-mentioned vein in several places, and seems to represent a different period of ore formation.
(?)	Northwest and below the last	Dump	....	Sphalerite, pyrite, quartz	.10	2.10	.....	20.00	.....	31.26	The oxidized vein here exposed is two feet wide, in diorite. Several tons of ore on dump are from a winze now full of water.
Jay Gould	Buskskin side of Loveland Mountain	50 feet from mouth of first adit above "Jay Gould tunnel"	6 inches	Pyrite, quartz	.10	.13	.....	.....	.....	2.80	The vein is so faulted that there is only five feet of this ore in sight.
Home Sweet Home	Buckskin side of Mt. Bross	Ore in tunnel house	....	Cuprite, galena, little bornite, quartz	.....	26.00	8.80	.....	.....	45.50	From pile containing several tons of ore.
Home Sweet Home	Buckskin side of Mt. Bross	Dump of caved adit above tunnel house	....	Enargite, quartz	.08	114.10	17.50	.....	.....	129.60	Considerable good ore like this on the dump.
(?)	Next-to-lowest opening west of last	Dump	18 inches	Cuprite, galena, rhodochrosite, quartz	.....	31.60	12.10	.....	16.40	72.85	All the ore exposed in the adit is completely oxidized. The sulphides on the dump must have come from the floor, now covered with ice.
(?)	Opening above last	Dump	8 inches	Galena, cuprite, quartz	.....	42.80	5.40	.....	3.00	46.75	Chunks of ore on dump show that the vein must have been at least eight inches wide.
(?)	Just west of Red Amphitheater on Mt. Bross	300 feet from mouth of adit	2 feet	Limonite, gouge	.06	2.70	.....	.....	.....	2.80	Vein is lost by faulting 200 feet farther in. It is crossed by several very small veins of the rhodochrosite type.
Kentucky Belle	Head of Buckskin Gulch	Near main stope	4 feet	Limonite, gouge	.10	.50	.....	.....	.....	2.30	Bodies of good sulphide ore have been found in this property, but none were seen at time of visit.
Paris	Buckskin side of Mt. Bross	Ore in mill	....	Limonite stained quartzite	.08	.90	.....	.....	.....	2.15	
Paris	Buckskin side of Mt. Bross	Ore in mill	....	Limonite	.20	4.20	.....	.....	.....	6.55	
Phillips	Buckskin side of Loveland Mountain	200 feet west of Buckskin Creek	20 feet	Limonite stained, cellular quartzite	.12	......	.....	.....	.....	2.40	The cellular appearance is due to the removal of pyrite with which it was once impregnated.
Phillips	Buckskin side of Loveland Mountain	On top of last sample	10 feet	Limonite, quartz, etc.	.30	.30	.....	.....	.....	6.20	This is the wash over the quartzite. It is now a conglomerate, the cementing material being limonite.
Phillips	Buckskin side of Loveland Mountain	400 feet west of Buckskin Creek	6 inches	Sphalerite	1.14	4.50	.....	29.40	.....	66.65	There is five feet of solid pyrite below this sphalerite.
Phillips	Buckskin side of Loveland Mountain	On top of last sample	3 feet	Gouge	.06	2.00	.....	.....	.....	2.40	This underlies a sill of Lincoln porphyry.

NOTE —The values on this table are figured on the assumption that copper is worth $0.17, zinc $0.07 and lead $0.045 a pound; and that silver is worth $0.60 and gold $20.00 an ounce

In the Parting Quartzite.—The parting quartzite is very rarely mineralized. The Star mine, on the northeastern slope of Mount Bross, is in this horizon, however, and there the ore is mostly quartzite, carrying gold in the free condition. A little galena, chalcopyrite, pyrite, malachite, and azurite are also found, and limonite stains the quartz yellow or brown near the surface.

In the Blue Lime.—The blue lime is the great silver-lead horizon, and all the minerals of these elements named in the accompanying list are found therein.

Argentiferous galena is the principal mineral mined where the ore is unoxidized, and chalcopyrite is present in subordinate amounts. Sphalerite and pyrite are relatively uncommon. Barite, quartz, and calcite are the gangue minerals most frequently encountered, while a little gypsum or pyrolusite is occasionally found.

From the above brief statements it will be evident that siliceous formations are gold-bearing, while limestone is apt to carry lead and silver.

MINERALS FOUND IN THE ALMA DISTRICT

The following ore and gangue minerals are known to occur in the Alma district: alabandite, anglesite, anhydrite, argentite, azurite, barite, bornite, calcite, dolomite, cerargyrite and other halogen salts of silver, cerussite, chalcanthite, chalcopyrite, chromite, copper, cuprite, enargite, fluorite, gadolinite, galenite, gold, gypsum, hematite, jamesonite, kaolin, limonite, magnetite, malachite, melanterite, mimetite, orthoclase, proustite, psilomelane, pyrargyrite, pyrite, pyrolusite, pyromorphite, quartz, rhodochrosite, serpentine, siderite, silver, stephanite, stibnite, tennantite, tetrahedrite, zinkenite.

In the hope that it will be helpful to prospectors, a brief description of each of these minerals is given in Appendix A of this report.

GRADE OF THE ORE

It is almost impossible to make any general statements concerning the grade of the ore, for the reason that it varies from place to place in each mine and in different mines, particularly when they are not in the same geological horizon.

No systematic attempt was made to sample any mine or prospect; in many properties only one sample was taken, and that sometimes came from the breast, and in other instances it was from a stope or the dump. These samples were collected for the sole purpose of ascertaining whether any values at all were present. It was recognized that the assay returns would doubtless be much lower than the average of the ore removed from the old workings, since the miners would be very unlikely to leave any good ore in sight when abandoning the properties.

It was, then, no surprise to find that scores of the samples gave blank assays. These are not incorporated in the accompanying table, nor was it thought worth while to tabulate information concerning scores of other samples which yielded assay returns that amounted to less than one dollar per ton.

It is unfortunate that many of the largest and formerly most productive properties are now filled with ice, are caved, or are otherwise inaccessible. For this reason, they could not be sampled and the table just mentioned is correspondingly incomplete. From Emmons' report[1] and other sources it has been learned that the grade of the ore in the following properties was, or is (if marked with an asterisk), as given below:

Moose: One hundred to seven hundred ounces of silver per ton.

Phillips: The poorer sulphides ran $6 in gold per ton, and the high-grade ore was very rich, containing much free gold.

Kentucky Belle:* A stope on the four-foot vein averages $8 to $10 per ton in gold and silver; a streak four to twelve inches wide yields $25 to $60 per ton in the same metals.

Dominion: Two feet of ore assayed $68 to $500 per ton in silver.

Atlantic-Pacific: The oxidized ore was worth $40, and the sulphide ore $12 per ton.

Star:* The values vary from a trace up to fourteen ounces of gold and two hundred of silver per ton. Carload lots have yielded from $20 to $40 per ton.

Kansas: Mined two feet of $25 sulphides.

Chicago: A large lot of ore ran $11.30 in gold, silver, and copper before milling. The jig concentrates were worth $51.95 in the same metals.

Rip Van Winkle: A pocket of $60 ore was encountered, and there is still good ore exposed in the mine.

Puritan:* Yields ore running $7.60 in gold and silver.

Lower Rhinegold:* A two-foot vein gives average returns of $10 per ton.

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[1] Loc. cit.

Upper Rhinegold:* $24 ore was found one hundred and forty feet from the mouth of the adit. A sample from the breast showed the presence of ore worth $5.70 per ton.

Iron Clad:* The vein varies from two inches to two feet wide, and contains ore worth from $20 to $40 per ton.

It will be understood that the writer does not vouch for the above statements; they are largely hearsay, but are believed to be fairly reliable.

SECONDARY ENRICHMENT

It is claimed by those familiar with early conditions in the district that the oxidized portions of several of the veins were very rich, and that the comparative leanness of the sulphides encountered at shallow depth was so disappointing as to cause many miners to cease operations. These rich, oxidized croppings were undoubtedly the result of secondary enrichment brought about both by the removal of soluble vein matter by downward-circulating meteoric water, and by the mechanical disintegration and removal of the lighter vein matter at the surface, and a consequent concentration of the heavy gold which formed a part thereof.

Erosion by glaciers, streams, and rain-wash has been so vigorous that in many places the enriched, oxidized ore has been completely scoured off; and, even where found, the amount is usually too limited to be worth much consideration.

As most of the veins are in the zone of low-grade copper-iron sulphides, and enriched sulphide ore does not occur, it follows that there is not apt to be much depreciation or improvement in the grade of the ore with depth, although relatively rich ore-shoots may occur at any point. The high-grade veins in Buckskin Gulch belong, however, to a higher, richer zone, and they may be expected to average of lower grade as depth upon them is attained.

INFLUENCE OF IGNEOUS ROCKS UPON THE ORE DEPOSITS

Although it seems not unlikely that the ore is, in a sense, genetically connected with the igneous rocks, as is later suggested, positive evidences of direct connection are lacking. In other words. there is no reason to believe that the deposits were formed as a result of deposition from emanations expelled by the cooling intrusions, nor is it probable that the sulphides were precipitated from circulating ground water which derived its metallic content from surrounding igneous rocks through which it seeped.

It is nevertheless true that unusually rich ore is found in proximity to a sheet of porphyry in the Star Mine on Mount Bross, and that ore is more or less closely associated with igneous rocks in the Phillips, Excelsior, Kentucky Belle, Criterion, Home Sweet Home, Dolly Varden, and other properties; but in no case was it possible to detect anything indicating that the ore-bearing solutions were derived from, or became mineralized by, flowing through, the adjacent igneous rocks. It is not unlikely, however, that something in the intrusions may have acted as a precipitant in cases where notably rich ore occurs in proximity to the igneous material.

Although there appears to be no direct genetic relationship between intrusions and ore-bodies in the sense that the later were derived from the former, it is, however, a fact that the sills have often been the main factor in determining the position of the replacement deposits. Thus, in the Moose mine on Mount Bross the principal ore-body is a limestone replacement directly below a sill of porphyry. Fig. 6 illustrates conditions existing in that property. It has not been determined, however, whether the fault shown is of normal or reverse type. Similar conditions

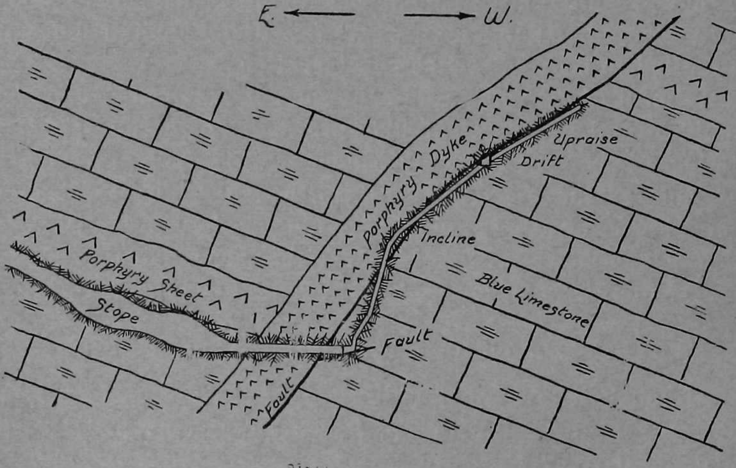

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Fig. 6.

FIGURE 6—Idealized section through part of the Moose mine. The dip of the strata here is abnormal, being to the west instead of to the east.

exist in a number of other mines. In each case the location of the ore is doubtless due to the fact that contacts of igneous rocks and other earth materials are natural lines of weakness. Ore-bearing solutions working up from below through fissures tend, then, to follow the lower contacts of intrusions, and, if conditions are favorable, considerable replacement of the underlying rocks may occur. This is particularly apt to be the case if the intrusions occur after the formation of the fissures, thus forcing any solutions rising subsequently through the fissures to spread along the lower surfaces of the sills.

ORIGIN OF THE ORE

The writer has recently published* a brief statement of the fissure theory of the origin of the sulphide replacement deposits of Leadville. This is believed to be substantially the one accepted by a majority of the geologists and mining engineers familiar with that district. As geological conditions near Alma and Leadville are very similar, the statement will apply as well to one area as to the other—possibly its correctness will be even less subject to question in the case of the Alma district because of the greater number of known fissure veins found there. The theory is as follows:

1. After the deposition of the sediments, the intrusion of the various porphyries occurred; this material rose in the molten condition from depths below any yet reached by the mines.
2. At some later date ore-bearing solutions came upward through vertical or inclined fissures, porous zones, or combinations of these.
3. It seems probable that the ore-bearing solutions represent an extreme type of differentiation of the magma from which the porphyry intrusions were derived. In this sense the ores may be said to be genetically connected with the intrusions.
4. The upward movement of the solutions may have taken place through clean-cut fissures produced by earth stresses, through openings at the contacts of dikes and sediments resulting from the shrinkage of the former while cooling, or through porous zones where joint-planes were unusually numerous. (Near Alma the solutions also arose through sheeted zones and porous layers of schist.)
5. At certain horizons the solutions encountered nearly horizontal lines of weakness (the various contacts) along which they

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* Economic Geology, Vol. VII, p. 322.

flowed, and away from which they sometimes spread vertically, depositing their metallic contents by metasomatic replacement of the country rock, usually limestone (the quartzites are also considerably replaced near Alma). The extent of this lateral spreading may have been very great, and replacement deposits may have been formed at great distances from the channels through which the vertical movement occurred.

6. The vertical spreading just mentioned may have been up or down, depending upon whether the solutions were flowing above or below an impervious or non-replaceable rock. The vertical spreading may in some cases have been concentrated along a fissure or a narrow jointed zone, the solutions ultimately spreading laterally along contacts considerably above or below that along which the lateral movement began.

7. Ore may or may not have been deposited in the various ore-solution channels above mentioned, depending upon the nature of the solutions and of the country rock, the rate of flow of the solutions, the temperature of the country rock, the pressure upon the solutions, and other factors.

8. It is quite possible that many replacement ore-bodies were formed along one or more contacts, each of which received its ore through the same vertical or inclined channel, and that these masses were separated from the channel and each other by barren stretches. It is not necessary, therefore, to seek a channel extending downward or laterally from each of the replacement ore-bodies.

9. It is not improbable (although it appears unlikely, in the case of the Alma deposits particularly) that a portion of the ore in the replacement deposits may have originated as a result of magmatic emanations from the porphyry intrusions, but this source is believed to have been of decidedly minor importance.

It is hardly necessary to point out that many of the veins represent deposits in ore channels through which the replacement deposits received their ore. Why deposition in such channels should be common near Alma and rare near Leadville is an unsolved problem. Possibly the difference is not so real as it appears at first sight. At Leadville the horizons where such ore channels would occur are usually deeply buried, and they have not, therefore, been thoroughly explored.

The theory above outlined is undeniably in accord with features observed in the Alma district, since in several cases veins may be traced directly upward until they connect with replacement deposits derived therefrom. This is the case, for instance, with the Kansas-Magnolia and Atlantic-Pacific veins on North Star Mountain.

HINTS TO PROSPECTORS

Promising points to prospect are the various "contacts" connected with the stratified rocks, i. e., at the contacts of the Archean rocks and the lower quartzite, the lower quartzite and the white lime, the white lime and the parting quartzite, the parting quartzite and the blue lime, or at the contacts of intrusions of igneous rocks and any of the foregoing. The last-mentioned are particularly apt to be ore horizons, especially the lower surfaces of intrusions. As has been already mentioned, the white lime appears to contain less ore than the other formations, and the white lime-parting quartzite contact is not positively known to contain ore at any point.

It is not true that it is justifiable to drive an adit anywhere on one of the contacts mentioned, but, if good float is found near such contacts, or the outcroppings appear porous or iron-rusted, the chances favor the presence of good ore.

The most favorable conditions of all probably exist when a vein passes up into the stratified rocks. Such a vein should be prospected in the sedimentaries, no matter if it contains no good ore in the Archean rocks below. If the intersection of the vein and one of the contacts in the sedimentary rocks is barren, the search should be extended to other contacts along the same vein.

Almost any vein in the stratified rocks is worth prospecting, even though barren at the point of discovery. Such exploration should be first made by shaft rather than adit, however, as the good ore may be confined to a certain nearly horizontal horizon.

Only wide veins in the Archean rocks should be prospected by a man with a limited amount of capital, since they alone may contain fairly large shoots of good ore. The narrow veins do not often increase materially in width when traced along their strikes; and, even though shoots of high-grade ore may be encountered, the amount recovered will hardly repay the cost of mining.

NEEDS OF THE DISTRICT

Primarily, the Alma district needs optimistic men, with plenty of capital, who will develop it in a systematic and thorough fashion, and who will rely on the advice of experienced geologists and mining engineers.

There is plenty of open ground for prospectors, and many now seeking riches in untried fields could profitably turn their attention to this and other old camps. Some of the ore, particularly in the replacement deposits, is of such high grade as to constitute a "poor man's mine;" but when a fair showing has been made, the prospect should in most cases be turned over to others who have the means to develop it rapidly and scientifically. A score of small prospects do not make as prosperous a camp as do two large, producing mines.

Not only is capital needed for the mining operations, but it is also required to solve the problem of the treatment of the low-grade ore already exposed, and to put such solution into operation. An enormous quantity of low-grade pyrite is exposed in the old Phillips workings, which would furnish a decided asset to a properly constructed pyritic smelter. Large quantities of the low-grade quartz-pyrite Archean vein material could also be used as flux at such figures as would greatly aid the miner in his search for shoots of higher-grade ore.

The water power now going to waste could be utilized, at no great expense, to concentrate and transport ore.

CONCLUSION AS TO THE FUTURE OF THE DISTRICT

In the opinion of the writer, the Alma district is sleeping; it is not dead. First-class ore in large quantities has been found there, and there is no reason to believe that all such deposits have been discovered and exhausted. The area is not far from Leadville, and the geological conditions in the two districts are very similar—in many respects identical. Evidences of mineralization in the form of veins in the Archean rocks are much more numerous near Alma than near Leadville; why, then, should replacement deposits be so much rarer and less important in the former area than in the latter?

The surface of the ground is often so free from soil and vegetation as to make prospecting a comparatively easy matter. Good roads exist. A base of supplies and the railroad are close at hand. Although the altitudes run above 14,000 feet, this need entail no discomfort in the summer. Why, if this be true, should prospectors and mining men rush to desert regions and new camps of unknown possibilities? What Colorado needs is not so much a great, new camp as it is a great renewal of interest and activity in her old camps of proven promise, of which the Alma district is one.

APPENDIXES

APPENDIX A

DESCRIPTION OF THE ORE AND GANGUE MINERALS OCCURRING NEAR ALMA, COLORADO

BY G. MONTAGUE BUTLER

The descriptions that follow are not intended to be complete; only those varieties known to occur near Alma are described. Few technical terms have been used, and those which it was impossible to avoid are defined below.

GLOSSARY

Adamantine: This is a peculiar luster, difficult to describe. It is possessed by transparent or translucent minerals which appear to have a very thin, transparent, silvery coating of some kind on the surface.

Botryoidal: An aggregate of more or less spherical masses resembling a bunch of grapes is said to be botryoidal.

Cleavage: The result of a tendency to split in certain fixed directions related to the crystallization of the mineral. When the cleavage is very good, broad, rather flat faces may be formed which show a high polish and luster. If the cleavage is poor, it may be indicated only by the fact that the specimen reflects light much more brilliantly when held in some positions than in others.

Effervescence: The act of desolving in a liquid with the evolution of much gas, so that the liquid appears to be boiling.

Flexible: Capable of being bent without breaking.

Fracture: The manner in which a substance breaks. The adjectives used in connection with this term refer to the appearance of the broken surfaces.

Hardness: A measure of the resistance to scratching or abrasion. The hardness of a substance is determined by comparing it with ten standard minerals forming a so-called "scale of hardness." They are the following:

1. Talc (light green, platy variety).
2. Gypsum (selenite variety) or halite.
3. Calcite (transparent).
4. Fluorite (transparent).
5. Apatite (transparent).
6. Orthoclase (with glassy luster).
7. Quartz (transparent).
8. Topaz (transparent).
9. Corundum (cleavable or transparent).
10. Diamond.

Finger-nails will scratch minerals with a hardness equal to, or less than, 2½. A copper coin will just scratch a mineral of hardness 4. A good knife will scratch minerals with a hardness of 5½. Glass is scratched by minerals over 6 in hardness.

Iridescent: Showing a play of colors like the surface of a soap-bubble.

Luster: The manner in which a mineral reflects light.

Metallic: Reflecting light like a metal. A metallic luster is shown only by opaque minerals.

Opaque: No light passes through, even on thin edges.

Streak: The color of a mineral when finely powdered. It is usually obtained by rubbing the mineral upon a piece of unglazed porcelain, called a streak-plate. In the descriptions that follow, the streak is white unless otherwise stated.

Sub-metallic: Imperfectly metallic, verging slightly toward vitreous. A mineral with a sub-metallic luster may be slightly translucent on thin edges.

Tarnish: A thin coating on the surface of minerals. It may also occur in cleavage or other cracks, and is usually of a different color from the rest of the mineral.

Translucent: Light passes through the substance, although objects cannot be seen through it.

Transparent: Objects can be seen through the substance.

Vitreous: Possessing the luster of glass or porcelain.

DESCRIPTIONS OF MINERALS

Alabandite: Sulphide of manganese. A rather soft (3½ to 4), sub-metallic, iron-black mineral, with a dark green streak, which cleaves in cubes, like galena. It usually occurs in granular masses, and is too rare to be considered an economically important ore.

Anglesite: Sulphate of lead. A very soft (3), white or light tinted, heavy mineral, which has practically no cleavage, and is usually opaque and has a dull luster. It is an oxidation product of galena and may show cubical markings parallel to the cleavage of that mineral. It sometimes occurs as adamantine-lustered, transparent crystals in cavities in galena. It is a very valuable ore of lead and contains 73.6 per cent of that metal.

Anhydrite: Sulphate of calcium. A soft (3 to 3½), vitreous-lustered, white to grayish or light tinted, translucent to opaque mineral, which usually occurs in granular masses like limestone, but which fails to effervesce in acid. It sometimes cleaves with unequal ease in three directions at right angles to each other. It is a gangue mineral.

Argentite: Sulphide of silver. It is usually called "silver glance." A very soft (2 to 2½), metallic-lustered, lead-gray to black, heavy mineral with a lead-gray streak, from which it is possible to cut shavings as from lead. It usually occurs in irregular grains or masses, and is the richest ore of silver, of which it contains 87.1 per cent. It is often associated with galenite and sphalerite.

Azurite: Hydrous carbonate of copper. A soft (3½ to 4), vitreous- to dull-lustered, dark to light blue, transparent to opaque, non-cleavable mineral, which effervesces vigorously in acid and has a blue streak. It is an alteration product of other copper minerals, and is usually associated with them or with limonite. When pure, it contains 55.4 per cent copper, but it rarely occurs in sufficiently large quantities to form an important ore of that metal.

Barite: Sulphate of barium. It is usually called "heavy spar" or "baryta." A soft (3), vitreous-lustered, white or light-tinted, translucent to opaque, heavy mineral, that has a very good cleavage in one direction, which gives it a platy structure. It usually occurs in rather tabular crystals or platy masses, and is a very common gangue mineral, especially with lead ores.

Bornite: Sulphide of copper and iron. It is often called "peacock," "horseflesh," or "purple copper ore." A soft (3 to 3½), metallic-lustered dark reddish brown mineral, that quickly tarnishes purple or iridescent and has a grayish black streak. It contains about 55 per cent copper and is a valuable ore of that metal.

Calcite: Carbonate of calcium or lime. It is often, although erroneously, called "lime," and is also known as "lime spar" or "calc spar." A soft (3), vitreous- to earthy-lustered, transparent to opaque mineral, that effervesces vigorously in hydrochloric (muriatic) acid, even when the acid is very dilute. It frequently occurs in crystals, which are usually six-sided, and it may show a very perfect cleavage in three directions. The color is white when pure, but impurities may give it any tint. When it is compact and very fine-grained, it is called "limestone," and, when visibly granular, it is known as "marble." It forms a common rock and is an abundant gangue mineral.

Cerargyrite: Chloride of silver. Cerargyrite, embolite (chloride and bromide of silver), bromyrite (bromide of silver), and other minerals of similar composition are often called "horn-silver." A very soft (1 to 1½), waxy-lustered, gray or yellow to greenish or brownish, non-cleavable mineral, that resembles, and cuts exactly like, wax. It usually occurs in crusts or veinlets, and is a very important ore of silver, of which it contains 75.3 per cent.

Cerussite: Carbonate of lead. A soft (3 to 3½), adamantine- or silky-lustered, white, non-cleavable, heavy mineral, that occurs in silky, crystalline crusts, granular to compact masses, or as disseminated grains, often in limonite. It is a very common and important oxidized ore of lead, of which it contains 77.7 per cent; and it often carries sufficient silver to make it a high-grade ore of that metal.

Chalcanthite: Hydrous sulphate of copper. A soft (3½), vitreous-lustered (alters to dull), deep blue or greenish blue, non-cleavable mineral, that tastes nauseating and metallic, and usually occurs in crusts. It is an alteration product of sulphide copper ores, but is too rare to be mined as an ore of copper. Native copper may easily be precipitated from mine water carrying chalcanthite in solution.

Chalcopyrite: Sulphide of copper and iron. It is commonly called "copper pyrites" or "fool's gold." A soft (3½ to 4), metallic-lustered, bright brass-yellow, non-cleavable mineral, that has a greenish black streak, and which may show an iridescent tarnish. It usually occurs in masses or disseminated grains, and is one of the most important ores of copper, of which it contains about 34 per cent when pure. It often carries considerable quantities of gold and silver.

Chromite: Oxide of chromium and iron. It is also called "chrome iron ore." A hard (5½), brilliant metallic-lustered, black mineral, with a dark brown streak. A large specimen has an uneven fracture, but the fracture of each little grain is smoothly rounded. It is the principal ore of chromium, and contains 56.2 per cent of that metal.

Copper: Native copper with 5 per cent or more of impurities. A soft (2½ to 3), metallic-lustered, copper-red, heavy mineral, that may be hammered into thin sheets or whittled with a knife. It has a copper-red streak, and usually shows a bronze-green or black tarnish. Copper occurs in sheets, masses, disseminated grains, and wire- or tree-like groupings of indistinct crystals. Large amounts are mined in some localities, but it does not commonly occur in economically important quantities.

Cuprite: Oxide of copper. It is sometimes called "red oxide of copper" or "ruby copper." A soft (3½ to 4), adamantine- or submetallic- to dull-lustered, red to nearly black, non-cleavable mineral, with a brownish red streak. It may be transparent or opaque, and it occurs in coarse- to fine-grained masses, or in crystals which may be well formed or elongated into hairs. It is an important and very rich ore of copper, of which it contains 88.8 per cent.

Enargite: Sulph-arsenate of copper. A soft (3), bright metallic-lustered, iron-black to dark gray mineral, that has a jet-black streak and two perfect cleavages nearly perpendicular to one another. It usually occurs in cleavable, columnar masses, and is an important ore of copper, of which it contains 48.3 per cent when pure. Silver sometimes replaces the copper to a considerable extent.

Fluorite: Fluoride of calcium. It is commonly called "fluor-spar" or "fluorine." A soft (4), vitreous-lustered, transparent to translucent mineral, which cleaves easily in four directions at acute and obtuse angles, and occurs in many colors—green is probably the commonest. It is usually found in crystals or cleavable masses, and is a gangue mineral.

Gadolinite: Silicate of yttrium, iron, and beryllium. A hard (6½ to 7), vitreous- to greasy-lustered, dark brown or greenish black, non-cleavable, rather heavy mineral, with a greenish gray streak. It is transparent and of a grass- or olive-green color in thin splinters, and it occurs in compact masses or in rough, coarse, prismatic crystals.

Galenite: Sulphide of lead. It is commonly called "galena." A soft (3 –), metallic-lustered, lead-gray to bluish gray, very brittle, heavy mineral, which tarnishes to black, has a lead-gray streak, and shows a very perfect cleavage in three directions—parallel to the faces of a cube. It occurs in coarse to fine granular or cleavable masses and in cubical crystals. It is the principal ore of lead, of which it contains 86.6 per cent, and it usually carries such quantities of silver that it is considered the most important silver ore.

Gold: Native gold with varying amounts of impurities. A soft (2½ to 3), metallic-lustered, golden-yellow to nearly white, heavy mineral, which may be hammered into thin sheets, or cut or indented with a knife, has a yellow to nearly white streak, and never tarnishes. It occurs in nuggets, disseminated grains, scales, and in wire-, net-, or fern-like groupings of indistinct crystals.

Gypsum: Hydrated sulphate of calcium. A very soft (1½ to 2), vitreous- to dull-lustered, white or light tinted, transparent to translucent mineral with very perfect cleavage in one direction. The cleavage flakes are somewhat flexible, although not to the same extent as mica, which is also tougher. Gypsum occurs platy and in compact, fibrous, or granular masses. It is a rather uncommon gangue mineral.

Hematite: Oxide of iron. A hard (6), metallic- to dull-lustered, black to red, non-cleavable mineral with a red streak. It is commonly found in the Alma district in tiny metallic scales or as dull, red, earthy masses. When it occurs in large quantities, it constitutes a valuable ore of iron, of which it contains 70 per cent.

Jamesonite: Sulph-antimonite of lead. A soft (2 to 3), metallic-lustered, light to dark gray mineral, with a grayish black streak. It may show a rather indistinct cleavage in one direction. Jamesonite occurs in bladed aggregates, fibrous masses, and in hair-like forms; and it is often associated with a yellow powder. It sometimes contains enough silver to make it an ore of that metal.

Kaolin: Hydrated silicate of aluminum. A very soft (2 to 2½), dull-lustered, white or gray, earthy substance, which has a strong, clay-like odor when moistened. It usually results from the alteration of feldspar and is an extremely common mineral. It is the principal ingredient of clay and shale, and sometimes occurs as "gouge."

Limonite: Hydrated oxide of iron. It is also called "yellow or brown iron ore." A dull-lustered, brown or yellow, opaque mineral with a yellow to yellowish brown streak. It occurs as a stain on rocks or in earthy masses which are apparently very soft. Limonite is an extremely common ore or gangue mineral in the oxidized zone, and it may be rich in gold and silver.

Magnetite: Oxide of iron. It is commonly called "magnetic iron ore." A hard (6), metallic- to dull-lustered, non-cleavable, opaque, heavy mineral with a black streak. It attracts the magnet strongly and is itself sometimes a magnet. It often occurs as the so-called "black sands" of placers. When present in large quantities, it constitutes a valuable ore of iron, of which it contains 72.4 per cent.

Malachite: Hydrous carbonate of copper. A soft (3½ to 4), dull- to silky-lustered, bright emerald-green or darker, non-cleavable mineral with a green streak. It effervesces vigorously when touched with hydrochloric (muriatic) acid; occurs in earthy masses, fibrous crusts, or as a stain; and is a very common alteration product of other copper ores, with which it is often associated, as well as with limonite.

Melanterite: Hydrous sulphate of iron. A very soft (2), vitreous-lustered, green (yellow after alteration), light, translucent mineral, that cleaves easily in one direction and has a white streak. It tastes sweetish, astringent, and metallic; and occurs fibrous, hair-like, as botryoidal crusts, in compact masses, or as a powder.

Mimetite: Arsenate of lead with chlorine. A soft (3½), resinous-lustered, pale yellow or brown, non-cleavable, translucent, heavy mineral with a white streak, which occurs in tapering groups of six-sided crystals and as crusts. It is not infrequently found in the oxidized portions of lead deposits associated with cerussite, anglesite, pyromorphite, etc. It contains 69.7 per cent of lead, and is an unimportant ore of that metal.

Proustite: Sulph-arsenite of silver. It is commonly called "light ruby silver." A very soft (2 to 2½), adamantine-lustered, vermilion to reddish black, non-cleavable, heavy mineral with a red streak. The color darkens on exposure to light. It occurs in compact masses, disseminated grains, and six-sided crystals. Proustite is usually associated with other silver minerals, and is itself a very important ore of silver since it contains 65.4 per cent of that metal.

Psilomelane: Impure hydrated oxide of manganese. A hard (6 ±), dull- or submetallic-lustered, dark gray to black mineral, that has a brownish or grayish black streak. It breaks with a smooth, curving fracture, and occurs either in compact masses, in layers with pyrolusite, or as fern-like markings along the joint-planes of rocks. It may have sufficient value to mine if it occurs in large quantity.

Pyrargyrite: Sulph-antimonite of silver. It is commonly called "dark ruby silver." Pyrargyrite is like proustite (q. v.) in every particular, except that it is darker in color (usually dark gray to nearly black) and streak, and it contains only 59.9 per cent silver.

Pyrite: Sulphide of iron. It is commonly called "pyrites," "iron pyrites," "white iron," "fool's gold," etc. A hard (6 to 6½), metallic-lustered, light to dark brass-yellow, non-cleavable, brittle mineral with a black streak. It occurs massive, as disseminated grains, and frequently as well-formed crystals of cubical or other shape. Pyrite sometimes carries enough gold and silver to constitute it an ore of those metals.

Pyrolusite: Oxide of manganese. A soft (1 to 2½), metallic- to dull-lustered, black mineral with a sooty, black streak. It usually soils the fingers, and occurs in radiating needles or fibers, velvety crusts, or compact masses. It is often found in layers with psilomelane. Pyrolusite has many uses, and may be mined at a profit when it occurs in large quantities.

Pyromorphite: Phosphate of lead with chlorine. Pyromorphite is like mimetite (q. v.), except that it is usually green in color, and it contains 76.4 per cent lead.

Quartz: Oxide of silicon. It is often called "silica." A hard (7), vitreous- to dull-lustered, non-cleavable, transparent to opaque mineral with a white streak, which is colorless when pure, but to which impurities may impart any color. It occurs in veins as masses with an uneven fracture or as six-sided crystals; as glassy grains in igneous rocks; in granular masses (as quartzites and sandstones); and as the filling or lining of cavities, in which case it is usually transparent to opaque, has a smooth, rounded fracture, and shows botryoidal surfaces. Quartz is an extremely common gangue mineral, and may carry gold and silver, particularly when porous and iron-stained.

Rhodochrosite: Carbonate of manganese. It is commonly called "manganese spar." A soft (3½ to 4½), vitreous-lustered, dark red to pink, transparent to translucent mineral, which cleaves easily in three directions, turns black on exposure to damp air, and effervesces vigorously in hot, concentrated hydrochloric (muriatic) acid. It occurs in cleavable or granular masses and in crystals, and is often associated as a gangue mineral with ores of lead, zinc, silver, and copper.

Serpentine: Hydrous silicate of magnesium and iron. A soft (4 ±), waxy- to silky- or dull-lustered, non-cleavable, tough, translucent to opaque mineral, which feels smooth and, often, slightly greasy. It is usually light to dark green in color, and occurs in compact masses or fibrous. Serpentine is often associated with calcite and is formed by the alteration of ferro-magnesian minerals. When fibrous, it is called "asbestos" and is valuable; the other varieties have some use as ornamental stones.

Siderite: Carbonate of iron. It is sometimes called "brown spar." A soft (3½ to 4), vitreous- to dull-lustered, translucent to opaque mineral, which effervesces vigorously in hot, concentrated hydrochloric (muriatic) acid. It occurs in crystals, cleavable masses, and coarse to fine granular; and is often more or less mixed with clay. When pure, siderite is the most valuable ore of iron, of which it contains 48.4 per cent.

Silver: Native silver with varying amounts of impurities. Silver is like gold (q. v.), except that it is white in color and tarnishes yellow to brown or black.

Stephanite: Sulph-antimonite of silver. It is commonly called "brittle silver." A soft (2 to 2½), metallic-lustered, iron-black, very brittle mineral with an iron-black streak. It usually occurs in compact or finely granular masses, or as disseminated grains. Stephanite is a rich and important ore of silver, of which it contains 68.5 per cent.

Stibnite: Sulphide of antimony. A very soft (2), light gray or nearly white, brittle mineral with a lead-gray streak and a brilliant metallic luster, which cleaves easily in one direction, yielding blade-like strips that often appear to be ruled with lines running perpendicular to the longest dimension. It usually occurs in poorly formed crystals or as cleavable masses, and is the principal ore of antimony, of which it contains 71.8 per cent.

Tennantite: Sulph-arsenite of copper. It is commonly called "gray copper." A soft (3 to 4.5), metallic-lustered, gray, non-cleavable mineral, that has an uneven fracture and usually shows a reddish or brownish streak. It occurs commonly in fine-grained masses, and usually contains enough silver to make it a valuable ore of that metal as well as of copper.

Tetrahedrite: Sulph-antimonite of copper. It is commonly called "gray copper." Tetrahedrite is like tennantite (q. v.), excepting that the color is apt to be darker and the streak may be nearly, or quite, gray.

Zinkenite: Sulph-antimonite of lead. A soft (3 to 3½), metallic-lustered, steel-gray, heavy mineral with a steel-gray streak. It occurs in columnar or fibrous masses, and as indistinct crystals that are usually six-sided and longitudinally grooved. Zinkenite is too rare to possess economic value.

APPENDIX B

INDEX KEY TO MINING CLAIMS

BY ARTHUR J. HOSKIN

The following placers were patented as subdivisions of the rectangular survey and were not given survey numbers in the office of the Surveyor-General:

	Section	Township	Range
Gold Belt Placer	17	9	78
Ruth Placer	34	8	78
Union Placer	15	9	78
West Shore Placer	1	9	78
Powless Placer	1	9	78

CLAIMS NUMERICALLY ARRANGED

Unless the word "placer" is given, the claim is a lode.

Survey No.	Name	Section	Township	Range
37	Orphan Boy	10	9	78
38	De Mary	10	9	78
39	Honey Comb	10	9	78
40	Excelsior	3	9	78
41	Cleaner	3	9	78
42	Andes	14	8	78
50A	Washington	11	8	78
50B	Washington Mill Site	14	8	78
51	Dwight	22	8	78
52	Dudley	22	8	78
53	Gill	22	8	78
54	Bross	22	8	78
55	Phillips	3	9	78
59	Wilson	15	8	78
60	Hiawatha	27	8	78
72	Grose & Treweek's Placer	12	9	78
73	Dolly Varden	27	8	78
75	Joseph A. Thatcher et al. Placer	27	8	78
80	Haines	15	8	78
89	Hall & Morse Placer	22	8	78
93	Moose	22	8	78
96	Alps	22	8	78
97	Hoosier	22	8	78
98	Silver Star	22	8	78

Survey No.	Name	Section	Township	Range
106	Sweet Home	33	8	78
107	Pulaski	33	8	78
134	Tunnel No. 1	27	8	78
135	Tunnel No. 2	27	8	78
136	Compromise	27	8	78
137	Juniata	27	8	78
139	Ten Forty	3	9	78
140	Silver Gem	21	8	78
141	Eagle	15	8	78
142	Lime	15	8	78
143	Phillips	3	9	78
144	Premier	34	8	78
152	Jo Thatcher	27	8	78
154	Phillips	3	9	78
155	Burnside	16	8	78
156	Security	3	9	78
157	German	22	8	78
160	D. H. Hill	15	8	78
165	Buffalo Head	34	8	78
166	Rising Sun	34	8	78
167	Ivanhoe	34	8	78
169	Corsican	16	8	78
170	Gem	16	8	78
171	Young Hopeful	16	8	78
175	Eclipse	1	9	79
179	Rollins & Morrison Placer	3	9	78
180	Dodge Union No. 4	10	9	78
181	Union No. 5	3	9	78
182	Cleaner	3	9	78
183	Ten Forty	3	9	78
184	Wolcott Placer	12	9	78
185	Lincoln	15	8	78
189	McNab	22	8	78
190	Highland	22	8	78
191	Moscow	15	8	78
192	Russia	15	8	78
194	Grand View	16	8	78
195	Mohawk	16	8	78
198	Golden Era	4	9	78
199	Belle Gill	22	8	78
202	Enterprise	23	8	78
203	Girtrude	16	8	78
204	Mother	7	9	78
205	Paris	12	9	79
206	London	12	9	79
207	Hard to Beat	1	9	79
211	Danville	15	8	78
212	Helvetia	3	9	78
213	Occidental	16	8	78

Survey No.	Name	Section	Township	Range
214	Snow Bird	21	8	78
215	Guinea Pig	21	8	78
225	Emma	22	8	78
227	Columbia	10	9	78
230	Nova Zembla	14	8	78
234	Phillips	3	9	78
243	Pogue	16	8	78
246	Chicago	14	8	78
247	Hall & Brunk S. M. Co. Placer (or McIntyre Placer)	36	8	78
248	Polaris	22	8	78
249	Iron Dyke	27	8	78
250	Friday	22	8	78
251	Undercliff	22	8	78
257	Coney	15	8	78
258	Old North Side	15	8	78
269	Pogue	16	8	78
272	Keystone	36	9	79
291	No End	3	9	78
320	Ocean Wave	22	8	78
321	Tunnel	22	8	78
322	Capt. Plummer	21	8	78
323	Julia	21	8	78
325	Substitute	34	8	78
335	Buckeye	11	8	78
336	Columbia	11	8	78
338	Musk Ox	15	8	78
342	Silver Saddle	34	8	78
366	Senate	10	9	78
392	Morrison	9	9	78
476	Milwaukee	27	8	78
525	Atlantic	10	8	78
540	Chloe	10	9	78
556	Hoosier	16	8	78
557A&B	Mountain Glen and Mill Site	14	8	78
570	Peru	11	8	78
571	Jay Gould	33	8	78
627	Alleghany Placer	11	9	79
645	Orphan Boy	10	9	78
646	Champaign	31	8	78
766	J. G. Blaine	33	8	78
855	Mt. Bross T. & M. Co. Placer (or Mineral Park Placer)	35	8	78
881	Hathaway & Mills Placer	24	8	78
882	Jones Placer	24	8	78
891	Ernest	10	9	78
912	20 Years Ago	..	..	..
926A	Tanner Boy	33	8	78
926B	Howell Mill Site	33	8	78

Survey No.	Name	Section	Township	Range
934	Kansas	11	8	78
950	Criterion	3	9	78
1029	Little Corrinne	2	9	79
1069	Red Rover	2	9	79
1155	Grace	6	9	78
1178	Forest Queen	5	9	78
1179	Hoodlum	6	9	78
1180	January	10	9	78
1191	Little Fannie	3	9	78
1203	Avalanche	4	9	78
1204	Faro	4	9	78
1211	Baltic	1	9	79
1270	Dauser	15	9	78
1324	Last Chance	9	9	78
1325	Silverado	9	9	78
1337	Parole	32	8	78
1345	Peru Extension	11	8	78
1346	Ogden	14	8	78
1347	Logansport	14	8	78
1358	Belle Peabody	5	9	78
1394	Jacob's Wonder	31	8	78
1395	Wonderful	6	9	78
1408	Mountain King	9	9	78
1409	Rarus	4	9	78
1410	Evening Star	4	9	78
1411	Mountain Queen	9	9	78
1412	Lady Della	4	9	78
1413	Queen Extension	4	9	78
1415	Evening Star	10	9	78
1456	Belle Fountain	9	9	78
1457	Key	18	9	78
1518	Little Ross	33	8	78
1600	Hock Hocking	16	9	78
1641	Imperial Placer	1	9	79
1649	New York	1	9	79
1650	Ajax	18	9	78
1657	Kansas	9	9	78
1662	Giant Silver	16	9	78
1675	Fairbury	15	8	78
1676	Reservoir Placer	36	8	78
1688	Mary Adair	9	9	78
1697	Anaconda	3	9	78
1735	Henry D.	18	9	78
1740	Shovel	3	9	78
1763	Gregory	34	8	78
1764	Gilbert	34	8	78
1777	Elegant	16	9	78
1779	Susquehanna	15	9	78

Survey No.	Name	Section	Township	Range
1780	Juniata	15	9	78
1816	Chicago	..	..	..
1827	Kansas City No. 1	20	8	78
1845	La Salle	5	9	78
1847	Hugo	1	9	79
1872	Montgomery	15	9	78
1873	Phillips	3	9	78
1874	Ophir	15	9	78
1890	Second Advent	14	8	78
1899	Centennial	10	8	78
1962	Echo	16	9	78
1965	Rock of Ages	3	9	78
1974	Nesbit	16	9	78
1997	American	7	9	78
1998	Huron	7	9	78
2008	Bullion	16	8	78
2009	Modoc	16	8	78
2015	Mammoth	11	8	78
2034	Hannibal	15	8	78
2035	Col. Curry	15	8	78
2036	Golden Ledge	15	8	78
2037	Cummins Placer	14	8	78
2067	Bond	16	9	78
2068	Badger	16	9	78
2075	Truman	6	9	78
2091	Aetna	12	9	79
2092	Hidden Treasure	12	9	79
2093	Pick	12	9	79
2102A	Three Brothers	6	9	78
2102B	Mill Site	6	9	78
2107	Lizzie Abington	5	9	78
2122	Home Rule	2	9	78
2124	Bonanza King	31	8	78
2126	Bullger	16	9	78
2160	Prosperity	4	9	78
2161	Little Mary	30	8	78
2162	Queen of the Lakes No. 2	30	8	78
2173	Laura	5	9	78
2174	Imperial	5	9	78
2179	Three Rivers	33	8	78
2201	Crown	21	8	78
2202	Emerald	21	8	78
2203	Reliance	21	8	78
2210	Crown Prince	16	9	78
2214	Last Chance	27	8	78
2226	Brighton	31	8	78
2238	Rock Island	10	9	78
2239	Little Rose	4	9	78

Survey No.	Name	Section	Township	Range
2240	Little Lulu	4	9	78
2241	Little Maude No. 2	4	9	78
2242	Lady Elgin	4	9	78
2243	Eva	5	9	78
2244	Little Bell	5	9	78
2259A	Phillips	10	9	78
2259B	Mill Site	3	9	78
2276	Evening Star	16	9	78
2303	Independence Placer	23	8	78
2304	Galena	23	8	78
2318	Ontario	33	8	78
2326	Everlasting	33	8	78
2359A	Caroline	3	9	78
2359B	Criterion Mill Site	3	9	78
2433	Elie	23	8	78
2434	Hoil	23	8	78
2435	Ketsby	23	8	78
2436	Kankakee	23	8	78
2438	Connoran	9	9	78
2439	Nil Desperandum	14	8	78
2474	Rip Van Winkle	14	8	78
2499	Dennison	34	8	78
2512	Dominion	34	8	78
2513	Terry	33	8	78
2514	Adrian	34	8	78
2531	Tip Top	18	8	78
2538	War Eagle No. 1	34	8	78
2541	Privateer	33	8	78
2542	Peabody	36	8	79
2543	Shakespeare	25	8	79
2544	Rough & Ready	16	9	78
2562	Galveston	3	9	78
2584	Nestor	23	8	78
2585	Croesus	23	8	78
2586	Ajax	23	8	78
2601	Wisconsin	7	9	78
2605	Putnam	14	8	78
2606	Sunny South	6	9	78
2627	D. P. Morgan	10	8	78
2628	Little Emma	10	8	78
2629	David S. Draper	10	8	78
2660	Ontario	22	8	78
2661	Roxabell	22	8	78
2662	Eldorado	22	8	78
2663	Banning Fissure	22	8	78
2667	Professor	23	8	78
2713	Gold Vault	14	8	78
2735	Robert Keeley	15	9	78

Survey No.	Name	Section	Township	Range
2770	Silver Leaf	15	9	78
2779	American Eagle	9	9	78
2811	Comstock	32	8	78
2812	Grimsby	6	9	78
2828	Prussia Placer	14	8	78
2837	Excelsior	15	9	78
2890	Nellie May	16	9	78
2923	Keystone	3	9	78
2924	Iamia	3	9	78
2928	Tip Top	7	9	78
2929	Iola	7	9	78
2930	Shelby	9	9	78
2936	Home	33	8	78
2955	Susie May	15	9	78
2978	St. James No. 1	26	8	78
2979	St. James No. 2	26	8	78
2981	Alice	15	9	78
2991	Sonora	16	9	78
2992	Barbeau	16	9	78
2993	Wyandotte	20	8	78
3032	Oriole	4	9	78
3033	Argentum	4	9	78
3034	Double Standard	10	9	78
3036A	Ora	16	9	78
3036B	Mill Site	16	9	78
3037	Emma C.	15	9	78
3044	Humboldt No. 1	29	8	78
3053	Orphan Boy Ex	9	9	78
3054	Union	9	9	78
3055	Brown	15	9	78
3056	Little Nell	15	9	78
3058	Illinois	15	9	78
3072A	Gold Leaf	15	9	78
3072B	Mill Site	15	9	78
3073A	Ora King	20	8	78
3073B	Mill Site	29	8	78
3074	London Mill Site	1	9	79
3081	Gold Queen	21	8	78
3102	Nancy C.	20	8	78
3103	Tiger	28	8	78
3104	Dominion Boy	28	8	78
3105	Becker	28	8	78
3106	Colorado Springs	28	8	78
3107	Ottawa Boy	28	8	78
3108	Duke of Edinburgh	28	8	78
3133	Helvetia	3	9	78
3210	Red Lion	4	9	78
3211	Sir Charles	4	9	78

Survey No.	Name	Section	Township	Range
3228	Zulu Chief	3	9	78
3235	Leni Lodi	15	9	78
3247	Frisco	16	9	78
3285	Monarch	14	8	78
3286	Berlin	14	8	78
3287	Little Hero	14	8	78
3295	Congress	9	9	78
3301	Minnesota	1	9	79
3399	Diomedes	23	8	78
3400	Prince Albert	23	8	78
3401	Superior	23	8	78
3403	Ant Hill No. 1	1	9	79
3404	Ant Hill No. 2	1	9	79
3405	Ant Hill No. 3	1	9	79
3434	Cut Off	34	8	78
3435	Nellie Morgan	15	9	78
3436	Potosi	28	8	78
3451	Iowa	28	8	78
3489	Gurley	10	9	78
3508	Quail	20	8	78
3513	Phoenix	18	8	78
3514	Summit	18	8	78
3515	Copperopolis	18	8	78
3516	Crescent	18	8	78
3517	Superior	18	8	78
3518	Revere	15	8	78
3563	Nelson	33	8	78
3564	Ludden	32	8	78
3601	Kansas Extension	9	9	78
3611	Queen of the Lakes	29	8	78
3622	Virginia	21	8	78
3624	Colorado Prince	34	8	78
3628	Foundout	1	9	79
3681	Golconda	21	8	78
3682	Peri	21	8	78
3683	Shamrock	21	8	78
3694	Magnolia	11	8	78
3731	Bristol	10	9	78
3745	Black Barnet No. 2	29	8	78
3769	White Placer	25	8	78
3770	Norwood Placer	13	8	78
3817	Cliff	1	9	79
3818	Triangle	1	9	79
3842	The Little Mamie	9	9	78
3858	Morning Star	27	8	78
3893	Pratt Placer No. 2	36	8	78
3894	Golden Star	17	8	78
3898	Whipple Placer	25	8	78

Survey No.	Name	Section	Township	Range
3917	Gray Placer	24	8	78
3922	Carman Placer	24	8	78
3923	Excelsior	3	9	78
3926	Edna	6	9	78
3927	Sunday Placer	25	8	78
3933	Shenango Placer	13	8	78
3964	New Discovery	14	8	78
3965A	Panabase	3	9	78
3965B	Mill Site	3	9	78
3966	Young	3	9	78
3967	Bald Eagle	3	9	78
3971	Golden	11	8	78
3998	Coosa Placer	36	8	78
3999	Elyton Placer	25	8	78
4000	Oxmoor Placer	24	8	78
4013	Rockingham	3	9	78
4022	S. M.	1	9	79
4053	Stephens	9	9	78
4054	Godfrey	9	9	78
4118	Saint Louis	15	8	78
4191	Kidnaped	1	9	79
4210	Lee Goss	11	8	78
4226	Great Scott	28	8	78
4277	Franklin	5	9	78
4288	Last Stake	33	8	78
4296	Good Samaritan	9	9	78
4306	Little Money	34	8	78
4307	Pride of Alma	34	8	78
4316	B. B. & G.	17	8	78
4325	Belle of Buckskin	4	9	78
4326	Lamb	15	8	78
4348	Emma Nevada	7	9	78
4349	Ameringen	17	8	78
4374	Denemite	16	8	78
4392	Golden Eagle	1	9	79
4396	Southwood	10	9	78
4416	Little Champion	31	8	78
4490	Fanny	31	8	78
4607	Addie	22	8	78
	Dora	22	8	78
	Mary	22	8	78
4661	Evangelist	10	9	78
4670	Grand Prize	31	8	78
4684	Mill Creek	22	8	78
4749	Cheever	3	9	78
4862	Rendesvous	15	8	78
4863	Diamond	15	8	78
4864	Slip	15	8	78

Survey No.	Name	Section	Township	Range
4865	Moss-Vail	15	8	78
4905	Daisy	3	9	78
4982	Agnes	1	9	79
5027	Queen Mary	32	8	78
5091	St. Louis	31	8	78
5193	Our Fritz	15	8	78
5275	Golden Chariot	10	9	78
	Golden Blade	10	9	78
	Napoleon the Great	10	9	78
5285	Lower Outcrop	15	8	78
5397	Jersey	10	9	78
5412	Last Chance	16	8	78
5515	Comstock	17	8	78
5540	Harvey	3	9	78
5607	East London No. 2	1	9	79
5775	Ajax	10	9	78
	France	10	9	78
	Mascotte	10	9	78
	Monitor	10	9	78
5823	Lockridge	10	9	78
	Midland	10	9	78
	Vincent	9	9	78
5824	R. G. P.	10	9	78
5825	East Lake	10	9	78
5828	Redman	1	9	79
5844	Denver	10	9	78
5885	Chicago	3	9	78
5889	Empire	33	8	78
	Lackawanna	34	8	78
	Luzerne	34	8	78
5918	Lillie Langtry	9	9	78
6031	Orphan Girl	9	9	78
6133	Albert	21	8	78
6176	German	9	9	78
	Little Pittsburgh	9	9	78
6177	Commercial	21	8	78
	Hildreth	21	8	78
6178	Bendigo	21	8	78
6223	Ida	7	9	78
6292	Calumet	16	8	78
	Hecla	16	8	78
6358	Weston	16	9	78
6437	Magnet	33	8	78
6498	Franklin	9	9	78
6518	Jo Dandy	18	9	78
6534	June	31	8	78
6547	Forest	10	9	78
6611	Golconda	31	8	78

Survey No.	Name	Section	Township	Range
6617	Isabella	30	8	78
6619	Saint Louis	10	9	78
6620	Gold Bug	3	9	78
	Ludington	10	9	78
	Third Street	10	9	78
6671	Legal Tender	9	9	78
6752	Derby	3	9	78
	Norwalk	3	9	78
6798	Allen	34	8	78
	Block	34	8	78
	Eastern	34	8	78
6825	Mammoth	16	9	78
	Yorktown	16	9	78
6934	American Flag	3	9	78
6945	Iroquois	10	9	78
	Ridge	10	9	78
	Silver	10	9	78
	Strip	10	9	78
7025	Bonanza Queen	6	9	78
	Coburn	6	9	78
	Emma	31	8	78
	Ontario	31	8	78
	Ravin	6	9	78
	Snow Flake	31	8	78
	Tip Top	31	8	78
7109	Alma	28	8	78
	Alma No. 2	28	8	78
	Black Prince	29	8	78
	Denver	28	8	78
7118	Black Bear	5	9	78
7181	Little Pearl	9	9	78
7187	Dark Cloud	34	8	78
7206	Alexander	33	8	78
7250	Prospect	11	8	78
7287	Grover Cleveland	28	8	78
7288	Winnie	33	8	78
7326	Orphan Boy Placer	10	9	78
7405	Venture	1	9	78
7415	John Logan	9	9	78
7447	Ada	34	8	78
	Amie	3	9	78
	Fannie	3	9	78
	Iowa	3	9	78
	Michigan	3	9	78
	Minnie	3	9	78
	Ohio	34	8	78
	Vermont	34	8	78
7678	Maumee	18	9	78

Survey No.	Name	Section	Township	Range
7687	Boston City	9	9	78
	Boston City No. 1	9	9	78
7709	Crescent	3	9	78
7721	Boreas	9	9	78
	Mabel	9	9	78
8042	Paris	3	9	78
	Paris No. 2	3	9	78
8270A	Jo Dandy	6	9	78
8270B	London Mill Site	6	9	78
8411	Highland Mary	33	8	78
8412	Adeline	32	8	78
8413	Enterprise	33	8	78
8413	Detroit	33	8	78
8522	Gold Bug Mill Site	3	9	78
8621	Saginaw City	19	8	78
8794	Gratification	3	9	78
9001	Quail No. 1	20	8	78
9032	Baby McKee	31	8	78
9034	Kennebec	10	9	78
9051	Panabase No. 2	3	9	78
9404	Lady Washington	3	9	78
9557	Blue Bell	20	8	78
	Blue Bird	20	8	78
	Democrat	20	8	78
	Lone Jack	20	8	78
9608	Sun Flower	15	8	78
9809	Powderly	22	8	78
9836	Adelia	3	9	78
	Nova Scotia	3	9	78
9969	Kansas Mill Site	11	8	78
9970	Fraction	15	8	78
11264	Gold Belt No. 3	14	9	79
11351	Wolverine	16	8	78
11824A	Beatrice	9	9	78
	Black Flag	9	9	78
	Free Coinage	9	9	78
	Little Johnnie	9	9	78
11824B	Gold Dust Mill Site	9	9	78
11968	Amoskeag	16	9	78
	Chickadee	16	9	78
	Edison	16	9	78
11971	Armstrong	16	9	78
	Bismark	16	9	78
	Broncho	16	9	78
	Solid Smith	17	9	78
11973	Agrippa Placer	35	8	78
11993	Baltimore	15	9	78
	Colorado	15	9	78
	Hill	15	9	78

Survey No.	Name	Section	Township	Range
	Nebraska	15	9	78
	Norfolk	15	9	78
12036	Bulger Basin Placer	16	9	78
12063	Atlanta	33	8	78
	Eureka	33	8	78
12080	Chase	34	8	78
	Highlander	34	8	78
12109	Union	..	..	..
12143	Belmont	27	8	78
	Linwood	27	8	78
	Reelfoot	27	8	78
12154	Alsatia	34	8	78
	Angola	34	8	78
	Ashland	34	8	78
	Carrollton	34	8	78
	Cinderella	34	8	78
	Dixie	34	8	78
	Elmot	34	8	78
	Greenwood	34	8	78
	Gretna	34	8	78
	Obion	34	8	78
	Pecan	34	8	78
	Plaquemine	34	8	78
	Rosedale	34	8	78
	Silverette	34	8	78
	Uhlan	34	8	78
	Vidalia	34	8	78
	Waterloo	34	8	78
	Woodland	34	8	78
12474	Highland Chief Extension	27	8	78
	Sparkill	27	8	78
12478	Accommodation	1	9	79
	Oliver Twist	1	9	79
12566	Blue Jay	2	9	78
	Camp Bird	2	9	78
	Silver Seal	2	9	78
12675	Crown Point	18	8	78
12684	Porphyry	15	8	78
12685	Sun Flower No. 2	15	8	78
12696	Snow Bird	16	8	78
12782	Climax	15	9	78
12819	Red Jacket	16	8	78
13054	Davenport	14	8	78
13144	Finale	9	9	78
	Silver Luella	9	9	78
13211	Kansas Extension No. 2	9	9	78
13300	Tarascon	34	8	78
13321	Boston Girl	4	9	78
13326	Anna	11	8	78

Survey No.	Name	Section	Township	Range
13336	Buncombe	10	9	78
13432	Northside	15	9	78
13433	Eva Olin	15	9	78
	Brownlow	15	9	78
	Winchester No. 2	15	9	78
13438	Iron Duke	15	9	78
13467	Gray John	17	8	78
13511	Kangaroo	15	8	78
13554	Arion	11	9	78
	Flying Jib	10	9	78
	Nancy Hanks	10	9	78
13571	Nyack	15	9	78
14133	Zelma Placer	3	9	78
14134	Winrow Mill Site	3	9	78
14244	Paris Placer	4	9	78
14290	Alpine	17	8	78
	Cumberland	17	8	78
	Pelican	17	8	78
	Silver Standard	17	8	78
	Athens	7	9	78
	Aunt Emma	18	9	78
	Ben Ali	13	9	79
	Bessie	13	9	79
	Bonnie Scotland	13	9	79
	Depew	18	9	78
	Druggist	18	9	78
14297	Elizabeth	12	9	79
	Emmons	12	9	79
	Expansion	7	9	78
	Golden Hopes	12	9	79
	Hanna	12	9	79
	Jen Connell	7	9	78
	Josephine	7	9	78
	Kinley Mac	12	9	79
	Leona	12	9	79
	Leroy	12	9	79
	Lila	18	9	78
	Little Helen	12	9	79
	Logan	12	9	79
	Mascot	12	9	79
	Mabel	13	9	79
	Meta	12	9	79
	New York Queen	18	9	78
	Nina	7	9	78
	Paradise	13	9	79
	Philemon	7	9	78
	Rita	12	9	79
	Roosevelt	12	9	79

Survey No.	Name	Section	Township	Range
	Salvator	12	9	79
	Samuel	12	9	79
	Triumvirate	13	9	79
	Uncle Allan	12	9	79
	Verde	12	9	79
	Viva	13	9	79
	Wesley Mills	12	9	79
	Winchell	12	9	79
14416	Maine No. 1	12	9	79
	Maine No. 2	12	9	79
	Maine No. 3	12	9	79
	Maine No. 4	12	9	79
	Maine No. 5	12	9	79
	Maine No. 6	12	9	79
	Maine No. 7	12	9	79
14456	Lucky	18	8	78
14611	Anna	16	9	78
	Charley Williams	21	9	78
	Florence	16	9	78
	LaPorte	21	9	78
	Leadville	21	9	78
	Maggie Morgan	16	9	78
	Red Flag	21	9	78
15121	A. Alexander	19	8	78
15174	Alhambra	16	8	78
15209	East Saginaw	19	8	78
15285	Gettysburg	..	..	..
	Harrisburgh	..	..	..
15289	October	22	8	78
	Triangle	22	8	78
15323	Gold Pouch	10	9	78
15368	Shamrock	22	8	78
15373	Michigan No. 1	2	9	79
	Michigan No. 2	2	9	79
	Michigan No. 3	1	9	79
	Michigan No. 4	1	9	79
	Michigan No. 5	35	8	79
	Michigan No. 6	35	8	79
	Michigan No. 7	36	8	79
	Michigan No. 8	36	8	79
15384	Aspen No. 1	1	9	79
	Aspen No. 2	1	9	79
15491	London Extension No. 1	35	8	79
	London Extension No. 4	35	8	79
15509	Express	35	8	79
	Killarney	35	8	79
	O'Connell	35	8	79
15660	Crisis Placer	15	9	78

Survey No.	Name	Section	Township	Range
15669	Beacon Placer	15	9	78
15714	Silver Monument	7	9	78
15749	Doctor	2	9	79
	Doctor No. 2	12	9	79
15844	Pratt Placer	36	8	78
15889	Allentown	7	9	78
	Mater	7	9	78
15957	Harold	7	9	78
16258	Hannah K.	15	9	78
	Van Baalen	15	9	78
16358	Annie F.	2	9	79
	Eleanor V.	1	9	79
	Margaret No. 1	11	9	79
	Margaret No. 2	11	9	79
	Margaret No. 3	11	9	79
	Margaret No. 4	11	9	79
	Margaret No. 5	11	9	79
	Margaret No. 6	11	9	79
	Margaret No. 7	11	9	79
	Margaret No. 8	11	9	79
	Margaret No. 9	2	9	79
	Margaret No. 10	2	9	79
16363	Gold Vault Extension	14	8	78
	Texas Steer	14	8	78
	Yellow Dog	14	8	78
	Yocum	14	8	78
16431	Arcadia	27	8	78
	Bonanza	27	8	78
	Buster	27	8	78
	Garfield	27	8	78
	Glendale	27	8	78
	Greenhorn	27	8	78
	Laconia	27	8	78
	Minnie	27	8	78
16443	Rosa Lee	10	9	78
	Strassburg	10	9	78
16535	Lady of New York	3	9	78
16619	Republic	11	8	78
16621	Duplex	27	8	78
	Repeater	27	8	78
	Telegram	27	8	78
	Telegraph	27	8	78
16647	Collinwood	15	9	78
16692	King of the Rockies No. 1	4	9	78
	King of the Rockies No. 2	4	9	78
16726	Gloriana	4	9	78
16748	Humboldt	10	9	78

Survey No.	Name	Section	Township	Range
	Silver King	10	9	78
16777	La Tosca	23	8	78
	Yuonne	23	8	78
16791	Lulu	15	8	78
	Tornado	15	8	78
16810	Oxford	16	9	78
16912	Copperhead	1	9	79
	Miners Hope	1	9	79
	Twin Brothers	1	9	79
16932	Edith	3	9	78
	Red Cross No. 7	2	9	78
	Red Cross No. 8	2	9	78
	Red Cross No. 9	2	9	78
17024	Clipper	6	9	78
17065	Victorious	3	9	78
17221	Smuggler	15	8	78
17327	Senator Patterson	7	9	78
	Towne	7	9	78
17328	Easton	7	9	78
17329	Midland	9	9	78
17392	Grey Eagle	1	9	79
17471	Comstock No. 1	1	9	79
	Comstock No. 2	1	9	79
17480	Sun Flower No. 1	33	8	78
	Sun Flower No. 2	33	8	78
17514	Clipper No. 2	1	9	79
17663	Morning Star	27	8	78
17664	Barry Lindon	27	8	78
	Last Rose of Summer	27	8	78
	Rory O'More	27	8	78
17813	Waverly No. 1	33	8	78
	Waverly No. 2	33	8	78
17904	Dinero	7	9	78
	Genevieve	18	9	78
	Oil City	18	9	78
17935	Prince Oscar	6	9	78
	Vulcan	31	8	78
	Wealth	31	8	78
18053	Goldsmith	7	9	78
	Helen Gould	7	9	78
	Helen Gould No. 2	7	9	78
	Helen Gould No. 3	7	9	78
18426	Pine Tree	18	9	78
	Miami	18	9	78
	Dot	18	9	78
18430	Flora A.	18	9	78
	Fraction	7	9	78
	Reconstruction	18	9	78

Survey No.	Name	Section	Township	Range
18489	Pioneer	10	9	78
	Planet Jupiter	10	9	78
	Sir James	10	9	78
18571	Bob	1	9	79
	Bun	1	9	79
18722	Chilkoot	4	9	78
	Matterhorn	4	9	78
18758	California	17	9	78
	California No. 2	20	9	78
18771	Good Fortune	12	9	78
18797	Daisy	18	9	78
18854	Dunraven	17	8	78
18855	Archibald	19	8	78
19173	Samson	33	8	78
19286	Careless Boy	28	8	78
	Careless Boy No. 5	28	8	78

CLAIMS ALPHABETICALLY ARRANGED

Name	Survey No.	Name	Survey No.
A. Alexander	15121	Ameringen	4349
Accommodation	12478	Amie	7447
Ada	7447	Amoskeag	11968
Addie	4607	Anaconda	1697
Adelia	9836	Andes	42
Adeline	8412	Angola	12154
Adrian	2514	Anna	13326
Aetna	2091	Anna	14611
Agnes	4982	Annie F.	16358
Agrippa Placer	11973	Ant Hill No. 1	3403
Ajax	1650	Ant Hill No. 2	3404
Ajax	2586	Ant Hill No. 3	3405
Ajax	5775	Arcadia	16431
Albert	6133	Archibald	18855
Alexander	7206	Argentum	3033
Alhambra	15174	Arion	13554
Alice	2981	Armstrong	11971
Alleghany Placer	627	Ashland	12154
Allen	6798	Aspen No. 1	15384
Allentown	15889	Aspen No. 2	15384
Alma	7109	Athens	14297
Alma No. 2	7109	Atlanta	12063
Alpine	14290	Atlantic	525
Alps	96	Aunt Emma	14297
Alsatia	12154	Avalanche	1203
American	1997	B. B. & G.	4316
American Eagle	2779	Baby McKee	9032
American Flag	6934	Badger	2068

Name	Survey No.
Bald Eagle	3967
Baltic	1211
Baltimore	11993
Banning Fissure	2663
Barbeau	2992
Barry Lindon	17664
Beacon Placer	15669
Beatrice	11824A
Becker	3105
Belle Gill	199
Belle Fountain	1456
Belle of Buckskin	4325
Belle Peabody	1358
Belmont	12143
Ben Ali	14297
Bendigo	6178
Berlin	3286
Bessie	14297
Bismark	11971
Black Barnett No. 2	3745
Black Bear	7118
Black Flag	11824A
Black Prince	7109
Block	6798
Blue Bell	9557
Blue Bird	9557
Blue Jay	12566
Bob	18571
Bonanza	16431
Bonanza King	2124
Bonanza Queen	7025
Bond	2067
Bonnie Scotland	14297
Boreas	7721
Boston City	7687
Boston City No. 1	7687
Boston Girl	13321
Brighton	2226
Bristol	3731
Broncho	11971
Bross	54
Brown	3055
Brownlow	13433
Buckeye	335
Buffalo Head	165
Bulger Basin Placer	12036
Bullger	2126
Bullion	2008
Bun	18571
Buncombe	13336
Burnside	155
Buster	16431
California	18758
California No. 2	18758
Calumet	6292
Camp Bird	12566
Capt. Plummer	322
Careless Boy	19286
Careless Boy No. 5	19286
Carman Placer	3922
Caroline	2359A
Carrollton	12154
Centennial	1899
Champaign	646
Charley Williams	14611
Chase	12080
Cheever	4749
Chicago	246
Chicago	1816
Chicago	5885
Chickadee	11968
Chilkoot	18722
Chloe	540
Cinderella	12154
Cleaner	41
Cleaner	182
Cliff	3817
Climax	12782
Clipper	17024
Clipper No. 2	17514
Coburn	7025
Col. Curry	2035
Collinwood	16647
Colorado	11993
Colorado Prince	3624
Colorado Springs	3106
Columbia	227
Columbia	336
Commercial	6177
Compromise	136
Comstock	2811
Comstock	5515
Comstock No. 1	17471
Comstock No. 2	17471
Coney	257
Congress	3295
Connoran	2438
Coosa Placer	3998

Name	Survey No.	Name	Survey No.
Copperhead	16912	Dunraven	18854
Copperopolis	3515	Duplex	16621
Corsican	169	Dwight	51
Crescent	7709	Eagle	141
Crescent	3516	Eastern	6798
Crisis Placer	15660	East Lake	5825
Criterion	950	East London No. 2	5607
Criterion Mill Site	2359B	Easton	17328
Croesus	2585	East Saginaw	15209
Crown	2201	Echo	1962
Crown Point	12675	Eclipse	175
Crown Prince	2210	Edison	11968
Cumberland	14290	Edith	16932
Cummins Placer	2037	Edna	3926
Cut Off	3434	Eldorado	2662
Daisy	4905	Eleanor V.	16358
Daisy	18797	Elegant	1777
Danville	211	Elie	2433
Dark Cloud	7187	Elizabeth	14297
Dauser	1270	Elmot	12154
Davenport	13054	Elyton Placer	3999
David S. Draper	2629	Emerald	2202
De Mary	38	Emma	225
Democrat	9557	Emma	7025
Denemite	4374	Emma C.	3037
Dennison	2499	Emma Nevada	4348
Denver	5844	Emmons	14297
Denver	7109	Empire	5889
Depew	14297	Enterprise	202
Derby	6752	Enterprise	8413
Detroit	8413	Ernest	891
D. H. Hill	160	Eureka	12063
Diamond	4863	Eva	2243
Dinero	17904	Evangelist	4661
Diomedes	3399	Eva Olin	13433
Dixie	12154	Evening Star	1410
Doctor	15749	Evening Star	1415
Doctor No. 2	15749	Evening Star	2276
Dodge Union No. 4	180	Everlasting	2326
Dolly Varden	73	Excelsior	40
Dominion	2512	Excelsior	2837
Dominion Boy	3104	Excelsior	3923
Dora	4607	Expansion	14297
Dot	18426	Express	15509
Double Standard	3034	Fairbury	1675
D. P. Morgan	2627	Fannie	7447
Druggist	14297	Fanny	4490
Dudley	52	Faro	1204
Duke of Edinburgh	3108	Finale	13144

Name	Survey No.
Flora A.	18430
Florence	14611
Flying Jib	13554
Forest	6547
Forest Queen	1178
Foundout	3628
Fraction	9970
Fraction	18430
France	5775
Franklin	4277
Franklin	6498
Free Coinage	11824A
Friday	250
Frisco	3247
Galena	2304
Galveston	2562
Garfield	16431
Gem	170
Genevieve	17904
German	157
German	6176
Gettysburg	15285
Giant Silver	1662
Gilbert	1764
Gill	53
Girtrude	203
Glendale	16431
Gloriana	16726
Godfrey	4054
Golconda	3681
Golconda	6611
Gold Belt No. 3	11264
Gold Bug	6620
Gold Bug Mill Site	8522
Gold Dust Mill Site	11824B
Golden	3971
Golden Blade	5275
Golden Chariot	5275
Golden Eagle	4392
Golden Era	198
Golden Hopes	14297
Golden Ledge	2036
Golden Star	3894
Gold Leaf	3072A
Gold Pouch	15323
Gold Queen	3081
Goldsmith	18053
Gold Vault	2713
Gold Vault Extension	16363

Name	Survey No.
Good Fortune	18771
Good Samaritan	4296
Grace	1155
Grand Prize	4670
Grand View	194
Gratification	8794
Gray John	13467
Gray Placer	3917
Great Scott	4226
Greenhorn	16431
Greenwood	12154
Gregory	1763
Gretna	12154
Grey Eagle	17392
Grimsby	2812
Grose & Treweek's Placer	72
Grover Cleveland	7287
Guinea Pig	215
Gurley	3489
Haines	80
Hall & Brunk S. M. Co. Placer	247
Hall & Morse Placer	89
Hanna	14297
Hannah K.	16258
Hannibal	2034
Hard to Beat	207
Harold	15957
Harrisburgh	15285
Harvey	5540
Hathaway & Mills Placer	881
Hecla	6292
Helen Gould	18053
Helen Gould No. 2	18053
Helen Gould No. 3	18053
Helvetia	212
Helvetia	3133
Henry D.	1735
Hiawatha	60
Hidden Treasure	2092
Highland	190
Highland Chief Extension	12474
Highlander	12080
Highland Mary	8411
Hildreth	6177
Hill	11993
Hock Hocking	1600
Honey Comb	39
Hoodlum	1179

Name	Survey No.
Hoil	2434
Home	2936
Home Rule	2122
Hoosier	97
Hoosier	556
Howell Mill Site	926B
Hugo	1847
Humboldt	16748
Humboldt No. 1	3044
Huron	1998
Iamia	2924
Ida	6223
Illinois	3058
Imperial	2174
Imperial Placer	1641
Independence Placer	2303
Iola	2929
Iowa	3451
Iowa	7447
Iron Duke	13438
Iron Dyke	249
Iroquois	6945
Isabella	6617
Ivanhoe	167
Jacob's Wonder	1394
January	1180
Jay Gould	571
Jen Connell	14297
Jersey	5397
J. G. Blaine	766
Jo Dandy	6518
Jo Dandy	8270A
John Logan	7415
Jones Placer	882
Joseph A. Thatcher et al. Placer	75
Josephine	14297
Jo Thatcher	152
Julia	323
June	6534
Juniata	137
Juniata	1780
Kangaroo	13511
Kankakee	2436
Kansas	934
Kansas	1657
Kansas City No. 1	1827
Kansas Extension	3601
Kansas Extension No. 2	13211
Kansas Mill Site	9969
Kennebec	9034
Ketsby	2435
Key	1457
Keystone	272
Keystone	2923
Kidnaped	4191
Killarney	15509
King of the Rockies No. 1	16692
King of the Rockies No. 2	16692
Kinley Mac	14297
Lackawanna	5889
Laconia	16431
Lady Della	1412
Lady Elgin	2242
Lady of New York	16535
Lady Washington	9404
Lamb	4326
LaPorte	14611
La Salle	1845
Last Chance	1324
Last Chance	2214
Last Chance	5412
Last Rose of Summer	17664
Last Stake	4288
La Tosca	16777
Laura	2173
Leadville	14611
Lee Goss	4210
Legal Tender	6671
Leni Lodi	3235
Leona	14297
Leroy	14297
Lila	14297
Lillie Langtry	5918
Lime	142
Lincoln	185
Linwood	12143
Little Bell	2244
Little Champion	4416
Little Corrinne	1029
Little Emma	2628
Little Fannie	1191
Little Helen	14297
Little Hero	3287
Little Johnnie	11824A
Little Lulu	2240
Little Mary	2161
Little Maude No. 2	2241

Name	Survey No.
Little Mamie (The)	3842
Little Money	4306
Little Nell	3056
Little Pearl	7181
Little Pittsburgh	6176
Little Rose	2239
Little Ross	1518
Lizzie Abington	2107
Lockridge	5823
Logan	14297
Logansport	1347
London	206
London Extension No. 1	15491
London Extension No. 4	15491
London Mill Site	3074
London Mill Site	8270B
Lone Jack	9557
Lower Outcrop	5285
Lucky	14456
Ludden	3564
Ludington	6620
Lulu	16791
Luzerne	5889
Mabel	7721
Mabel	14297
Maggie Morgan	14611
Magnet	6437
Magnolia	3694
Maine No. 1	14416
Maine No. 2	14416
Maine No. 3	14416
Maine No. 4	14416
Maine No. 5	14416
Maine No. 6	14416
Maine No. 7	14416
Mammoth	6825
Mammoth	2015
Margaret No. 1	16358
Margaret No. 2	16358
Margaret No. 3	16358
Margaret No. 4	16358
Margaret No. 5	16358
Margaret No. 6	16358
Margaret No. 7	16358
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Margaret No. 10	16358
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Mascot	14297
Mascotte	5775
Mater	15889
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McNab	189
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Michigan No. 1	15373
Michigan No. 2	15373
Michigan No. 3	15373
Michigan No. 4	15373
Michigan No. 5	15373
Michigan No. 6	15373
Michigan No. 7	15373
Michigan No. 8	15373
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Midland	17329
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Mill Site	2259B
Mill Site	3036B
Mill Site	3072B
Mill Site	3073B
Mill Site	3965B
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Mineral Park Placer	855
Miners Hope	16912
Minnesota	3301
Minnie	7447
Minnie	16431
Modoc	2009
Mohawk	195
Monarch	3285
Monitor	5775
Montgomery	1872
Moose	93
Morning Star	3858
Morning Star	17663
Morrison	392
Moscow	191
Moss-Vail	4865
Mother	204
Mountain Glen and Mill Site	557A & B
Mountain King	1408
Mountain Queen	1411

Name	Survey No.
Mt. Bross T. & M. Co. Placer	855
Musk Ox	338
Nancy C.	3102
Nancy Hanks	13554
Napoleon the Great	5275
Nebraska	11993
Nellie May	2890
Nellie Morgan	3435
Nelson	3563
Nesbit	1974
Nestor	2584
New Discovery	3964
New York	1649
New York Queen	14297
Nil Desperandum	2439
Nina	14297
No End	291
Norfolk	6752
Northside	13432
Norwalk	11993
Norwood Placer	3770
Nova Scotia	9836
Nova Zembla	230
Nyack	13571
Obion	12154
Occidental	213
Ocean Wave	320
O'Connell	15509
October	15289
Ogden	1346
Ohio	7447
Oil City	17904
Old North State	258
Oliver Twist	12478
Ontario	2318
Ontario	2660
Ontario	7025
Ophir	1874
Ora	3036A
Ora King	3073A
Oriole	3032
Orphan Boy	645
Orphan Boy	37
Orphan Boy Ex	3053
Orphan Boy Placer	7326
Orphan Girl	6031
Ottawa Boy	3107
Our Fritz	5193
Oxford	16810

Name	Survey No.
Oxmoor Placer	4000
Panabase	3965A
Panabase No. 2	9051
Paradise	14297
Paris	205
Paris	8042
Paris No. 2	8042
Paris Placer	14244
Parole	1337
Peabody	2542
Pecan	12154
Pelican	14290
Peri	3682
Peru	570
Peru Extension	1345
Philemon	14297
Phillips	55
Phillips	143
Phillips	154
Phillips	234
Phillips	1873
Phillips	2259A
Phoenix	3513
Pick	2093
Pine Tree	18426
Pioneer	18489
Planet Jupiter	18489
Plaquemine	12154
Pogue	243
Pogue	269
Polaris	248
Porphyry	12684
Potosi	3436
Powderly	9809
Pratt Placer	15844
Pratt Placer No. 2	3893
Premier	144
Pride of Alma	4307
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Prince Oscar	17935
Privateer	2541
Professor	2667
Prospect	7250
Prosperity	2160
Prussia Placer	2828
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Putnam	2605
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Name	Survey No.
Queen Extension	1413
Queen Mary	5027
Queen of the Lakes	3611
Queen of the Lakes No. 2	2162
Rarus	1409
Ravin	7025
Reconstruction	18430
Red Cross No. 7	16932
Red Cross No. 8	16932
Red Cross No. 9	16932
Red Flag	14611
Red Jacket	12819
Red Lion	3210
Redman	5828
Red Rover	1069
Reelfoot	12143
Reliance	2203
Rendesvous	4862
Repeater	16621
Republic	16619
Reservoir Placer	1676
Revere	3518
R. G. P.	5824
Ridge	6945
Rip Van Winkle	2474
Rising Sun	166
Rita	14297
Robert Keeley	2735
Rockingham	4013
Rock Island	2238
Rock of Ages	1965
Rollins & Morrison Placer	179
Roosevelt	14297
Rory O'More	17664
Rosa Lee	16443
Rosedale	12154
Rough & Ready	2544
Roxabell	2661
Russia	192
Saginaw City	8621
Saint Louis	6619
Saint Louis	4118
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Samson	19173
Samuel	14297
Second Advent	1890
Security	156
Senate	366
Senator Patterson	17327
Shakespeare	2543
Shamrock	15368
Shamrock	3683
Shelby	2930
Shenango Placer	3933
Shovel	1740
Silver	6945
Silverado	1325
Silverette	12154
Silver Gem	140
Silver King	16748
Silver Leaf	2770
Silver Luella	13144
Silver Monument	15714
Silver Saddle	342
Silver Seal	12566
Silver Standard	14290
Silver Star	98
Sir Charles	3211
Sir James	18489
Slip	4864
S. M.	4022
Smuggler	17221
Snow Bird	214
Snow Bird	12696
Snow Flake	7025
Solid Smith	11971
Sonora	2991
Southwood	4396
Sparkill	12474
Stephens	4053
St. James No. 1	2978
St. James No. 2	2979
St. Louis	5091
Strassburg	16443
Strip	6945
Substitute	325
Summit	3514
Sunday Placer	3927
Sun Flower	9608
Sun Flower No. 1	17480
Sun Flower No. 2	12685
Sun Flower No. 2	17480
Sunny South	2606
Superior	3401
Superior	3517
Susie May	2955
Susquehanna	1779
Sweet Home	106

Name	Survey No.
Tanner Boy	926A
Tarascon	13300
Telegram	16621
Telegraph	16621
Ten Forty	139
Ten Forty	183
Terry	2513
Texas Steer	16363
The Little Mamie	3842
Third Street	6620
Three Brothers	2102A
Three Rivers	2179
Tiger	3103
Tip Top	2531
Tip Top	2928
Tip Top	7025
Tornado	16791
Towne	17327
Triangle	3818
Triangle	15289
Triumvirate	14297
Truman	2075
Tunnel	321
Tunnel No. 1	134
Tunnel No. 2	135
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Twin Brothers	16912
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Undercliff	251
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Union	12109
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Van Baalen	16258
Venture	7405
Verde	14297
Vermont	7447

Name	Survey No.
Victorious	17065
Vidalia	12154
Vincent	5823
Virginia	3622
Viva	14297
Vulcan	17935
War Eagle No. 1	2538
Washington	50A
Washington Mill Site	50B
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Wealth	17935
Wesley Mills	14297
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Yellow Dog	16363
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Yorktown	6825
Young	3966
Young Hopeful	171
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Zelma Placer	14133
Zulu Chief	3228

APPENDIX C

BIBLIOGRAPHY

The following list of publications bearing on the Alma district may prove of interest to those who may wish to make further investigation:

Bechler, Gustavus R.—
  Ninth Ann. Report of U. S. Geol. and Geogr. Surv. of the Territories, 1875, pp. 378-381.

Capps, Stephen R., Jr.—
  Pleistocene Geology of the Leadville Quadrangle, U. S. Geol. Surv., Bulletin 386, 1909.

Emmons, Samuel F.—
  Geology and Mining Industry of Leadville, U. S. Geol. Surv., Monograph 12, with Atlas, 1886.

Emmons, Samuel F.—
  U. S. Geol. Surv., Geologic Atlas, Tenmile District Special Folio, Colorado, 1898.

Girty, G. H.—
  Carboniferous Formations and Fauna of Colorado, U. S. Geol. Surv., Prof. Paper 16, 1903.

Hall, Frank—
  History of Colorado, Vol. 4.

Lakes, Arthur—
  Glacial Placer Beds on Flanks of the Mosquito Range, Mines and Minerals, Vol. 22, p. 469.

Lakes, Arthur—
  South Park, Colo., Mines and Minerals, Vol. 23, p. 78, 1902.

Peall, Dr. A. C.—
  Annual Report, U. S. Geol. Surv. of the Territories, 1873, Chap. 2, p. 212.

Ransome, Frederick L.—
  Geology and Ore Deposits of the Breckenridge Quadrangle, Colo., U. S. Geol. Surv., Prof. Paper 75, 1911.

Robbins, F.—
  Mining and Scientific Press, Vol. 86, p. 168.
  State Bureau of Mines, Report of, 1901-1902, Park County, p. 145.

Warwick, A. W.—
  The Leadville District, Mining Magazine, Vol. 14, pp. 430-439, 1905.

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whitish to
the lower part, thin
nd dolomitic quartz-
ng brownish in the

COLORADO STATE GEOLOGICAL SURVEY
R. D. GEORGE, STATE GEOLOGIST

BULLETIN 3 PLATE I

Triangulation and Topography by Arthur J. Hoskin, Charles E. Smith and Horace B. Patton, with the assistance of students of the Colorado School of Mines. Surveyed in 1910 and 1911.

Claim boundaries compiled by Arthur J. Hoskin.

LEGEND

Buildings shown thus: ∴

Section Monuments shown thus: +

Correct to May 1, 1912.

MAP SHOWING TOPOGRAPHY AND MINING CLAIMS OF THE ALMA DISTRICT, COLORADO

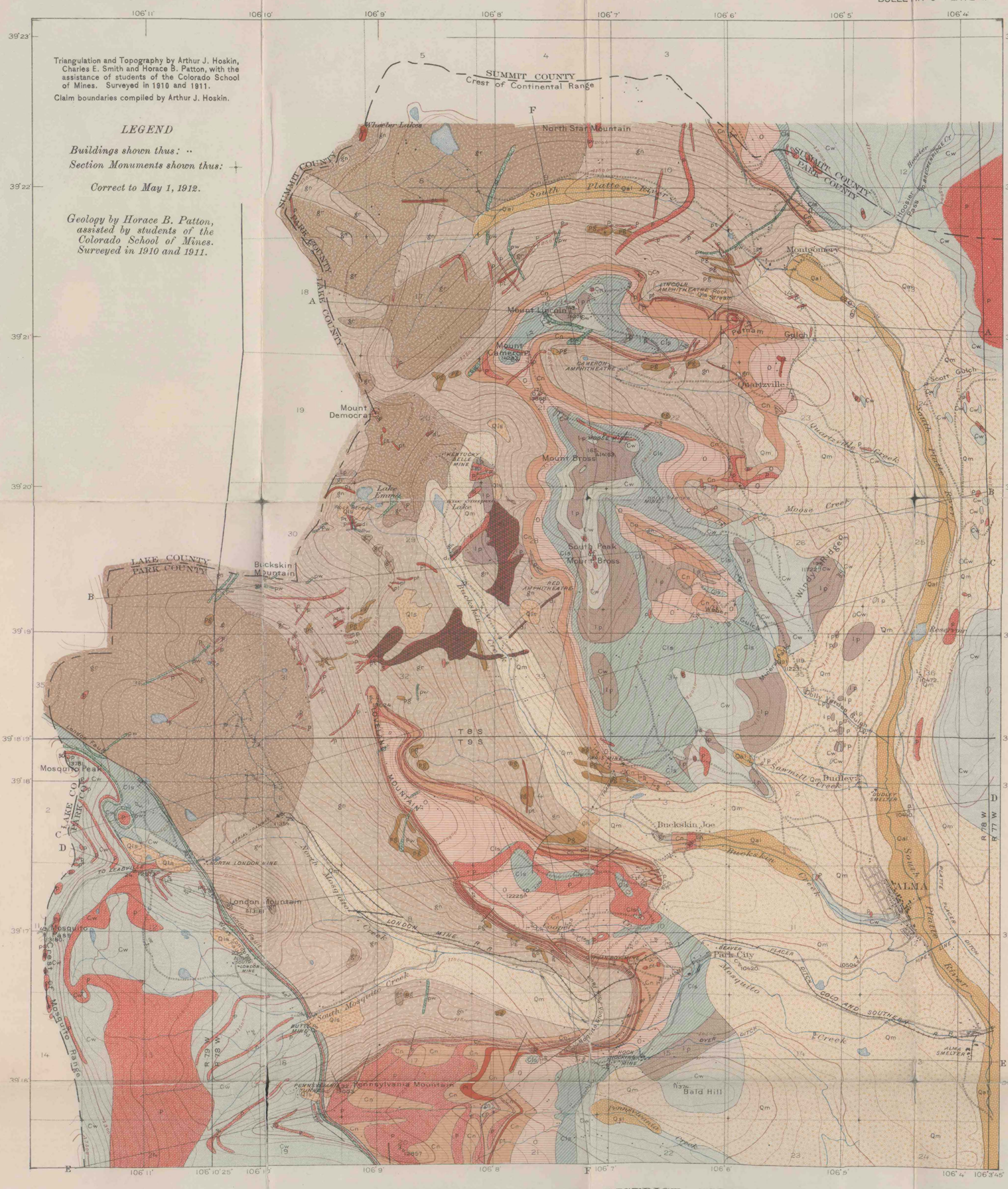
Scale $\frac{1}{30000}$

1 $\frac{3}{4}$ $\frac{1}{2}$ $\frac{1}{4}$ $\frac{1}{8}$ $\frac{1}{16}$ 0 1 Mile

Contour interval 100 feet

A. HOEN & CO. BALTIMORE.

COLORADO STATE GEOLOGICAL SURVEY
R. D. GEORGE, STATE GEOLOGIST



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Claim boundaries compiled by Arthur J. Hoskin.

LEGEND

Buildings shown thus: ..
Section Monuments shown thus: +

Correct to May 1, 1912.

Geology by Horace B. Patton, assisted by students of the Colorado School of Mines. Surveyed in 1910 and 1911.

MAP SHOWING GEOLOGY OF THE ALMA DISTRICT, COLORADO

Scale $\frac{1}{30000}$

1 Mile

Contour interval 100 feet

A. HOEN & CO. BALTIMORE.

LEGEND

SEDIMENTARY ROCKS

QUATERNARY

Recent

Qal
Alluvium
Gravel, sand and clay of recent stream deposition, mostly lying on glacial drift.

Qls
Landslides and Rock Streams
Large masses of rock falling or sliding from very steep mountain slopes, usually broken into small fragments in the process, and lodged at the base of the mountain.

Pleistocene

Qm
Glacial Moraines and Drift
Unstratified mixtures of boulders and clay, deposited by ice action during the latest glacial ice period.

CARBONIFEROUS

Cw
Weber Grits and Shale
Coarse to fine grits mostly of quartz, also locally much feldspar, passing into quartzites and into shales of different colors, the shales being especially pronounced at the bottnm of the series; also a little limestone.

Cls
"Blue Limestone"
Unusually dark bluish gray, compact to granular thick-bedded dolomitic limestone, often silicious.

ORDOVICIAN

O
"White Limestones" and "Parting Quartzite"
Granular to compact, whitish to grayish, dolomitic, extremely silicious limestones, at the top of which is usually a whitish quartzite.

CAMBRIAN

Cn
"Lower Quartzite"
Thick beds of whitish to grayish quartzite in the lower part, thin bedded, shale and dolomitic quartzite weathering brownish in the upper part of the series.

METAMORPHIC AND IGNEOUS ROCKS

ARCHEAN

gn
Gneiss and Schist
Chrystalline quartz-feldspar-biotite rock with schistose or banded and often contorted structure, frequently injected with pegmatites and granite.

gr
Granite
Medium to coarse-grained, plutonic rocks composed of quartz, feldspar and black and white mica, occurring in irregular bosses and in smaller dikes in the gneisses and schists.

pg
Pegmatite
Large to small, irregular dikes cutting gneiss, schist and granite, and composed of extremely coarse grained, sometimes fine grained light colored aggregates of quartz and feldspar with local white mica.

OF LATER AGE THAN THE ARCHEAN

di
Diorite
Fairly dark colored, medium-grained masses composed of plagioclase feldspar, hornblende and biotite and occuring in dikes and larger intrusions in the Archean gneiss and schist.

pt
Diorite Porphyrite
Dark colored and often very fresh looking, fine grained porphyritic rocks showing conspicious hornblende crystals and occurring in sheets and dikes.

p
Quartz Monzonite Porphyry
Porphyritic rocks, from fine to fairly coarse grain, and occurring in sheets and dikes.

lp
Lincoln Porphyry
Porphyries with coarse-grained groundmass and with large crystals of orthoclase from one to two inches long, also with conspicious quartz crystals.

pw
White Porphyry
A light gray to white porphyry of very fine and uniform grain, and showing either no phenocrysts or extremely small and few phenocrysts of feldspar or quartz.

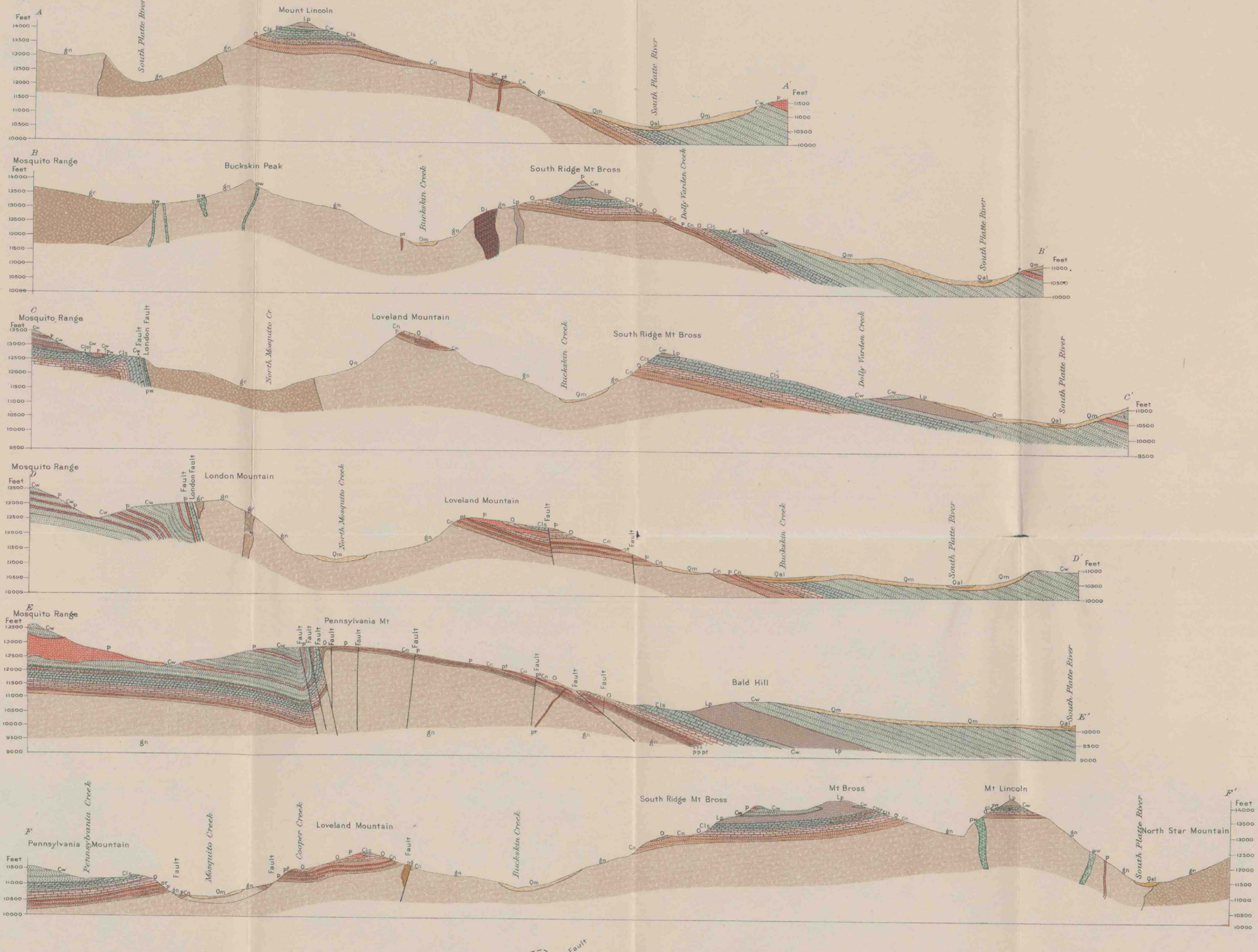
Faults

55°
Dip and Strike

Bull. 3

COLORADO STATE GEOLOGICAL SURVEY
R. D. GEORGE, STATE GEOLOGIST

BULLETIN. 3 PLATE III

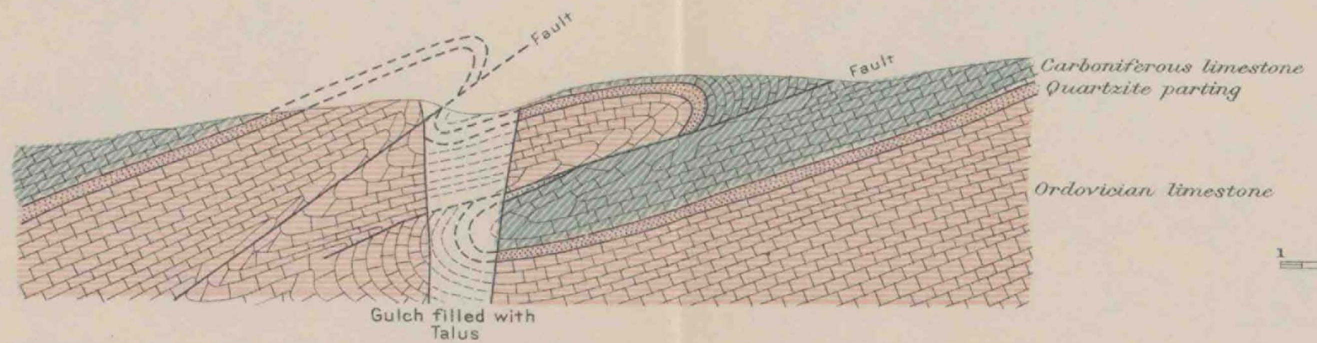


For explanation of Formations see Plate II in pocket.

Scale $\frac{1}{30000}$

1 ¾ ½ ¼ 0 1 Mile

Contour interval 100 feet



DIAGRAMATIC SKETCH OF PART OF MOSQUITO GULCH FOLD-FAULT ON PENNSYLVANIA MOUNTAIN. LOOKING SOUTH.

SECTIONS TO ACCOMPANY GEOLOGIC MAP OF ALMA DISTRICT, COLORADO

Bull. 3