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DEPARTMENT OF THE INTERIOR
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ORE DEPOSITS

OF THE

SILVER PEAK QUADRANGLE, NEVADA

BY

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CHAPTER III.—GENETIC RELATIONS OF METALLIFEROUS ORE DEPOSITS—Continued. Page.

ILLUSTRATIONS.

OUTLINE OF REPORT.

In the Silver Peak quadrangle there is a thick series of Paleozoic limestones, with slates and some impure quartzites, all belonging within the Cambrian and Ordovician periods. The detailed stratigraphy of these rocks is still in doubt. The Ordovician strata apparently overlie the Upper Cambrian conformably. No sedimentary rocks intermediate in age between the Ordovician and the probable Eocene have been found within the area of the quadrangle, but there are extensive and thick deposits belonging to the Tertiary. These consist of soft shale, sandstones, volcanic tuffs, etc., with interbedded layers of andesitic and rhyolitic lava, the thickness of the whole accumulation being very likely several thousand feet. Some of the beds are undoubtedly lake sediments, while others bear the marks of a dry, subaerial origin. It is probable that practically the whole Tertiary, from the Eocene through the Pliocene, is represented. These Tertiary deposits at Silver Peak are part of a larger belt which has been identified in the Tonopah district, in the Funeral Range, and elsewhere. This belt runs northwest and southeast in the region lying immediately east of the Sierra Nevada, and reaches at least as far north as northern Nevada and as far south as the Mojave Desert. Much of the material in these beds was laid down in inclosed lake basins, and some of it during periods of aridity, as is indicated by chemically precipitated calcareous limestones, gypsiferous beds, beds of colemanite (borate of lime), etc. The belt of Tertiaries practically coincides with a belt in which borax is found in commercial quantity.

Within the Silver Peak quadrangle are abundant granitic rocks, intrusive into the Paleozoic strata, especially in three chief areas—in the northeast corner, near Lone Mountain; on Mineral Ridge, near Silver Peak village, and in a long belt in the southern part of the quadrangle. In the first-named region the rocks are chiefly true granites, composed of alkali-feldspar and quartz, with some biotite and muscovite. These rocks often pass into slightly later aplitic types, consisting chiefly of quartz and alkali-feldspar, and so having the composition of alaskites. In Mineral Ridge the prevalent phase of the intrusive rock is alaskite, with frequent phases corresponding to the siliceous biotite-granite of Lone Mountain. The alaskite gradually passes by diminution of the feldspar into pure quartz "veins," which have very much the same chemical and genetic relation to the alaskite that the alaskite has to the granite. The granites in the southern part of the quadrangle vary in composition from alaskite to normal granite and to quartz monzonite, the proportions of lime, soda, and potash being variable. The various closely related phases of the granitic intrusions are regarded as derived from a single, general, granitic magma, and it is probable that the different areas represent practically a single period of intrusion. From the evidence in the Silver Peak quadrangle alone the age of this intrusion is determined only as post-Ordovician and pre-Tertiary, but from evidence derived from neighboring Nevada localities it appears probable that the intrusion is of the same age as the granitic rocks of the Sierra Nevada—namely, late Jurassic or early Cretaceous.

Dikes of diorite, generally altered to greenstone, are abundant in the Silver Peak region. They are always younger than the granitic rocks, and also are younger than the aplites or alaskites. On Mineral Ridge they are younger than the quartz veins, which are the siliceous extreme of the alaskitic injection. On account of their association with the granitic areas, it is suggested, however, that the diorites may be a later manifestation of the granitic intrusions and may represent a magma complementary to the alaskites, the two representing the results of differentiation of a portion of the original granitic magma.

In this region large quantities of lava were erupted during most of the Tertiary. Indeed, the volcanic activity continued into the Quaternary. The lavas consist of rhyolites, andesites, and basalts, with some dacites.

The Pleistocene detrital deposits, which are abundant in this region, are not sharply divided from those of the late Tertiary. They are almost entirely subaerial. The process of erosion is typical of this desert country and results in the formation at the foot of the mountains of broad aprons of drift, which pass down into flat detritus-covered valleys. In the lowest portion of each mountain valley there is a flat playa deposit, caused by sedimentation from the water which gathers there after occasional unusually great precipitation. Sand dunes accumulate in wind eddies in certain portions of the valleys.

It is probable that the Nevada ranges, such as the Silver Peak Range, shared in the stresses which uplifted the Sierra Nevada at the close of the Jurassic, but to a less degree. The Sierra Nevada experienced a greater uplift, resulting in the western Nevada province being transformed into an elevated trough. During the Cretaceous this depressed belt was one of erosion and free drainage. During the whole Tertiary and down to the present, lake basins were repeatedly formed and again altered or destroyed by new crustal disturbances accompanied by copious volcanic eruptions. It is probable that such disturbances were accompanied by some folding and faulting, resulting in local elevations and depressions, so it is probable that in this belt there are both mountains and valleys whose configuration is due primarily to deformation rather than to erosion. The rock structure of the Silver Peak Range is known to be complicated—to such an extent, indeed, that it has not been worked out. The presence of folds and faults is certain. Tertiary beds are in places arched up over the lower part of the Silver Peak Range, attesting flexing and faulting accompanying the uplift of the range in Tertiary time. It is not yet certain what the resulting balance has been in this region between the forces of erosion and deformation. The writer, however, regards it as probable that at least part of the surface configuration may be due to direct deformation.

The Silver Peak, or Mineral Ridge, district is the oldest and most important of the several mining districts of the quadrangle. It contains abundant silver mines, as well as gold mines which have been considerably worked and are still regarded as of potential value. The silver deposits were discovered in 1864. The chief production has come from the gold ores, mainly from the mines of the Drinkwater group, which have been worked intermittently. Subsequent to the discovery of Tonopah a number of prospects were located around Lone Mountain, some of which have proved valuable. Prospects on the west side of Silver Peak Range, 1 mile east of Dyer's ranch, in Fish Lake Valley, have been located several times, but have had no production. In the southwestern part of the quadrangle the Windypah, or Fesler, district is still in the prospecting stage. In the extreme southern part of the quadrangle, on the northern slopes of the Palmetto Mountains, are certain prospects which have had no production. The total production of Mineral Ridge is estimated at $1,418,000; the other mines and prospects of the quadrangle have not produced any considerable amount. One of the largest areas of sand dunes is reported to have yielded assays showing a considerable amount of gold throughout, and has been considered as a mining proposition, but it has not yet been proved that more than traces of gold are present.

The typical auriferous quartz of the Mineral Ridge district is white and crystalline, and is in appearance and nature like that of the characteristic gold quartz found in so many districts in the world. It occurs in the form of overlapping lenses, intrusive into metamorphosed slaty limestones along a certain zone, and associated with similar lenses of alaskite. The quartz contains throughout gold and a little silver, the gold being principally in a free state, though some is contained in sulphides. Typical quartz and typical alaskite form two ends of a rock series between which every gradation is abundantly represented. As a rule, the gold grows rapidly less with incoming feldspar, although occasionally feldspar-bearing rocks carry good values. The alaskite is made up especially of quartz and feldspar, with some muscovite, the feldspar consisting of orthoclase, microcline, anorthoclase, albite, and oligoclase-albite. In the crystallization of the rock two distinct periods or generations of crystals are always represented. The chief lesson taught by a study of the crystallization is that the quartz is distinctly younger than the feldspar. The muscovite is generally in fine fibers and has formed at the expense of some of the feldspar, and on examination might be disposed of as secondary sericite, but this muscovite has formed only at the expense of the feldspars of the first generation, and it is clear that the partial alteration of the feldspar of the first generation took place when the magma was partially consolidated and before the deposition of the remainder, which formed the second generation. Many observations show that the first generation of crystals was rigid enough to be partially cracked and fissured in place and that the residual fluid solidified as quartz in these fissures, as well as in the interstitial places between the crystals. Besides occurring in these forms, the quartz magma collected in larger masses, and by itself formed on a small scale an independent intrusive in nearly the same sense as the alaskitic magma had done.

Some subsequent mineralization, later than the primary consolidation of the auriferous quartz magma, has been noted in certain mines of the district. In these mines the primary lenses have been cracked by subsequent movement, and the cracks, especially those near the hanging wall, have been filled with auriferous pyrite and galena. These ores, it is thought, have not been leached and concentrated from the ores first deposited, but represent a later fresh supply brought in by ascending waters. It is believed that these solutions were not dependent in any way upon the diorite, which often follows the primary lenses and is always later than them; but it is believed that the mineralizing solutions were similar in composition to the primary solutions, though more aqueous and attenuated.

Primary auriferous magmatic quartz, similar in origin to that of the Mineral Ridge district, has been found also in the Windypah district, in the southern part of the quadrangle, but has not been proved to be economically important.

A special type of auriferous deposits in the Mineral Ridge district is represented by the Great Gulch mine. This is a deposit of auriferous arsenopyrite, which is believed to be similar in age and origin to the subsequent ores of the previously described gold mines.

On the margins of the auriferous quartz district of Mineral Ridge are a number of mines and prospects containing more silver than gold. The general geology is like that of the gold-bearing ores. Alaskite and quartz lenses are intrusive into metamorphosed sediments and are accompanied by greenstone dikes. The ore, however, is subsequent and has formed along cracks in the primary quartz. The whole history indicated is analogous to those auriferous quartz mines of the Mineral Ridge district which show notable subsequent mineralization, although the character of the ore in the silver mines is somewhat different, in that more silver and copper in proportion to the gold are present. Another type of silver-bearing veins has a gangue of contemporaneous quartz, and has formed by replacement of dolomite near the edge of the auriferous quartz district.

In all these silver-bearing deposits the mineralization seems to differ from the subsequent mineralization of the auriferous quartz mines chiefly in the presence of more silver and copper, although otherwise the facts are not unfavorable for regarding all as belonging to the same period. The writer here advances the hypothesis that solutions of granitic origin have deposited in the granite, or in rocks silicified by the metamorphic effect of the granite, gold predominantly, and that in or near the calcareous or dolomitic intruded rocks more silver and copper were precipitated from the same solutions, the difference being due to the selective precipitative influence of the wall rocks.

The veins of the Lone Mountain group of mines and prospects generally follow the stratification of sedimentary rocks, though more rarely they crosscut the formation. There is a strong likeness between the different ores of this district, which contain both gold and silver. The characteristic mineral is stetefeldtite. The chief gangue mineral is quartz, but there is usually some calcite, and in some types epidote, garnet, etc., are abundant. The general conclusion is that at the time of the intrusion of the granite mass in this district siliceous solutions emanated from the hardening mass, recrystallized and metamorphosed the intruded sediments, and deposited metalliferous veins along favorable channels. The genesis of these deposits is similar to that of certain of the silver-bearing deposits of the Mineral Ridge district.

In the southern part of the quadrangle the prospects in the Dyer district are identical in type with a certain class of the Lone Mountain district veins. The values are mostly silver and the predominating metallic mineral stetefeldtite. In the Windypah district, besides the type of prospects due directly to siliceous magmatic segregation and similar to the Mineral Ridge type of auriferous quartz, there are several other forms of ore deposits. One of these consists of auriferous quartz veins following shear zones in the granite. The resemblance of these veins in composition to the veins of magmatic quartz leads to the belief that they also are due to siliceous residual solutions, derived from consolidation of granite, but that they have formed in portions of the granite which have already consolidated. Both the above-named types occur in granite. A third type occurs in calcareous and argillaceous sediments near the granite contact, the country rock having been metamorphosed by the intrusion. The values here are chiefly in silver, with some gold, and among the metallic minerals stetefeldtite, as well as galena, chalcopyrite, etc., are prominent.

In the Palmetto district the prospects belong to the different types enumerated for the Windypah district.

An intimate interrelation has been recognized for all the metalliferous ores of the quadrangle, and all have been traced to the consequence of one event, namely, the intrusion of granitic rocks into Paleozoic sediments in probably post-Jurassic time. The ore deposits may be divided into two chief groups, (1) bodies of auriferous quartz which separated out in gelatinous form from alaskite during the process of crystallization and are of the same age and nature as the intergranular quartz of granite or alaskite; (2) quartz veins due to replacement or impregnation of original material along fracture zones by siliceous solutions more attenuated than those which deposited the ores of the first type and probably residual from the crystallization of the magmatic quartz of the first type. Deposits of the second group were formed chiefly in the intruded strata and to a less degree in the granites. They were contemporaneous with the contact metamorphism of the sediments. Such deposits contain relatively more gold when they occur in the granite and more silver and lead when they are in the intruded strata, and the gangue minerals also vary. The different character of the metallic minerals and gangue is believed to be due largely to the difference in wall rocks. In all the types of ore deposits the character of the solutions is believed to have been highly siliceous and alkaline, mineralizers such as fluorine and boron being present in a limited amount.

The most interesting type of deposits in the quadrangle is represented by the lenses of magmatic quartz, a type which has not heretofore been fully recognized. The other types can be paralleled in other provinces of the world.

Taking all the different types of deposits in the Silver Peak quadrangle as a whole, a number of similar examples present themselves in this same region. The ore deposits of the Belmont district and the southern Klondike are analogous to those of the Silver Peak region in respect to the nature of the veins, gangue, and wall rock. The auriferous quartz veins of the Sierra Nevada also present an analogy. The general conclusion is that the Silver Peak region is part of a larger province represented more abundantly in the Sierra Nevada of California and with only outlying smaller areas in adjacent portions of Nevada. All the ore deposits of this province owe their existence to the intrusion of the post-Jurassic granite, and it has been concluded that the ores were due to siliceous solutions which were the residue of the crystallization of the granitic rocks.

In a previous report (Professional Paper U. S. Geol. Survey No. 42) the writer described the ore deposits of Tonopah, which lies not far east of the Silver Peak quadrangle, as due to the action of magmatic waters and vapors following the eruption of certain Tertiary volcanic rocks. Analogies were pointed out between Tonopah and other districts in Nevada, and the comparison was extended to Idaho on the north and Mexico on the south. The writer characterized the region in which these silver-gold veins occur in Miocene volcanics as a metallographic province. The interresemblance of the different ore deposits connected with the granitic intrusion in western Nevada is such as to justify rating this region from this standpoint as a metallographic province also.

The conclusions drawn from the study of the Silver Peak region support a theory proposed by the writer in 1898 to explain the auriferous quartz veins of the Yukon district in Alaska. During the nineteenth century there has been considerable investigation concerning the nature of granite, pegmatite, and magmatic quartz veins, the results of which can be assembled to support the different steps of reasoning leading up to the conclusion referred to. It has been pointed out by Breislak, Fuch, Scheerer, and others that a granitic magma must contain a considerable amount of water and other mineralizers. One of the final phases of granitic intrusions, pegmatites, has been investigated and discussed by a number of observers, many of whom have recognized the fact that quartz veins are in many cases a phase of the granitic intrusion and may even be considered as the consolidation product of an ultrasiliceous magma. Among the writers whose work has contributed support to this view are notably Lehmann and Howitt. The presence of metallic minerals in these pegmatites and in the associated quartz veins is common. Magnetite is in some places so abundant as almost to form an ore. Among the metals which have been described as occurring in pegmatite in sufficient quantity to be economically valuable are copper, tin, antimony, and molybdenum. The presence of gold in granites, pegmatites, and aplites has frequently been noted, and gold is very characteristic of those quartz veins which are closely related to pegmatites and are of magmatic origin. Numerous examples in different parts of the world are furnished of gold quartz veins intimately dependent upon granitic intrusions.

Nonmetalliferous minerals also occur in the Silver Peak quadrangle. About 10 miles north of Silver Peak there is a deposit of alum and sulphur in rhyolite. This deposit is probably the result of fumarolic activity. The several playas within the quadrangle contain incrustations of common salt and borates of lime and soda. The borax industry is dormant at present, but has been of considerable importance. As regards the genesis of the deposits of salt in the playas, it was once held that they had been leached out from the disintegrated granites and other ordinary rocks of the drainage areas; but beds of borate of lime have been discovered in the early Tertiary sediments, and it is evident that a large part of the borates in playas in this region has been derived from leaching of the Tertiary deposits. Within the Silver Peak quadrangle the character of the salts is different in the different playas, although the rocks in the drainage areas are practically the same. Moreover, it is plain that the larger part of the salts is derived from hot springs which emerge in these valleys. The different character of the deposits in the playas therefore seems to depend largely upon the different nature of the springs.

Boron is one of the rarer elements, and its concentration into abundant deposits implies some active process of concentration. It occurs principally either in deposits from dry lakes or in deposits from volcanic fumaroles. Under the latter condition it appears in commercial quantities in Italy. On the Pacific coast of the United States there are several localities where hot springs containing borax and boracic acid seem to be dependent upon comparatively recent volcanic action. This suggests that the borax obtained by evaporation of dry lakes in this region may ultimately have been derived from volcanic fumaroles, since the Tertiary sediments which contain colemanite were formed during a long period of active volcanism.

Coal occurs in the Tertiary sediments at the north end of the Silver Peak Range. The chief seams are four in number. The coal is of rather poor quality, containing a good deal of ash. However, it might possibly be used as a gas coal.

ORE DEPOSITS OF THE SILVER PEAK QUADRANGLE, NEVADA.

By J. E. SPURR.

CHAPTER I.

GENERAL GEOLOGY.

STRATIFIED ROCKS.

CAMBRIAN-ORDOVICIAN STRATA.

Paleozoic limestones, with slates and some quartzites, are well represented in the area of the Silver Peak quadrangle (Pl. I). They belong entirely within the Cambrian and Ordovician periods. Fossils obtained by Mr. J. E. Clayton as early as 1866, at Silver Peak, and first regarded as Silurian or Devonian, were shown by Mr. Walcott to be Cambrian.[a] Some parts of the Cambrian limestone contain masses of the same corals that are found in the range lying next west (the White Mountains), so that Mr. Walcott regarded the two occurrences as essentially forming part of a single reef.[b]

From the Clayton collection of fossils Mr. Walcott identified the following:[a]

- Archæocyathus atlanticus.
- Archæocyathus undet.
- Ethmophyllum whitneyi.
- Strephochetus? sp.?
- Kutorgina (like K. cingulata).
- Hyolithes princeps.
- Olenellus gilberti.

Most of our knowledge of the Paleozoic strata is derived from the detailed work of Mr. H. W. Turner. The writer and Mr. F. B. Weeks have also collected fossils at various places within the district under discussion. The known fossils show the presence of strata belonging to the Lower Cambrian, the Upper Cambrian, and the Ordovician. The rocks, however, are characteristically considerably folded and faulted, and frequently metamorphosed; and the series, which is several thousand feet thick, presents in its different parts no very striking and constant lithologic differences. The detailed stratigraphy and structure, therefore, are still

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[a] Bull. U. S. Geol. Survey No. 30, p. 38.

[b] Am. Jour. Sci., 3d ser., vol. 49, p. 144.

in doubt, and partly for this reason the Cambrian-Silurian rocks are represented together on the accompanying geologic map.

The following notes are derived from the work of Mr. Turner:[a]

Lower Cambrian rocks are found in the southeast portion of the quadrangle. Here are mica-slates, quartzites, and limestones, containing *Olenellus*, *Archæocyathus*, and probably *Salterella*. In the hills north of Clayton Valley, in the northeast part of the quadrangle, the Cambrian shows a thickness of several thousand feet of dolomitic limestone and marble, quartzites, and green knotted schists beneath the lowest fossiliferous horizon, which is a limestone carrying *Archæocyathus*. Overlying this come slates containing *Ethmophyllum* and *Olenellus*.

In Mineral Ridge, west and northwest of Silver Peak, there is a lower series of considerable thickness, consisting of limestone and slates, with some dolomitic marble beds. This series has been intruded by numerous alaskitic sheets and by quartz veins, so that is has become largely schistose and gneissic.[b] This formation is overlain by massive dolomitic limestones and quartzites, and these are overlain, as Mr. Turner has shown, by Olenellus slates and dark limestone carrying Lower Cambrian fossils. The Olenellus slates and limestone are exposed, among other places, in Alcatraz and Goat "islands," near Silver Peak village.

Analyses of the Lower Cambrian carbonate rocks made for Mr. Turner by Mr. George Steiger show both dolomite and limestone, as well as types of intermediate composition.

Analyses of Lower Cambrian carbonate rocks.

	1.	2.	3.	4.
Lime (CaO)	28.52	30.35	34.49	52.00
Magnesia (MgO)	19.19	20.19	11.38	.42
Ferrous oxide (FeO)[a]	.95	1.89		
Carbon dioxide (CO_2)	44.09	47.21		
Insoluble in boiling hydrochloric acid	7.18	.31		
	99.93	99.95		

[a] Includes any alumina, phosphorus, or titanium that may be present.

Of these analyses Nos. 1 and 2 are true dolomites, No. 3 is a dolomitic limestone or marble, and No. 4 is a limestone. No. 1 is from the basal dolomite in the hills north of Clayton Valley, Nos. 2 and 3 are marbles from Mineral Ridge, while the exact locality of No. 4 is not given by Mr. Turner.

Upper Cambrian fossils have been found at several places in the quadrangle, as, for example, in the hills 4 miles east of Silver Peak village, and also in the north part of the Silver Peak range, 4 miles northeast of the mill of the Pacific Borax Company. In slates and thin-bedded limestones at these localities are linguloids; trilobites (*Acrotreta*), fragments of *Phyllocarida*, and some corals are found. Mr. Walcott regards this fauna as Upper Cambrian.

Ordovician strata overlie the Upper Cambrian in apparent conformity in such a way as to suggest continuous deposition between the two periods. The Ordovician

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[a] The determinations of fossils were made for Mr. Turner by Mr. C. D. Walcott.

[b] The interpretation of this formation is the writer's. (J. E. S.)

rocks contain graptolites, especially in the neighborhood of Emigrant Pass. Mr. Charles Schuchert found that most of these graptolites belong to the Normanskill or lower Trenton horizon of the Ordovician, while the Quebec horizon was represented by two characteristic genera, *Didymograptus* and *Tetragraptus*.

TERTIARY STRATA.

No sedimentary rocks intermediate in age between the Ordovician and the probable Eocene have been found within the area of the quadrangle, but there are extensive and thick deposits belonging to the Tertiary. These Tertiary deposits flank the edges of the mountains and underlie, in part at least, the Pleistocene veneer of the valleys. On account of folding and faulting since their deposition they arch upward along the sides of the mountains, although according to Mr. Turner they have not been found within 2,500 feet of the highest elevations. They consist of soft shales, sandstones, marls, tuffs, volcanic breccias, etc., with interbedded layers of andesitic and rhyolitic lava. The thickness of the whole accumulation is very likely several thousand feet. This mass has not yet been satisfactorily differentiated into separate members, but it undoubtedly contains materials deposited under widely varying conditions. Some of the beds are lake sediments; some appear to have been deposited in running water and were probably distributed by stream action. Others bear the marks of dry, subaerial origin. Also there is probably a great range in the period of deposition, as will be presently shown from a consideration of the fossil evidence. It is probable that practically the whole Tertiary, from the Eocene through the Pliocene, is represented. In short, it is probable that the beds are the record of the whole period of Tertiary sedimentation, beginning with the period when the Nevada land mass ceased to have free drainage to the ocean, at the close of the Cretaceous,[a] through the whole of the climatically changing but in general arid Tertiary period, when the material eroded from the mountains was accumulated in the valleys, in lakes, or in subaerial sheets, down through the Pliocene. Both the early and the more recent Pleistocene accumulations of the region are of very much the same nature as many of these Tertiary beds, and probably form a direct continuation of them; but in the Pleistocene material the proportion of lake beds does not appear to be nearly so large as in the Tertiary formations.[b]

This post-Cretaceous period, characterized by lack of external drainage, was also characterized by enormous volcanic activity.[c] Indeed, the writer looks with favor upon the hypothesis that the crustal basins, without external drainage, which held the Tertiary lakes of this region, were directly due to volcanic action, usually to a sinking or collapse after a period of active eruptions, just as the regional elevations with which the depressions alternated were due to the accumulation of volcanic material beneath. These Tertiary beds are made up largely of volcanic tuffs and breccias derived directly from eruptions, or of detritus removed by erosion from volcanic rocks; and there are numerous intercalated layers of solid lava, locally increasing in volume till the whole nature and process of sedimentation becomes obscured.

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[a] Spurr, J. E., Origin and structure of the Basin ranges: Bull. Geol. Soc. America, vol. 12, p. 249.

[b] Op. cit., p. 251.

[c] Op. cit., p. 249.

The Tertiaries at Silver Peak contain remains of fresh-water mollusks, fish, and plants, as well as coal beds. In 1897 Mr. S. A. Knapp[a] collected some fossils from near the coal beds at the north end of the Silver Peak Range, which Dr. J. C. Merriam, of the University of California, considered indicative of fresh-water origin, and possibly Miocene. In 1899 the present writer collected some poorly preserved shells from Tertiary beds, containing a large amount of detrital or tuffaceous andesitic material, about 10 miles southeast of Columbus, not far from the locality mentioned above. Dr. W. H. Dall thought these probably fresh-water fossils. He found a bivalve which may be a *Sphærium* and a gasteropod that may be a *Planorbis*. Farther northeast in the same series the writer found at one locality very abundant silicified wood. Mr. H. W. Turner also in 1899 collected shells and leaf remains from near the coal beds.[b] In the shell collection Dr. J. C. Merriam found *Campeloma* sp., *Unio* sp., *Planorbis* like *spectabilis* Meek, and *Ancylus* like *undulatus* Meek. Doctor Merriam remarked that the first three forms resemble species described from the Eocene of the western United States, and the last form a species described from supposed Miocene beds. He suggested that the beds from which the collection came might be early Miocene or late Eocene. Mr. F. H. Knowlton found that the fossil leaves represented mostly new species, many of them resembling living forms. One species, *Salix angusta*, is found in the Green River group (Eocene) and in the European Miocene; another, a *Cinchonidium* (?) is allied to a form in the Fort Union group (Eocene?). Higher in the series Mr. Turner collected fish remains which Prof. F. A. Lucas referred to a single species of *Leuciscus*, not differing greatly from living forms.[c] Thus the evidence presented by the fossils found in the Silver Peak quadrangle is not very definite, indicating only the likelihood that the beds may range in age between Eocene and Pliocene.

About 10 or 15 miles east of the Tertiary deposits in the northeastern part of the Silver Peak quadrangle, near the mining camp of Ray, similar Tertiaries, consisting of folded gravels, tuffs, lavas, and some white, thin-bedded, fossiliferous limestones are found. Beds of similar appearance outcrop at intervals between this place and the Silver Peak area. The fossils from the above-mentioned limestones collected by the writer were referred by Dr. W. H. Dall to the Wasatch or Bear River Laramie (Eocene), nearly equivalent in age to the marine Lower Eocene of the southeastern coastal plain. Doctor Dall identified *Vivipara couesi?*, *Planorbis utahensis* Meek, *Ancylus?* sp., *Corbicula ? occidentalis?* Meek (possibly *Sphærium idahoense* Meek).[d]

Eight miles south of this locality, in the Tonopah mining district, is a series of Tertiary lavas similar to those associated with the Tertiary sediments at Silver Peak.[e] There is also at Tonopah, associated with the lavas, a thick series of stratified lake beds, consisting mostly of rhyolitic tuffaceous material and containing infusoria. These lake beds the writer has provisionally correlated with beds of the Truckee group, described by the geologists of the Fortieth Parallel Survey, and found farther north in this region, especially in the Kawsoh Mountains.[f] These deposits were

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[a] Mining and Scientific Press, San Francisco, vol. 74, 1897, p. 133.

[b] Am. Geologist, vol. 25, p. 168; Twenty-first Ann. Rept. U. S. Geol Survey, pt. 2, pp. 192-224.

[c] Fossil fish were collected from this locality or near it, as noted by W. P. Blake in Proc. Cal. Acad. Sci., vol. 3, 1866, p. 306, but there is no record of their identification.

[d] Spurr, J. E., Geology of the Tonopah Mining District, Nevada: Prof. Paper U. S. Geol. Survey, No. 42, pp. 66-67.

[e] Spurr, J. E., ibid., p. 31 et seq.

[f] U. S. Geol. Explor. 40th Par., vol. 1, p. 412 et seq.

referred by King to the Miocene chiefly on the basis of a correlation made by him between them and the John Day beds of Oregon, still farther north, which contain vertebrate remains classed by Professor Marsh as clearly Miocene.[a] The whole series of volcanics at Tonopah were, according to the determinations of the writer, erupted during the Miocene and Pliocene periods.

Farther south, in the Funeral Range, at Furnace Creek, the writer observed upturned Tertiary strata resembling those at Silver Peak.[b] The series is several thousand feet thick and rests unconformably upon Paleozoic limestones. The beds are conglomerates, clays, sandstones, and chemically precipitated limestones or travertine, which also occurs in the Tertiaries at Silver Peak. The Furnace Creek beds are often gypsiferous, contain grass remains, and include also a bed of borate of lime, or colemanite. No fossils have as yet been found in them. These Tertiaries extend southward and are widely distributed. In and near the El Paso Range Mr. H. W. Fairbanks[c] has described a series of tilted clays, sandstones, volcanic tuffs, and interbedded lavas. This series is at least 1,000 feet thick. A seam of coal occurs in these beds, near which are found fossil leaves which Doctor Knowlton regarded as probably Eocene. Farther south, in the Mojave Desert, near Daggett, is a folded and faulted series of sandstones, shales, and tuffs more than 1,000 feet thick. The series overlies rhyolite and contains a bed of colemanite. Mr. W. H. Storms who has described this occurrence,[d] regards the period of folding as perhaps Oligocene.

From these observations it appears that a broad belt of Tertiary sediments, generally folded and faulted, runs northwest and southeast in the region lying immediately east of the Sierra Nevada, and reaches at least as far north as northern Nevada and as far south as the Mojave Desert. These beds consist of a variety of sediments, but wherever encountered contain much volcanic material in the form of pumice, tuffs, and intercalated lava sheets, showing vigorous rhyolite and andesite eruptions during the period of accumulation. Much of the material was laid down in inclosed lake basins, and some of it at least during periods of aridity like that existing at present, as is indicated by chemically precipitated calcareous limestone, gypseous beds, colemanite (borate of lime) beds, etc. The belt of Tertiaries which we are describing practically coincides with a belt in which borates are found in commercial quantities. The best deposits are interbedded layers in the Tertiaries, but the recent accumulations in the valley "alkali flats" or playas, due to the evaporation of the drainage waters, furnish some workable deposits. Inasmuch as the playa borax region, however, is associated with the upturned Tertiaries and does not occur under similar topographic and climatic conditions in the country to the east of this belt, it is probable that the material is often leached from the earlier beds, even in localities where these do not show it.

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[a] Op. cit., p. 423.

[b] Bull. U. S. Geol. Survey No. 208, p. 189.

[c] Am. Geologist, vol. 17, Feb., 1896, p. 67.

[d] Geology of San Bernardino County: Eleventh Ann. Rept. Cal. State Min. Bureau, 1892, p. 337.

IGNEOUS ROCKS.

PRE-TERTIARY.

GRANITIC ROCKS.

Granitic rocks, intrusive into the Paleozoic strata, are well represented in the quadrangle, especially in three chief areas—in the northeast corner, near Lone Mountain (which is just north of the northeast corner and is itself composed mainly of granite); on Mineral Ridge, near Silver Peak village, and in a long belt running northwestward across the southern part of the quadrangle.

In the first-named region (near Lone Mountain) Mr. H. W. Turner has found that the granitic rocks are chiefly true granites, composed of alkali feldspar and quartz, with some biotite and muscovite The feldspar includes orthoclase, microcline, and albite, with micropegmatitic and microperthitic intergrowths. The granite of the south base of Lone Mountain, near the edge of the quadrangle, was determined by Mr Turner to contain feldspar, quartz, biotite, iron oxide, titanite, and apatite, the feldspars comprising orthoclase, microcline, and oligoclase Zircon also was found by the writer in this Lone Mountain granite. The rock of the granite area, 6 miles in diameter, lying south of the Lone Mountain granite, has, according to Mr. Turner, practically the same composition, though its structure is often porphyritic, or even gneissic. The granitic rocks of this region often pass into or are cut by slightly later aplitic types consisting chiefly of quartz and alkali feldspar, and so having the composition of alaskites.

In Mineral Ridge the interbedded slates and thin limestones have been thoroughly injected by siliceous granitic rock, mainly along the planes of stratification, forming chiefly interbedded more or less lenticular bodies, and often penetrating the intruded rock minutely and altering it to a schistose or gneissic condition. The prevalent phase of the intrusive rock is alaskite, or quartz-alkali-feldspar rock, having a granular texture (like that typical of granite), which very frequently becomes coarser or finer (pegmatitic or aplitic). A frequent, but not common, phase of this alaskite is a siliceous biotite-granite like that at Lone Mountain. On the other hand, the alaskite passes by gradual transitions, by a diminution of the feldspar, into pure quartz (in veins), which has very much the same chemical and genetic relation to the alaskite that the alaskite has to the granite The pure or nearly pure quartz phase of this siliceous injection is much more abundant than the granitic type, while the intermediate or alaskite type is most widespread.

The alaskite consists almost wholly of quartz and feldspar, the species of the latter having been determined as orthoclase, microcline, and oligoclase-albite, with occasional muscovite, accessory zircon, and original pyrite The alaskite sometimes has an original slight parallel or gneissic structure, as also does its granitic phase. The granite contains the same minerals as the alaskite, with the addition of generally sparse biotite and more muscovite than the alaskites in general Sphene, magnetite (ilmenite?), pyrite, apatite, and tourmaline were also noted among the accessories.

A specimen of the granitic phase from the lower tunnel of the Mary mine was collected by Mr. H. W Turner and analyzed by Mr. George Steiger, showing the following partial composition:

Partial analyses of granite from the Mary mine.

Silica (SiO_2)	72.72
Lime (CaO)	.51
Soda (Na_2O)	1.65
Potash (K_2O)	6.93

This specimen was an uncrushed light-gray granite, composed of quartz, orthoclase, microcline, oligoclase, biotite, muscovite, zircon, and apatite.

The granitic masses mapped by Mr. Turner in the southern part of the quadrangle contain a variety of different phases. In texture some are like ordinary granite, while some are porphyritic. Areas occur where the feldspar (orthoclase) phenocrysts of the porphyritic variety become an inch or more in length. Finer-grained porphyritic varieties also occur. In composition the rock varies from a normal granite to alaskite on the one hand and quartz monzonite on the other, the proportions of lime, potash, and soda being variable. Aplitic dikes and masses, often of considerable size, and ordinarily of alaskitic composition, are common. They lie frequently in the granite, and are evidently of slightly later consolidation, though having a common origin with it. These dikes and masses are especially abundant near the contact of the granitic masses, and occur in the neighborhood of the granite, in the usually more or less metamorphosed Paleozoic strata into which the granite is intrusive.

Specimens of the granite from this region, examined microscopically by the writer, are made up of quartz, orthoclase, oligoclase, microperthite, and biotite, with sphene, apatite, and ilmenite. Mr. Turner found also pyroxene in the rock represented by the second analysis given below. These analyses of different types from the granitic rocks in the southern part of the quadrangle were made for Mr. Turner by Mr. George Steiger. They are arranged according to silica content.

Analyses of granite rocks from southern part of Silver Peak quadrangle.

	1.	2.	3.	4.	5.
Silica (SiO_2)	68.50	69.23	71.14	73.22	76.04
Lime (CaO)	.60	3.38	2.56	1.52	.46
Soda (Na_2O)	4.05	3.75	3.65	2.79	7.58
Potash (K_2O)	4.83	4.75	3.37	5.35	.07

No. 1 comes from about 6 miles south of Pipers Peak; No. 2 is from the Palmetto Mountains, 6 miles southwest of Barrel Springs; No. 3 is from 13 miles southwest of Pipers Peak; Nos. 4 and 5 are from about 5 miles southwest of Barrel Springs. These analyses indicate a considerable range in the composition, the rocks varying from a basic phase having the composition of a quartz-monzonite or granodiorite through the ordinary granite type to alaskite (No. 5).

APLITIC ROCKS.

In all the areas in the quadrangle where granitic rocks occur, as mentioned above, there are related rocks of more siliceous composition, which clearly represent the later or aplitic facies of the intrusions. These rocks have most frequently a dense, rather fine-grained texture, while often their structure is like that of granite. Pegmatitic phases occur, and are especially abundant in Mineral Ridge, near Silver Peak. This more siliceous aplitic phase of the granitic intrusion is best represented near Silver Peak, where it forms most of the injected material, very little true granite being found there. In the granitic region in the southern half of the quadrangle, also, there is an abundance of the aplitic facies, here mostly of the fine-grained type, though pegmatites are by no means uncommon; but here, as also in the southern part of the quadrangle, the aplitic rocks are greatly subordinate in amount to the more normal granitic type of the intrusion. They occur as dikes in the granite, and to a much greater extent in the neighboring intruded rocks.

The chemical and mineral composition of the aplitic rocks, so far as examined by the writer, is similar over all the quadrangle. They are quartz-alkali-feldspar rocks, or alaskites, more siliceous than the related granites. The feldspars consist mainly of orthoclase, microcline, albite, oligoclase-albite, and anorthoclase. Accessory minerals are frequent muscovite, biotite (sometimes becoming common), sphene, zircon, magnetite, and pyrite. The chemical composition varies considerably, as will be seen from the following partial analyses of specimens collected by the writer from the lower tunnel of the Drinkwater mine on Mineral Ridge, and examined by Mr. George Steiger:

Analyses of aplitic rocks from the Drinkwater mine.

	1.	2.	3.	4.	5.
Silica (SiO_2)	66.45	71.92	75.23	78.83	80.63
Soda (Na_2O)	1.92	1.41	2.72	1.03	.27
Potash (K_2O)	10.66	9.17	3.88	6.61	5.28

No. 1 has a medium granitic texture, and the microscope shows quartz and microcline, with rare muscovite and frequent tiny zircons. No. 2 has a texture similar to that of No. 1, and consists of quartz, microcline, orthoclase, and an undetermined striated feldspar. No. 3 is rather fine-grained, with an original banded or gneissic structure; it consists of quartz, orthoclase, microcline, and anorthoclase, with a little muscovite, and occasional original pyrite. No. 4 has a medium-grained, granular texture, and consists of quartz, microcline, and probable albite. No. 5 is medium grained and granular, and consists of quartz, microcline, a little muscovite, and frequent zircon.

In many phases of these alaskitic rocks a tendency is seen under the microscope for the different minerals—meaning essentially feldspar and quartz—to segregate into bunches, irregular in form or more frequently elongated, producing original gneissoid structure. These segregations increase in size till they are conspicuous to the naked eye, and by further enlargement quartz veins, often feldspathic, are formed. Such granitic and magmatic quartz is found in all the granite areas, but in the siliceous alaskitic area of Mineral Ridge occurs in great quantities, in thick veins or lenses.

AGE OF GRANITIC AND APLITIC ROCKS.

The various closely related phases of the granitic intrusives are regarded as variations from a single general granitic magma. No well-marked boundaries between the different phases of the main granitic intrusions have been observed, and the slightly later age of the aplitic rocks is according to the well-known law governing the consolidation of granitic magmas—that the normal type is followed by more siliceous phases, representing the closing stages of magmatic consolidation. It is probable also that the different areas represent, essentially, a single period of intrusion.

So far as the evidence in the Silver Peak quadrangle alone goes, we know only that the granitic intrusion was subsequent to the deposition of the Paleozoic strata and previous to that of the Tertiary sediments and lavas. The granitic rocks intrude Cambrian sediments in the northern part of the quadrangle and Ordovician and Cambrian in the southern part. Therefore their age is post-Ordovician and pre-Tertiary.

In the Pilot and the Excelsior ranges, a short distance north of the Silver Peak quadrangle, there are granitic rocks similar to those at Silver Peak.[a] Here they are probably intrusive in Triassic and Jurassic strata. Still farther north, in the Ellsworth Range,[b] similar granitic intrusives penetrate formations which the writer has provisionally referred to the Triassic. Some of these intrusive rocks are characterized by unusually large orthoclase phenocrysts, like the type above referred to in the southern part of the Silver Peak quadrangle. North of this area, in the Star Peak Range, are granitic rocks (accompanied by alaskite dikes) which are intrusive into Triassic and probably Jurassic strata.[c] Similar granitic rocks occur also in neighboring mountain ranges, and are in many cases known to be intrusive into Paleozoic strata.[d] At Belmont dikes intrusive into Silurian strata consist in part of coarse granite-porphyry, with very large feldspar phenocrysts, identical in appearance with the coarse porphyritic phases in the Ellsworth and Silver Peak ranges.

The work of Mr. H. W. Turner has shown that the granitic rocks in the southern part of the Silver Peak Range cross Fish Lake Valley, which lies west of the range, and are represented in the White Mountain Range. Granitic rocks are well represented in this range (even more than in the Silver Peak Range) and in portions at least are known to cut Cambrian strata. The White Mountain Range is separated from the Sierra Nevada by Owens Valley. This adjacent portion of the Sierra Nevada is made up almost wholly of granitic rocks, and the simliar granitic masses of the two ranges are separated only by patches of Tertiary volcanics or by the detritus flooring the intervening valley. In the Sierra Nevada these rocks consist mainly of granodiorite and granite, and the date of their intrusion has been fixed by studying the age of the intruded strata as in the epoch which included the close of the Jurassic and the beginning of the Cretaceous periods.

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[a] Spurr, J. E., Bull. U. S. Geol. Survey No. 208, 2d ed., pp. 103, 109, and geologic map.
[b] Op. cit., p. 102.
[c] Louderback, G. D., Bull. Geol. Soc. America, vol. 15, pp. 318, 336.
[d] Spurr, J. E., op. cit., pp. 92, 95.

In the various granitic areas outside of the Silver Peak quadrangle, which the writer has enumerated above, aplitic rocks, chiefly of alaskitic composition, are abundant as a later phase of the consolidation of the magma.

It appears probable, therefore, that the granitic rocks of the Silver Peak quadrangle and of various other ranges of western Nevada are similar in general nature and origin to the granitic rocks of the Sierra Nevada, and, like them, are of late Jurassic or early Cretaceous age.

DIORITIC ROCKS.

Dikes of diorite, usually not many feet wide, are abundant in the Silver Peak region. They are almost always more or less altered, sometimes completely. In their fresh form they consist, essentially, of feldspar and hornblende in varying proportions. By alteration they become a mass of secondary products, though the original structure may usually be distinguished. They are thus conveniently designated by the field name of greenstone.

In dikes of this sort on Mineral Ridge Mr. H. W. Turner has determined the primary feldspar as andesine and labradorite, and has noted as accessories apatite and ilmenite. Dikes of similar character, sometimes comparatively fresh, occur in the northeast corner of the quadrangle. In some of these Mr. Turner noted pyroxene and biotite. Certain dioritic areas in this vicinity, somewhat larger than the usual dikes, contain quartz in places, forming a quartz-diorite phase.

The alteration processes to which the diorites have usually been subjected have produced as secondary minerals chlorite, quartz, calcite, zeolites, epidote, zoisite, kaolin, talc, etc. Fine secondary biotite was observed, together with other alteration products, in one specimen from the southern part of the quadrangle.

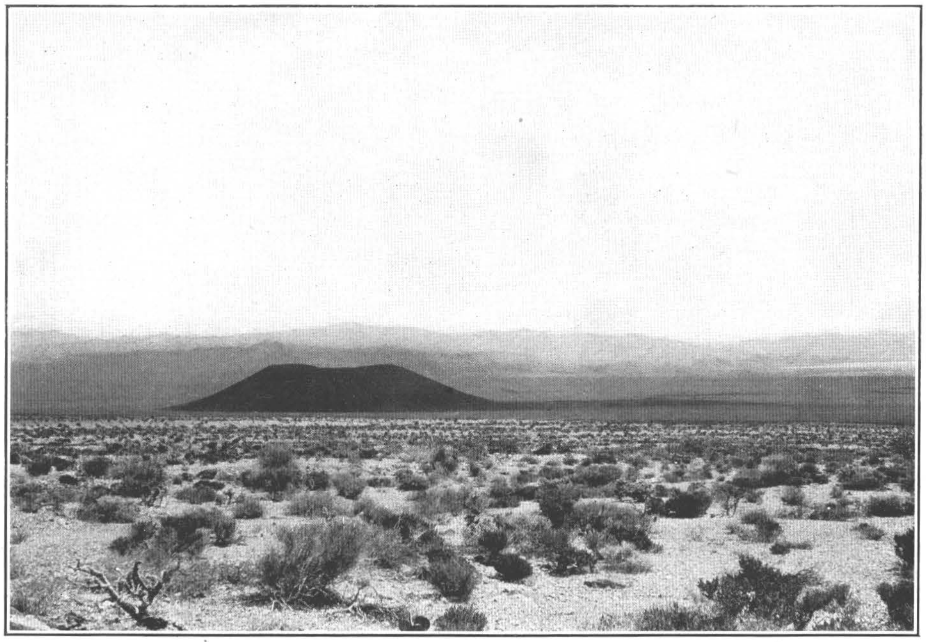
Two partial analyses of greenstone from dikes from Mineral Ridge were made by Mr. George Steiger for Mr. H. W. Turner, as follows:

Partial analyses of greenstone.

	1.	2.
Silica (SiO_2)	48.67	46.28
Magnesia (MgO)	8.75	19.54
Lime (CaO)	8.58	9.91
Soda (Na_2O)	3.39	2.21
Potash (K_2O)	.99	1.89

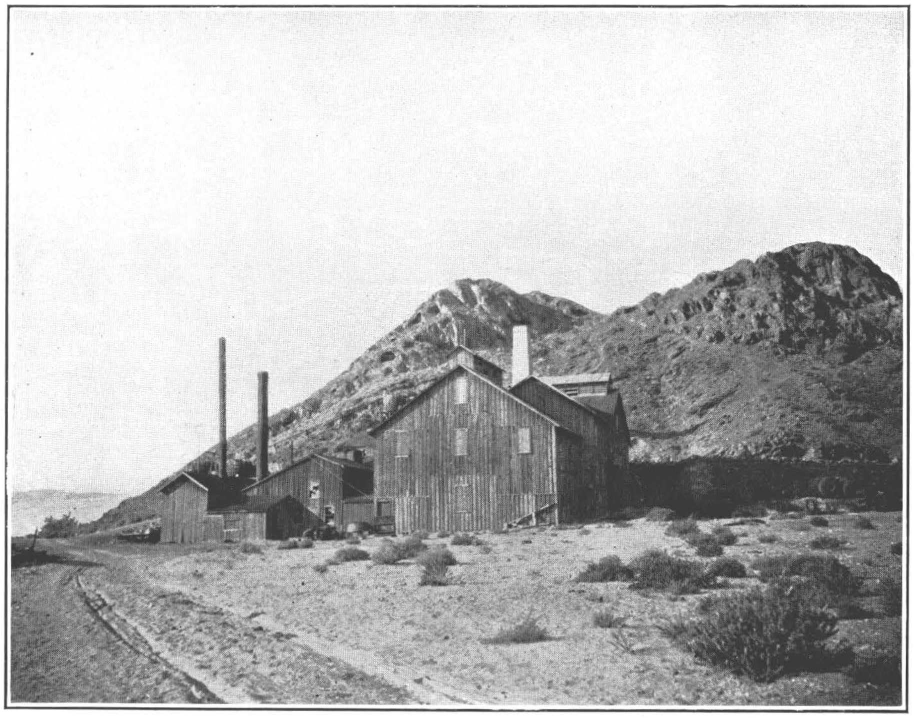
No. 1 is composed chiefly of hornblende and altered feldspar; No. 2 chiefly of hornblende. Both rocks are less siliceous than ordinary diorites.

The dioritic rocks appear from Mr. Turner's mapping to be associated with the areas of intrusive granitic rocks, being found especially in or near these rocks in much the same relationship (as regards location) that has been indicated for the aplitic rocks. In point of age the dioritic rocks are always younger than the granitic rocks, which they frequently cut. Where they are associated with the aplitic rocks (alaskites) they are also younger than these; and, as Mr. Turner has found, they are younger than the quartz veins of Mineral Ridge, which the writer has determined



A. RECENT BASALTIC CONE NEAR SILVER PEAK.

View from the southwest.



B. MILL AT SILVER PEAK.

to be the siliceous extreme of the alaskitic injection. Following the lines of least resistance, they often run along one side of such a quartz vein. The greenstone dikes of Mineral Ridge, like the granitic-alaskitic dikes, are chiefly present in the altered thin-bedded limestone and slate formation which has been described (p. 18) as having been thoroughly injected and altered by the alaskitic materials; but both the granite-alaskites and the greenstones have not infrequently found their way up into the overlying formation, which is a massive dolomite. At one locality, near the Vanderbilt mine, the writer has observed the same dikes passing from the underlying schistose series to the overlying dolomite.

These greenstone dikes are probably older than the Tertiary rocks, since they are not found in them. Therefore the only direct evidence of their age is that they are post-Ordovician and pre-Tertiary. The apparent association with the granitic areas and the limited quantities of the diorite, which approximates in habit and amount the aplitic (alaskitic) intrusions, suggest, however, that the dioritic rocks also may be a later manifestation of the granitic intrusions. Viewed in this light, the diorites may represent a magma complementary to the alaskites, and the two may represent the result of differentiation of a portion of the original granitic magma which took place after the first intrusion and consolidation but before the consolidation of the more slowly cooling portions. A view similar to this has been taken by Mr. Waldemar Lindgren as to the origin of the dioritic rocks in a portion of the Sierra Nevada.[a]

TERTIARY AND QUATERNARY LAVAS.

In the area under consideration lavas were erupted in large quantity during most of the Tertiary. This period of eruption comprised volcanic activities covering the whole of this Nevada province, which itself is probably only part of a much larger province.[b] As is the case with the Nevada province in general, the volcanic activity near Silver Peak continued into the Quaternary. Indeed, the last outbreaks, though slight, occurred in comparatively recent time, as is shown by a small cone of fresh basaltic material (cinders and lapilli), with a crater-like depression in the top, near the village of Silver Peak. (Pl. II, *A*.) This cone is practically undefaced by erosion, and the outbreak is later than the accumulation of the surrounding Pleistocene detritus which floors the valleys. Its age is therefore probably to be measured by hundreds of years only. This case is in some respects like that described by Professor Russell at Mono Lake, about 75 miles west-northwest of Silver Peak, where there are a number of volcanic cones (10 or 15) of very recent date, the lavas being in part hypersthene-andesite, in part rhyolitic.[c] These occurrences represent the most recent eruptions known within the arid Nevada-California province lying between the Sierra Nevada and the Colorado plateau region.

The knowledge gained of the Tertiary lavas of the Silver Peak region is entirely the result of the work of Mr. H. W. Turner, who has mapped the different rocks separately. In the accompanying map, based upon his work, they are all represented together, chiefly because the prime purpose of this report is to explain the ore

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[a] Am. Jour. Sci., vol. 3, Apr., 1897, p. 314.

[b] Spurr, J. E., Trans. Am. Inst. Min. Eng., vol. 33, p. 332.

[c] Eighth Ann. Rept. U. S. Geol. Survey, pp. 374, 375, 377, 380.

deposits, and the relations of these appear more clearly by uniting under one designation certain groups of formations. Mr. Turner has distinguished and studied rhyolites, andesites, and basalts, with some dacites, and these lavas seem to have been repeatedly erupted at different periods. Rhyolites and rhyolitic tuffs cover large areas. This rock contains fresh orthoclase (sanadine), quartz, and biotite. The dacites occur chiefly in relatively thin layers in the rhyolitic tuffs. Andesites are abundant. Some of these are of alkaline types approximating the composition of latites. Others are of the more ordinary andesitic composition. Basalt is also common, both hypersthene basalt and olivine basalt.

The chemical composition of some of the Silver Peak lavas is seen from the following table of analyses:

Analyses of Silver Peak lavas.

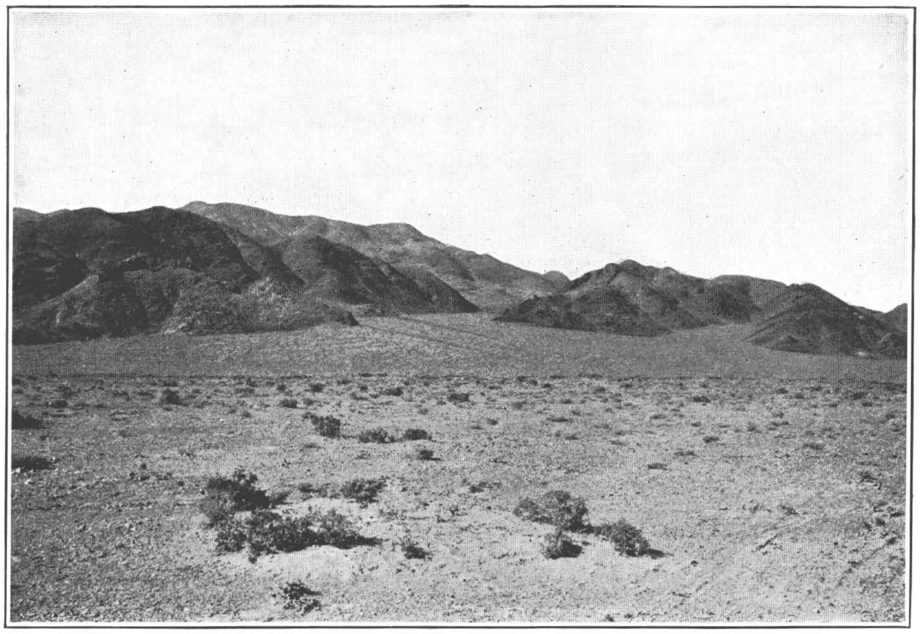
	1.	2.	3.	4.	5.	6.
	Rhyolite, spherulitic.	Rhyolite, granophyric.	Dacite.[a]	Andesite.[b]	Basalt.	Basalt.
SiO_2	72.54	75.93	69.76	64.28	54.78	47.09
Al_2O_3	13.32	....	14.05	....	....	18.40
Fe_2O_3	2.41	....	2.05	....	....	2.66
FeO	.09	....	None.	....	....	5.62
MgO	.51	....	.17	....	3.55	7.06
CaO	1.37	1.37	[c]1.73	3.79	7.48	10.19
Na_2O	3.40	2.80	3.90	3.97	3.28	2.37
K_2O	5.25	4.49	3.57	4.55	2.44	1.34
H_2O-	.21	....	.62	....	....	.66
H_2O+	.97	....	3.65	....	....	2.37
TiO_2	.35	....	.19	....	....	1.19
ZrO_2	.06	....	....	....	....	....
CO_2	None.	....	None.	....	....	None.
P_2O_5	.11	....	.07	....	....	.54
S	....	....	....	....	....	.03
MnO	None.	....	.10	....	....	None.
BaO	.03	....	.14	....	....	.17
	100.62	....	100.00	....	....	99.69

[a] More properly, perhaps, a latite.

[b] This belongs rather with the latites, as Mr. Turner has determined.

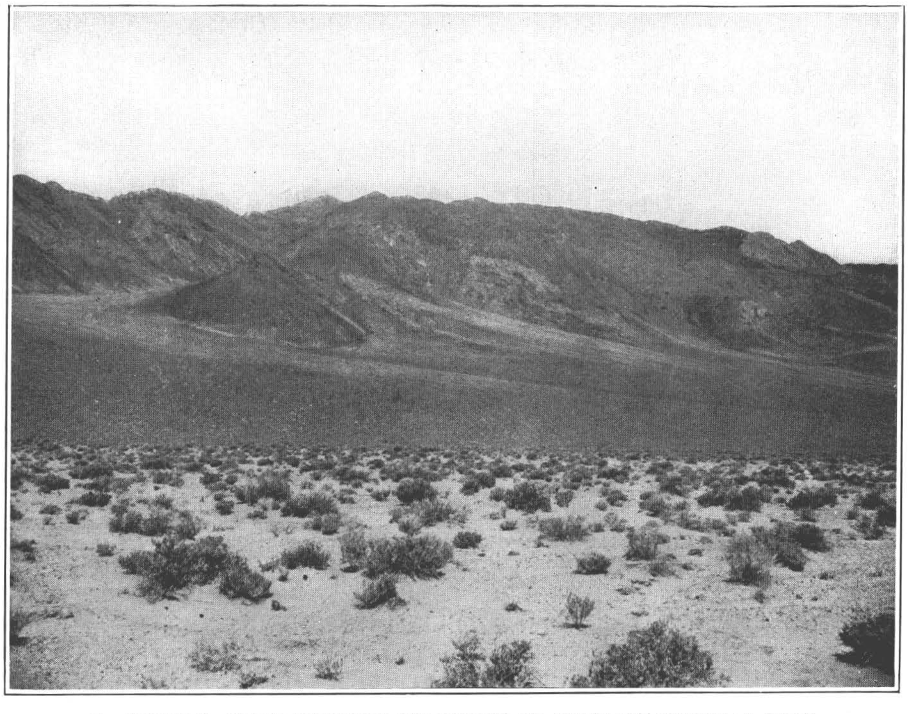
[c] Includes any SrO.

These analyses were made by Mr. George Steiger. The materials were collected and described by Mr. H. W. Turner, except the last, which was collected by the writer. No. 1 comes from a point about 2½ miles southeast of Red Mountain. It has a spherulitic groundmass, containing crystals of orthoclase, quartz, biotite, a little amphibole, and a little plagioclase (apparently oligoclase). Titanite, magnetite, and zircon are also present. No. 2 is from a locality about 2 miles northeast of Emigrant Peak. It has a largely feldspathic granular groundmass, in which are crystals of quartz, orthoclase, and a little biotite. No. 3 has a glassy groundmass, containing crystals of orthoclase, albite, labradorite, biotite, some hornblende, augite, and quartz (?). Magnetite and apatite are accessories. No. 4 is from the west slope of the Silver Peak Range, south of the Cave Spring road. It has a micro-



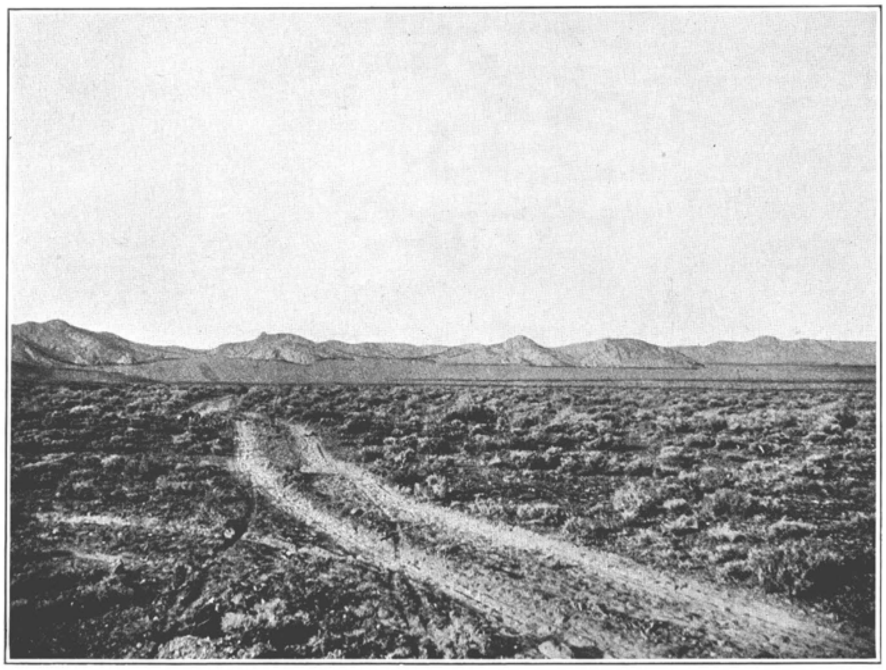
A. EDGE OF SILVER PEAK FLAT, 1½ MILES SOUTHWEST OF PAYMASTER CAMP.

Looking north. Shows streams of wash flowing down from the mountains of Cambrian rock and uniting to form a frontal wash apron.



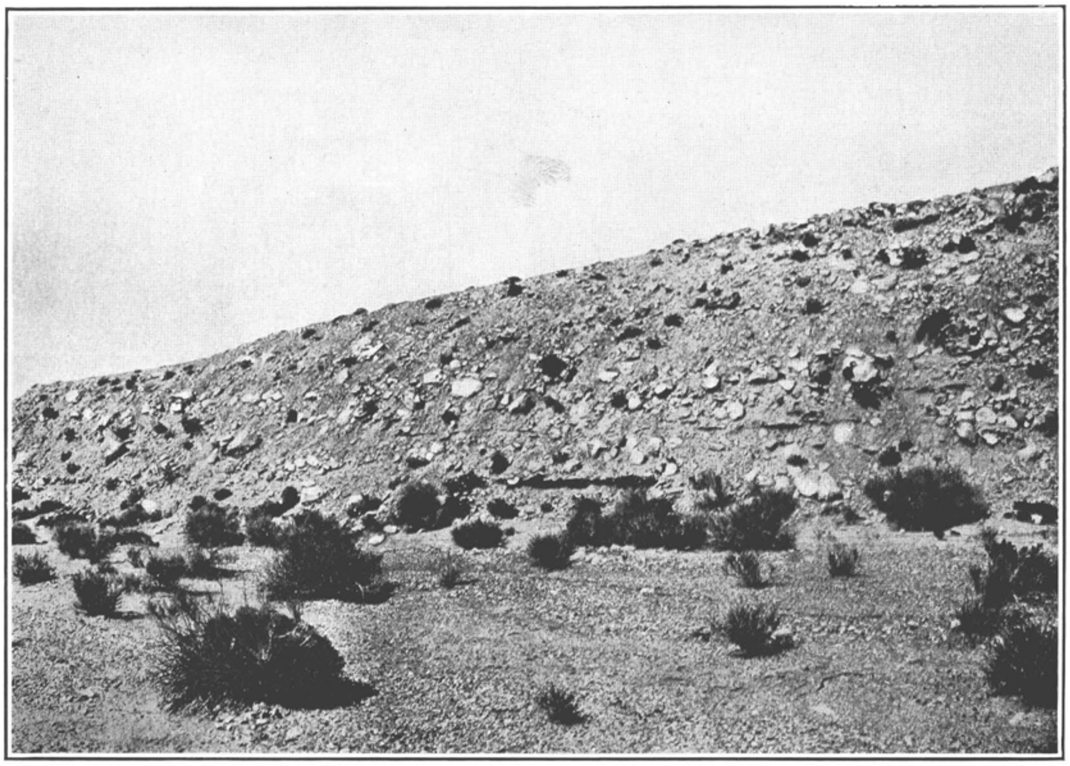
B. DETRITAL APRON FRINGING MOUNTAINS OF PROBABLY CAMBRIAN ROCK.

Looking east on road from Silver Peak to Tonopah, 3 miles north of Paymaster camp. Flat intermontane valley in foreground.



A. VIEW SOUTHWARD FROM NEAR THE LONE MOUNTAIN SYNDICATE PROSPECT.

Shows mountains to south with their fringing wash apron. The foreground is a lower part of the general Lone Mountain wash apron.



B. LAYERING OF SUBAERIAL WASH.

Section of western edge of Lone Mountain wash apron in northeastern part of quadrangle.

granular groundmass, containing crystals of andesine, labradorite, biotite, and augite, with magnetite and apatite. No. 5 is from Pipers Peak. It is coarse grained and contains hypersthene and olivine, the former in larger amount. No. 6 is from a butte 6 miles north of Silver Peak village, and represents an eroded flow lying on top of horizontally bedded ash and tuff. It is made up chiefly of feldspar (mainly anorthite, with some labradorite-bytownite) and olivine, with magnetite. Pyroxene may be present, but was not identified.

QUATERNARY DETRITUS.

PLEISTOCENE

The Pleistocene deposits are not sharply divided either in point of time or in nature from those of the late Tertiary. A single series runs from one period to the other, representing the result of erosion under similar topographic and climatic conditions. But the amount of material laid down in standing water in lakes inclosed in rock basins was very considerable at various periods in the Tertiary, while the size of the areas occupied by such lakes seems to have been much diminished by Pleistocene time and to have grown still less by the present time. Quaternary lakes of any importance were not formed in the Silver Peak area. The detrital deposits, therefore, are almost entirely subaerial. The process of erosion is that which is typical of all this desert country.[a] The material worn from the bare mountain ridges travels down the slopes and accumulates at their bases in the form of a broad apron of inclined wash or drift (Pls. III and IV). Away from the immediate neighborhood of the mountain bases the detritus spreads out into a level sheet, chiefly, probably, through the agency of the fierce winds which frequently sweep through these valleys.

In places the accumulation of the wash aprons and alluvial cones (gulch dumps) has been interrupted by recent crustal disturbances, involving tilting and probably faulting. Such is the case, as noted by Mr. H. W. Turner and subsequently by the writer, at a point at the west base of the northern part of the Silver Peak Range, east of the Pacific Borax Company's mill in Fish Lake Valley. As a result of the elevation of these gravels, they have become somewhat dissected and are fringed below with a new wash apron of recent detritus. Along most of the mountain front of the Silver Peak Range, however, no evidence of the interruption of the formation of these Pleistocene aprons by dynamic disturbance was noted. Along a considerable portion of the east front of the White Mountain Range, which lies next west of the Silver Peak Range and is separated from it by Fish Lake Valley, earlier Pleistocene wash aprons have subsequently been dissected in the manner above mentioned; but the upper limit of the Pleistocene aprons seems to lie at about the same elevation on the two sides of the valley (about 5,500 feet, as mapped by Mr. Turner), and the apron on the Silver Peak side is a single unbroken one, representing, apparently, the same period of dissection as the two periods of the White Mountain apron. Therefore the writer is inclined to believe that the interruption of the formation of the White Mountain apron and the subsequent partial dissection of the portion already formed were not due to faulting and uplift, but

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[a] Spurr, J. E., Prof. Paper U. S. Geol. Survey No. 42, p. 111.

rather to the advent in the White Mountains of the period of greater precipitation, which still continues. At a number of points on this east face of the White Mountain Range streams of running water leave the mountains and sink into the valley, affording water for a number of ranches. These streams are derived from the comparatively abundant precipitation, largely snow, which represents the overdrift from the Sierra Nevada precipitation, and which does not extend across to the Silver Peak Range. The effect of the erosion of this running water is clearly marked on the topography of the White Mountain side of Fish Lake Valley in contrast with the eastern Silver Peak side, in that the White Mountains are channeled by sharp canyons, at whose mouths the gulch dumps or alluvial fans possess far greater individuality and relief above the general wash apron than on the eastern side, where their relief is, in general, slight.

PLAYAS.

The sloping deposits of the detrital aprons which border the mountain fronts pass downward into lower and flatter Pleistocene deposits. In the lowest part of each mountain valley, hedged in between the different ranges, is a flat basin limited on all sides by the slightly higher detritus. Into this basin run and accumulate the waters after heavy rains or the melting of snows. At such times the basin becomes covered with standing water and is temporarily transformed into a shallow lake. Later the water which does not evaporate sinks beneath the surface. The material deposited from this standing water is a fine silt, which, when exposed by disappearance of the water, becomes a level mud. By further evaporation during periods of slight precipitation, the surface becomes very hard and smooth. Slowly, under the heat of the sun, the waters lying immediately below this hard crust are drawn upward and evaporate. In so doing they leave behind as a precipitate on the surface the mineral matters which they have taken into solution. These mineral matters often whiten the whole surface. They consist of salt, sulphate of soda, borax, etc. The areas covered by these deposits are popularly known as alkali flats, while by geologists they are called also playas. One of these sinks exists in each of the valleys within the Silver Peak quadrangle—one in Clayton Valley (Pl. V), one in Big Smoky Valley, and one within the portion of Fish Lake Valley shown on the map.

SAND DUNES.

The leveling of the detritus derived from the erosion of the mountain ranges in the valleys has already been alluded to as probably chiefly due to the winds, which are frequent in this country. The surplus of finer material thus caught up by the wind accumulates in what appear to be natural wind eddies and forms heaps or sand dunes. In each of the valleys just mentioned there is such an area of sand dunes of comparatively limited and very definite extent. These sand dunes are not necessarily on the edges of the valleys, as might be expected, but are often in the very middle. During strong winds the sand in these dunes is taken up and driven horizontally with great force, and great quantities of this material are then put into motion. This vigorous shifting, however, seems to be very local, for the general outlines of the

HILL OF CAMBRIAN LIMESTONE ALMOST SUBMERGED BY TERTIARY-QUATERNARY (QUATERNARY AT SURFACE) VALLEY DETRITUS.

Alcatraz "Island" near Silver Peak village in the midst of a "playa." View taken from Silver Peak.

sand-dune areas do not change much, according to the testimony of inhabitants. The largest of these areas lies in Clayton Valley and is indicated on the map as surveyed by Mr. Turner (Pl. I).

MOUNTAIN STRUCTURE.

The area in which the thick Triassic and Jurassic strata were deposited in western Nevada and adjacent California was, according to King,[a] outlined at the close of the Carboniferous by the uplift of eastern Nevada. Although no Mesozoic sediments have been found in the Silver Peak quadrangle, they exist in quantity a short distance farther north, in the Pilot Range,[b] and undoubtedly once existed around Silver Peak.

The plication of the strata of the Sierra Nevada into closely appressed and overthrown folds and its upheaval as a mountain range took place at the close of the Jurassic, as has been proved by Whitney. The same profound disturbance is manifested in the smaller ranges lying east of the Sierra Nevada, though its effects grow less toward the east. In the range next east of the Sierra Nevada there are overthrown folds like those of the Sierra Nevada, though the plication is not so intense.[c] Farther east, in the Silver Peak Range, the strata are complexly folded and faulted in a way which has not yet been deciphered. Still farther east the strata are bent only into open and easily recognized folds, though in some cases thrust faults have been observed, as in the Spring Mountain Range.[d] This indicates that the Nevada ranges shared in the same stresses as those which uplifted the Sierra Nevada, but chiefly in the western part, their effects increasing with proximity to the Sierra Nevada. This was also the view adopted by King.[e]

In the Sierra Nevada the date of the enormous granitic intrusions coincides with that of the intense plication and uplift. In the smaller ranges lying east of it the writer has shown (see p. 25) that granitic intrusions of probably the same age occur, and most abundantly in the nearest ranges, as in the White Mountains. Thus the mountain-making forces at this period affected the western part of the Basin province, as well as the Sierra Nevada, but in a less degree. The latter range suffered a much greater and more general uplift, by which the western Nevada province was transformed into an elevated trough, shut off from the sea on the west by the new barrier (see p. 18.)

This still relatively depressed belt contains no known sediments of proved Cretaceous age; so that this period was apparently one of erosion and free drainage. During the whole Tertiary, however, and down to the present, lake basins were repeatedly formed and again altered or destroyed by new crustal disturbances, accompanied by copious volcanic eruptions. Even at the present day the most depressed region of the dry Nevada province is along this belt, and the present lakes in it follow very roughly the old alignment. The depressed Death Valley, part of which is below sea level, is evidence of a continuation of the sinking of the crust, in places at least, down to the present day. Farther south this sunken belt is represented by the low-lying Mojave and Colorado deserts, and still farther by the Gulf of California.

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[a] U. S. Geol. Explor. 40th Par., vol. 1, p. 734.

[b] Bull. U. S. Geol. Survey No. 208, p. 104.

[c] See Spurr, J. E., Bull. Geol. Soc. America, vol. 12, p. 243.

[d] Bull. U. S. Geol. Survey No. 208, p. 177.

[e] U. S. Geol. Explor. 40th Par., vol. 1, p. 747.

It is not probable that such crustal disturbances could be accomplished without folding and faulting, resulting in local elevations and depressions within the affected belt; so it is natural to expect to find in this belt both mountains and valleys whose configuration is due primarily to deformation rather than to erosion.[a] And there are indications that this is actually the case, though sufficient study has been made to demonstrate it in but few places. The Funeral Range and the adjoining Death Valley, as already noted, seem to present one instance, though no detailed examination has been made.[b]

The Tertiary deformation has been contemporaneous with great volcanic activity. Therefore the two chief periods of deformation (including faulting and folding) and mountain making which we can distinguish for the province in which the Silver Peak range lies were periods of great igneous migrations. The writer has elsewhere presented some evidence for believing that the Tertiary deformation was, in part at least, the direct consequence of the lava migrations, instead of both being due to a common unknown cause.[c]

The rock structure of the Silver Peak range is known to be complicated—to such an extent, indeed, that it has not been worked out. The presence of complicated folds and faults is certain. The north face of the range (at the extreme northern part of the map) presents a bold fault scarp overlooking lower-lying Tertiary beds farther north. This was pointed out by Mr. H. W. Turner, and the writer has corroborated the fact that a fault lies along this scarp, though it is not yet determined whether the scarp is directly due to the faulting or is due directly to the erosion of rocks of unequal resistance brought together by the fault movement. The observations of the writer indicate that this may very likely be a reversed erosion fault scarp, the relatively downthrown side forming the scarp, but more work is necessary before any final statement is possible. The straight northeast face of the range, running northwestward from Silver Peak village, suggests faulting, and the writer has observed what may be a fault parallel with this face and near the base of the range. It does not, however, lie at the junction of the bed rock with the valley accumulations, but runs along a depression in the bed rock near the base of the mountain. The probable fault which lies in this depression separates brown Cambrian dolomites on the northeast from the lower-lying slate and limestone formation which has been thoroughly injected by granitic and alaskitic material. Here again there is no evidence as to whether the scarp behind the fault is directly due to uplift or to erosion. Other fault lines probably exist, such as that observed by Mr. Turner on the west side of the range, at a point east of the Pacific Borax Company's mill in Fish Lake Valley. This is a north-and-south fault, which separates the Paleozoic limestones on the east from the Tertiaries on the west, and is also accompanied by a scarp. At other points the outline of the mountains in respect to the valleys often suggests faulting, but the evidence as to the real origin of the configuration has not been satisfactorily determined. So in general we can only say that there is evidence of local crustal movements in the Tertiary and even of some in Pleistocene time.

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[a] Spurr, J. E., Origin and structure of the Basin Ranges: Bull. Geol. Soc. America, vol. 12, pp. 239, 241, 247.

[b] Spurr, J. E., Bull. U. S. Geol. Survey No. 208, p. 194.

[c] Geology of the Tonopah mining district, Nevada: Prof. Paper U. S. Geol. Survey No. 42, p. 81.

The Tertiary beds are in places arched up over the lower part of the Silver Peak range, but are not near the highest elevations. Flexing and faulting, accomplishing an uplift of the range in Tertiary time, is thus attested, though the fact that the upper portions of the range show no Tertiaries suggests that the mountains existed before the Tertiary period. In short, our knowledge of the structure and origin of these mountains and valleys is small. We are certain that great erosion and considerable deformation were contemporaneous, in the Tertiary and even in the Pleistocene, but the resulting balance between these forces in producing surface configuration is in almost every case uncertain, on account of the lack of thorough investigation. The writer, however, regards it as probable that part at least of the surface configuration may be due to direct deformation.

CHAPTER II.

DESCRIPTION OF METALLIFEROUS DEPOSITS.

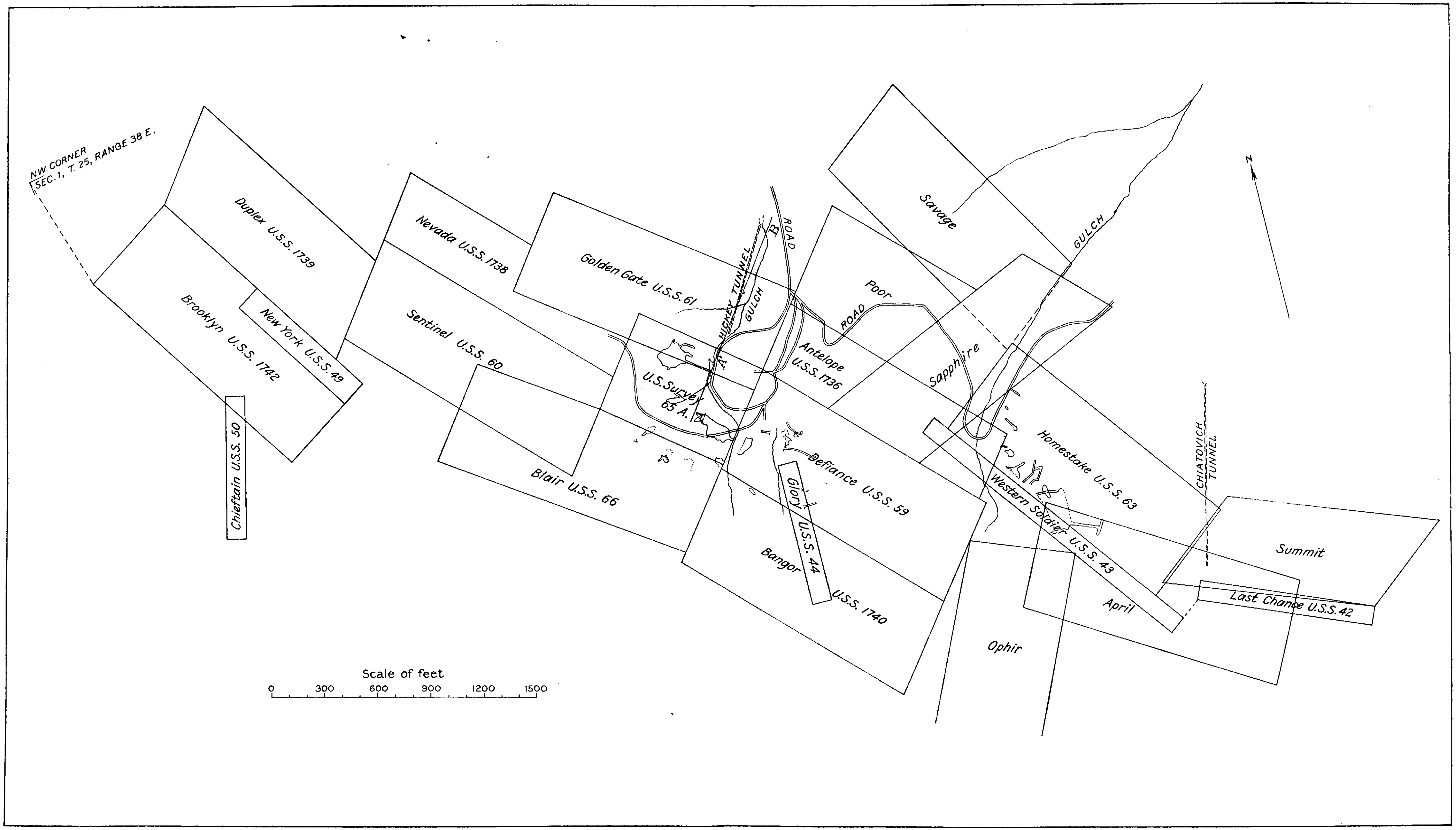
HISTORY OF MINING.

The Silver Peak or Mineral Ridge district is the oldest and probably the most important of the several mining districts of the quadrangle. It contains abandoned silver mines and also gold mines which have been considerably worked, but are still regarded as of potential value. The silver deposits were discovered in 1864 by the Robison Brothers, but were shortly left idle. In 1867 they were opened up again and worked until 1869. It is currently reported that the profits were small. They have not been worked since. The principal mines of the region are the Drinkwater or Blair group, which are gold ores. A 30-stamp mill for working the ores of these mines was finished at Silver Peak in 1867 and was worked for two years (Pl. II, *B*). The mine was then idle until the early eighties, when it was leased for two or three years. Another long period of idleness followed, and in 1893 another lease was given for one year. Immediately after this the mine became involved in litigation, which has been settled only recently. Mining and milling in a small and intermittent way has meanwhile been conducted on a number of properties, generally of minor importance, outside of the Blair mines.

It will be seen that the development of this older Silver Peak district (the Mineral Ridge district) was independent of the development of Tonopah, which was discovered in 1900; but the other mineral districts of the quadrangle mostly followed the Tonopah discovery, and the attention which is or has been drawn to them was due to the revival of prospecting and investment thus brought about in this country.

Around Lone Mountain some old prospects were examined and worked a little many years ago and then abandoned. With the revival of prospecting above referred to, these were relocated and some new ones were found. Many of these locations have not proved of value. On the other hand, a number of mines which were thus started have produced considerable ore. Not all the mines of the Lone Mountain district are covered in this report, but only such mines and prospects as are included within the quadrangle or are immediately adjacent.

The prospects on the west side of Silver Peak range, 1 mile east of Dyer's ranch, in Fish Lake Valley, were located in 1885–1887, and this district was the scene of a short-lived excitement, but was afterwards abandoned. Following the Tonopah discovery, it was relocated, but no new work was done, and at the time of the writer's visit it was again deserted. The Windypah, or Fesler, district, in the southwestern part of the quadrangle, east of Piper's ranch and in the Silver Peak Range, was discovered in the winter of 1903 by J. G. Fesler. An abandoned mine or prospect, the



CLAIM MAP OF BLAIR MINES AND TIETJEN MINES.

Scale, 100 feet=1 inch.

Good Hope, has existed for many years at a point a number of miles northeast of the district. Considerable prospecting had been done in the Windypah district at the time of the writer's visit, but no actual mining.

In the extreme southern part of the quadrangle, on the north slopes of the Palmetto Mountains, are certain prospects belonging to the Palmetto district. Farther south and outside of the quadrangle more important deposits belonging to the same general district exist, but are not treated in this report. The principal prospect within the quadrangle is the MacNamara, located in 1880. Another example of prospects in this vicinity is the Paymaster, which must be distinguished from the Paymaster of the Lone Mountain district. This was located ten or twelve years ago, but was abandoned and relocated in 1902. None of these prospects have produced any considerable amount of ore.

At the base of the northern end of the Silver Peak range coal beds exist. The coal is said to have been discovered by William Grozenger, of Candelaria, in 1893, and the outcrops of the coal seams were afterwards continuously located. These prospects have been bonded several times, once by the Tonopah Mining Company, and some development work has been done on the seams, but up to the present time there has been no mining.

PRODUCTION.

Statistics concerning the production of the mines of Mineral Ridge were given to the writer by Messrs. F. A. Vollmar, John Chiatovich, and Otis Valcalde, of Silver Peak. Although these statistics depend largely upon personal recollection, it is believed that they are fairly accurate. According to this, the Blair group of mines, including the Drinkwater, Crowning Glory, and Western Soldier (Pl. VI), have produced a total of $1,080,000. Close to these groups and on the same zone of ore lenses are the Homestake, with a credited production of $60,000; the Mary with $46,000, and the April with $10,000, making a total of $1,196,000 for this zone of lenses.

Outlying mines of similar character to those of the Drinkwater zone, scattered over Mineral Ridge, are reported to have produced the amounts stated below:

Production of mines on Mineral Ridge.

May	$4,000
Columbus	3,000
Vega	3,000
Crescent	2,500
Solbery	2,000
Golden Eagle	900
Esmeralda	400
Red Monster	300
Total	16,100

The Great Gulch mine, which is of somewhat different character from those just mentioned, has produced about $6,000. The foregoing values are almost entirely in gold.

The silver mines of the ridge, chiefly the Pocatello and the Vanderbilt, have produced, as estimated, about $200,000, making the total production of Mineral Ridge $1,418,000.

That part of the Lone Mountain district which lies within the map has produced only trifling amounts, all the deposits being mere prospects. Beyond the limits of the map, however, some of the mines of the Lone Mountain group have produced considerable ore, the amount of which has not been estimated. The Alpine mine, beyond the northern edge of the quadrangle, paid a dividend of $70,000 in the first year of its workings (1903). Considerable shipments of ore have also been made from other properties in this district.

The other districts mentioned are all in the prospecting stage and have produced only trifling quantities of ore.

DESCRIPTIVE GEOLOGY OF MINES AND PROSPECTS.

GOLD MINES AND PROSPECTS OF MINERAL RIDGE.

DRINKWATER TYPE.

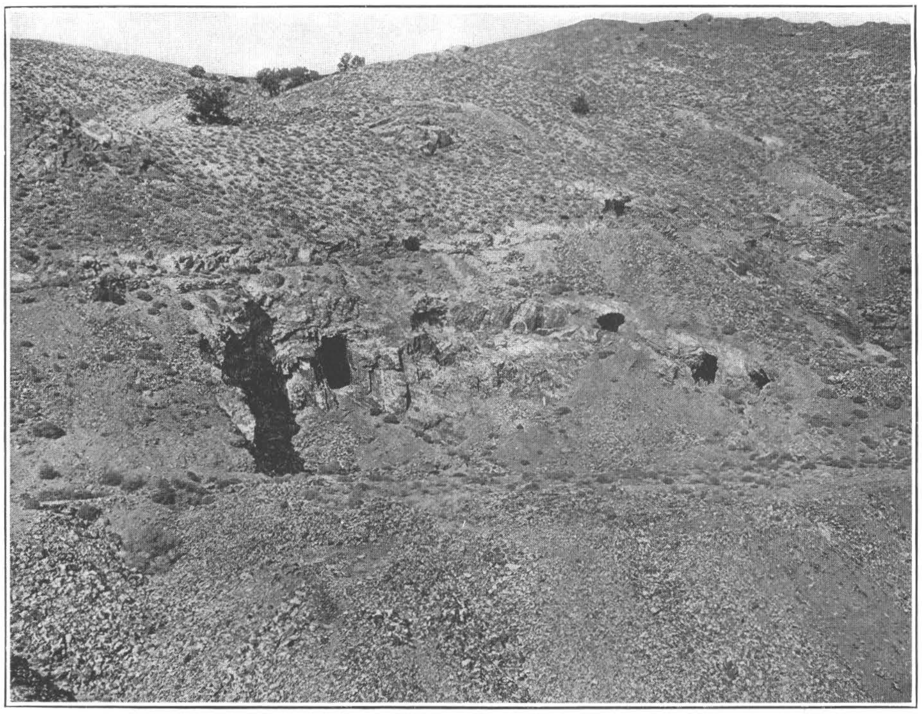
DRINKWATER AND CROWNING GLORY MINES.

EXTENT OF WORKINGS.

The Drinkwater and Crowning Glory mines form a group comprising the most important mines of the quadrangle. They have been operated at intervals for about forty years and have produced a gross total in the neighborhood of $1,000,000. The developments consist of numerous open cuts (Pl. VII, *A*) and underground workings reached by two tunnels. The upper or Drinkwater tunnel (Pl. VII, *B*) runs in on the vein zone, and the workings from it are those from which the greatest production has been derived. The lower or Hickey tunnel is an adit level running into the ore zone and has been used for development rather than for production.

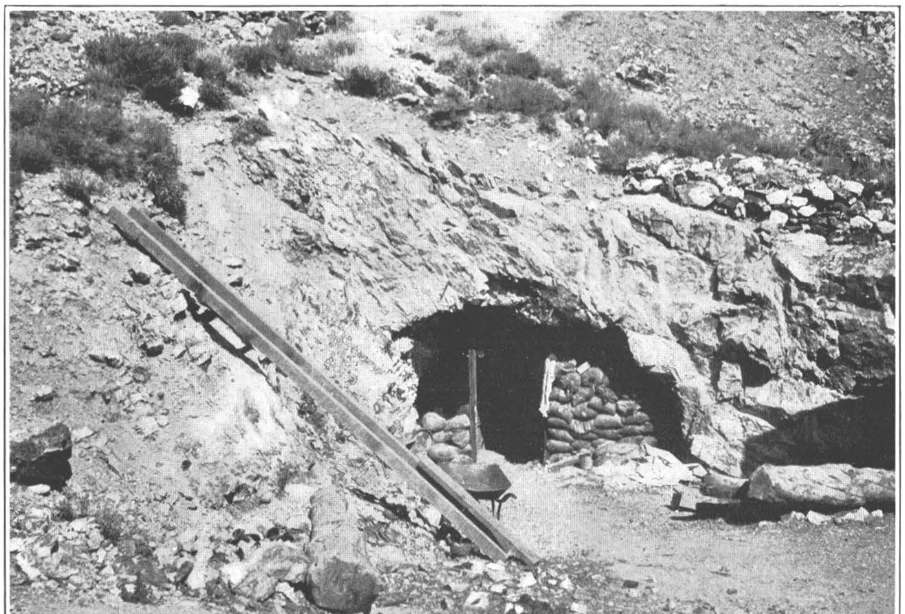
ORE IN SIGHT.

Besides the ore produced, named above, great quantities of auriferous quartz are exposed on the surface and in the underground workings. On this account examinations by engineers have been made a number of times. One of these examinations was made by Mr. George M. Maynard, of New York, through whose kindness the results obtained have been placed at the writer's disposal. The ore, it may be stated in advance of the more detailed description, occurs in lenses of quartz, which occupy a definite zone. At the main workings a large lens outcropping in the lower part of the zone has been called the Crowning Glory vein, while smaller lenses in the upper part of the zone have been called the Drinkwater vein. Between the two in the middle part of the zone are other lenses, which by some have been named the Magazine vein. The exhaustive sampling conducted by Mr. Maynard gave the measurable reserves of the underlying Crowning Glory zone at 107,370 tons with an average assay of about $5 a ton, and a total value of $537,550. The quartz thus sampled averaged 8.2 feet thick. The dumps from the Crowning Glory workings were found to contain 12,757 tons, having an average value of about $8.80 a ton and a total value of $112,340. Twenty-four boundary assays from outcrops and workings of the Crowning Glory zone, outside of the ore actually measurable, were made and gave an average value of $10.59, the average thickness of quartz sampled being

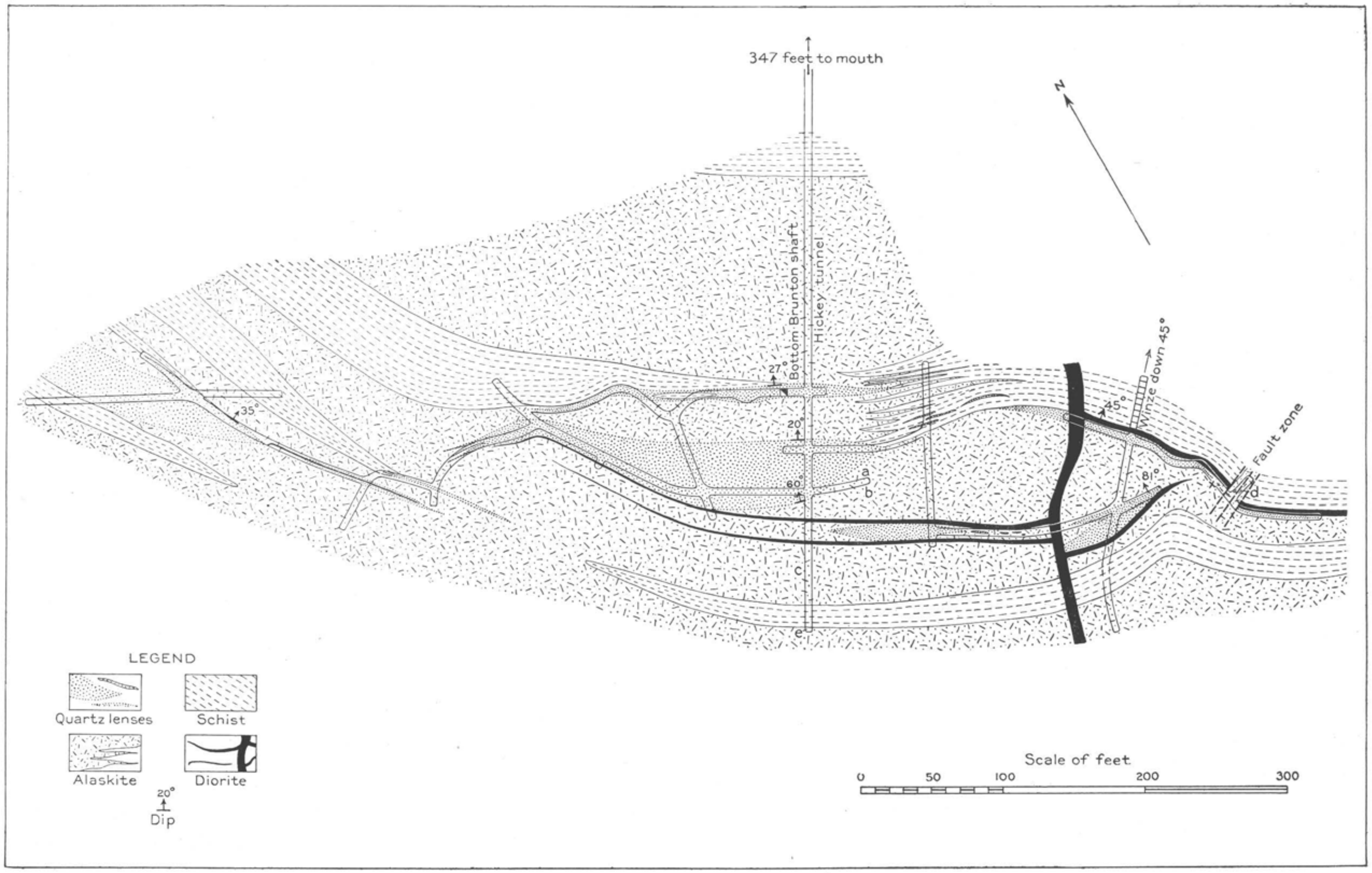


A. CROWNING GLORY LENS ZONE, DRINKWATER MINE.

Open-cut workings and mouths of tunnels.

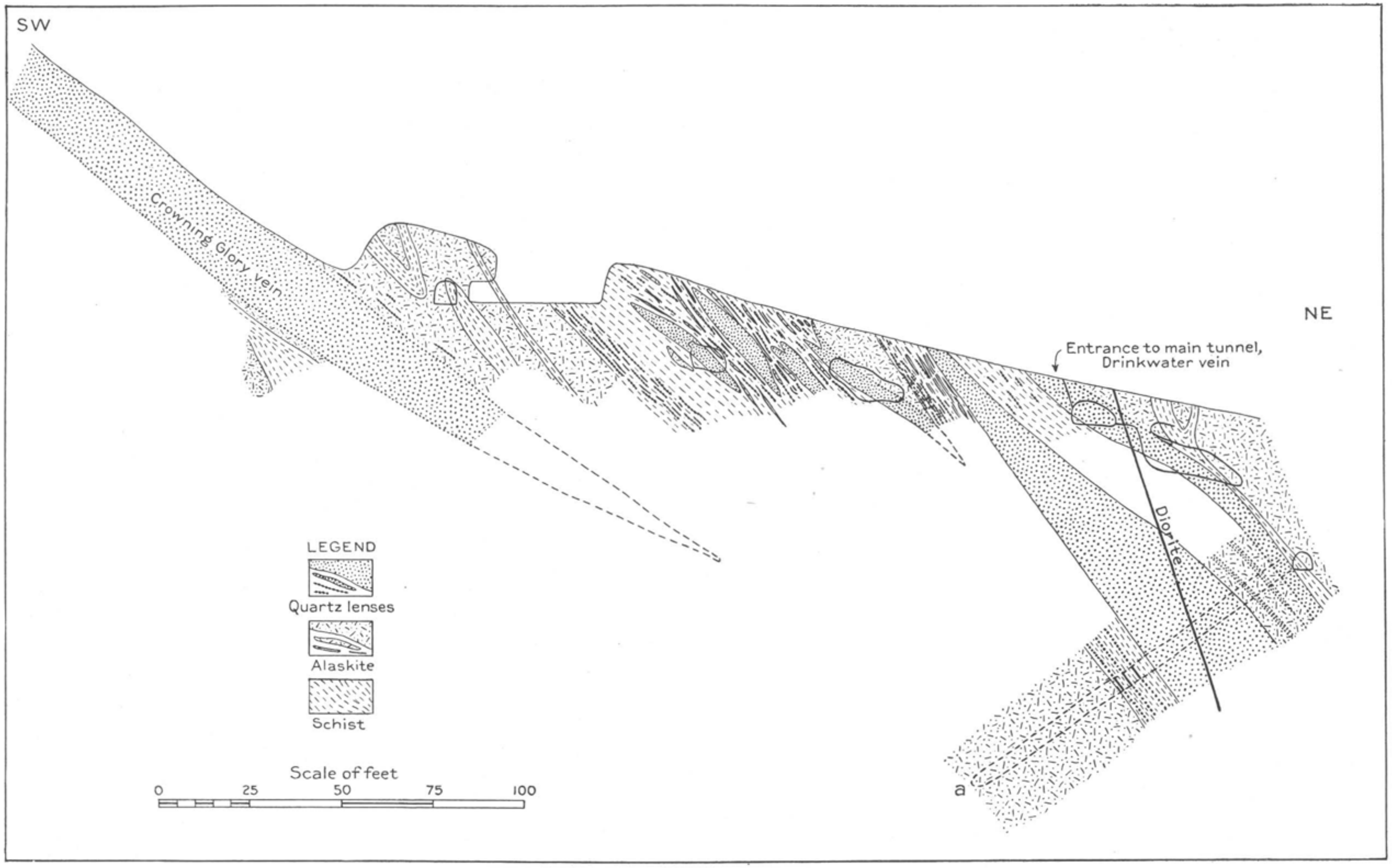


B. ENTRANCE TO UPPER WORKINGS, DRINKWATER MINE.



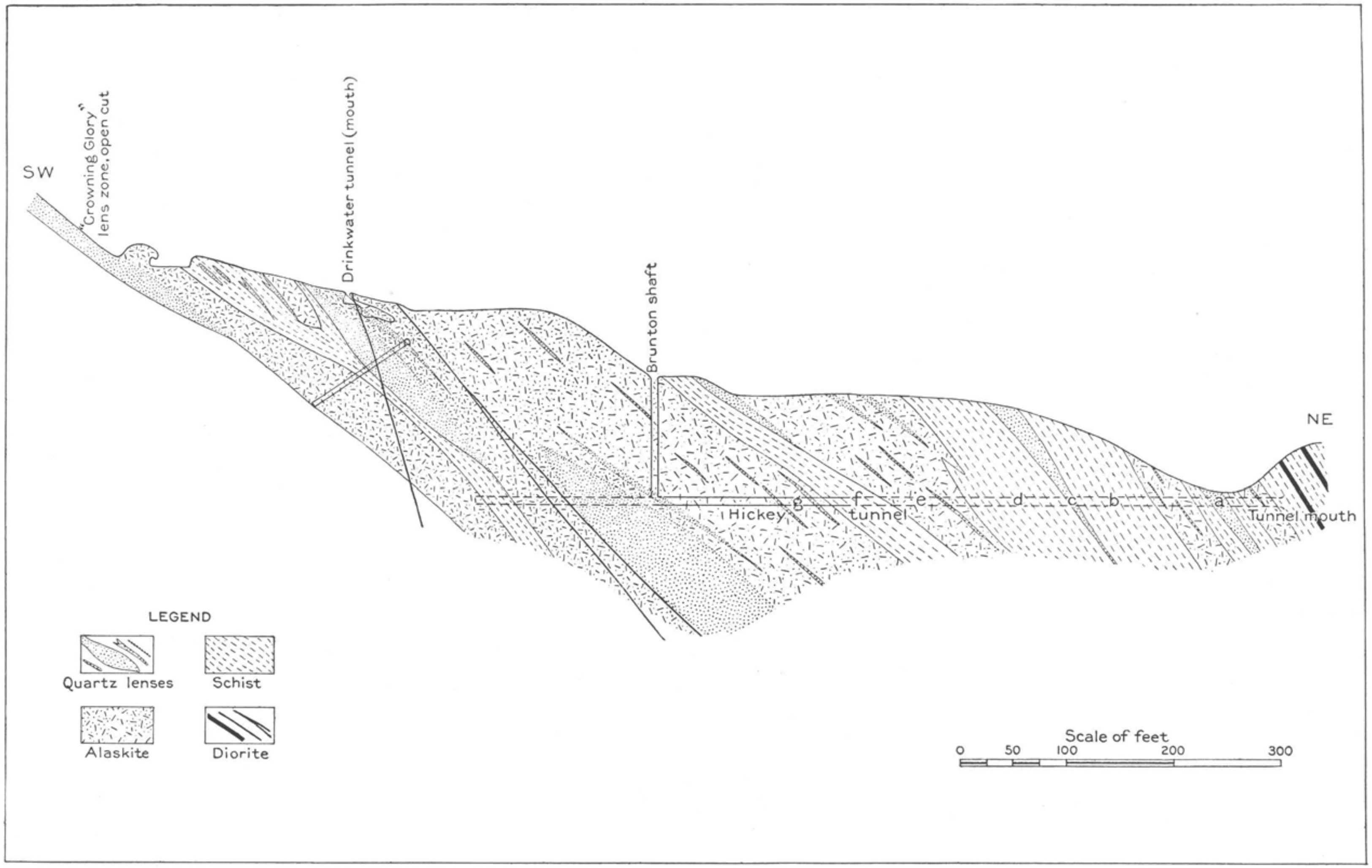
HORIZONTAL PLAN SHOWING GEOLOGY EXPOSED IN HICKEY TUNNEL WORKINGS (LOWER TUNNEL OF DRINKWATER MINE).

Shows shape and geological relations of auriferous quartz bodies.



VERTICAL CROSS SECTION OF CROWNING GLORY-DRINKWATER ORE ZONE.

Sketched from surface open cut and underground workings along line A—A′, mine map, Pl. VI. Scale, 30 feet=1 inch.



VERTICAL CROSS SECTION OF DRINKWATER MINE WORKINGS, SHOWING QUARTZ LENSES.

Taken along line A—B on plan, Pl. VI.

5.6 feet. In the intermediate or Magazine zone of lenses 12,000 tons of ore were measured, having an average value of about $4.37, giving a total value of $52,440. In the Drinkwater or upper zone the measurable reserves were computed to be 4,588 tons with an average assay value of $9.18, making a total valuation of $42,118. At the bottom of the Brunton shaft (Pl. X) the quartz lenses (which had just been cut at the time of the examination and had not yet undergone the development shown in Pl. VIII) yielded from the results of eleven general assays an average value of $9.51 for an average thickness of 7 feet. Outlying quartz lenses on this property (the Blair property, belonging to Mr. D. C. Blair, of New York) were also sampled by Mr. Maynard and showed values everywhere very similar to the above. Outcropping lenses are found here and there nearly to the top of the ridge which lies south of the mine.

Since Mr. Maynard's examination a number of years ago a considerable amount of new development work has been done which increases markedly both the measurable and the probable ore reserves. This has been done chiefly from the Hickey tunnel, and the results of these measurements are not available.

NATURE OF ORE.

The ore is a typical white crystalline quartz, which under the microscope is seen to be crowded with liquid inclusions. It sometimes contains original muscovite and more rarely small chlorite (var. ripidolite ?) crystals. In this quartz the values are chiefly gold. Silver, which is nearly always present, has an average value of about 1 per cent as compared with the gold. The gold is usually finely disseminated and in a free state, although it is also contained in scattered pyrite and rare galena, which occur sparsely through the quartz and are contemporaneous with it. Measurements have shown that these sulphides constitute about 1 per cent of the volume of the quartz. Mr. Maynard took an average sample from all his other samples procured for assay purposes, and from this separated 98 pounds of ore. From this the sulphides were concentrated and upon assay showed a value of $68.63 to the ton. The gold seems to be contained in the sulphides in a free state, since it was removed by amalgamation. Since the ore from which these sulphides were concentrated was an average of all samples taken we may roughly place its value at about $5 a ton. From a ton of such ore 1 per cent of sulphides, having the assay value above given, represents a value of only 68 cents. The remaining $4.32 or thereabouts is probably present as free gold.

The value of the quartz, however, is not regular. It is spotted, occurring in richer and poorer portions of irregular extent. Therefore certain lenses and certain groups of lenses may have a relatively high grade of ore, while others may be low grade or nearly barren. Thus, the ore now left in the mine, as is shown by Mr. Maynard's assays, has a value of $4 to $9 per ton on the average, but the ore which has been extracted and milled is said to have averaged $20 a ton. It must have been near this to give a profit under the high expense of hauling and milling. The large Chiatovich stope in the Drinkwater workings (Pl. XII) contained the richest ore and is said to have yielded values of $40 to the ton on milling. Chiefly from this stope Mr. Chiatovich took out a gross total of $196,000. Mr. Samuel Wasson, of Silver Peak, who was one of the leasers at a different period, reports having taken out a total of 3,000 tons, yielding a value of $16 to the ton on amalgamation, while the tailings contained about $7, most of which would be recoverable by cyaniding.

Besides the white vitreous quartz of the ordinary type there is a dense bluish variety, locally known as bull quartz, which, however, grades into the ordinary variety. As a rule this is held to contain less gold than the ordinary quartz, although values are practically always present, and some of this quartz contains more than some of the ordinary variety. A general sample taken by the writer and Mr. R. M. Geppert from the bluish bull quartz near the mouth of the Hickey tunnel (locality A, in Pl. X) was found by F. A. Vollmar, of Silver Peak, to contain gold, 0.00; by R. H. Officer, of Salt Lake City, to contain gold, 0.007; silver, 0.03 oz. Farther south in the same tunnel (locality C, Pl. X) similar quartz yielded F. A. Vollmar gold, 0.0025 R. H. Officer, gold, trace; silver, 0.015. This bluish quartz occurs in lenses similar to the lenses of the ordinary variety.

NATURE OF ORE BODIES.

The ore occurs in lenses of various dimensions, as seen in both horizontal and vertical plan. (See Pls. VIII, IX, and X.) Along the ore zone these lenses typically overlap. They disappear by wedging out; frequently, also, by forking or splitting into several forks, in which case the country rock comes in in layers between the quartz bands. Therefore, a series of quartz stringers in the country rock may unite laterally or vertically and widen to 3 or 4 feet of solid quartz. The result is great complexity, as may be seen in the maps of the stopes in the Drinkwater upper tunnel workings. These maps (Pl. XI, *A*, *B*, *C*) represent three sections parallel to the vein zone and separated only a few feet from one another; yet the stopes upon one section can not be identified from the maps with those upon an adjoining one. The quartz lenses seem to accompany intrusions of alaskite wherever the latter occurs on Mineral Ridge. Though they always contain gold, as determined by Mr. Maynard's assays, only in some of them is the amount sufficient to have warranted their handling. These more highly auriferous lenses are bunched in certain zones, in certain groups of each zone, and especially in certain lenses of each group. Such a bunch of lenses is represented by the main stopes in the Drinkwater tunnel workings, shown in vertical cross section in Pl. XII. A smaller bunch of lenses on the same zone is found near the mouth of the same tunnel. In general it seems that very large lenses are apt to be of lower grade than small ones.

These lenticular quartz bodies have probably their original form and have not been produced by crushing and shearing, as was at one time supposed by the writer. This is shown by the fact that their wedging out is not attended by unusual movements or shearing in the rock, and the fact that this wedging out is characteristically accomplished by a fraying near the edges and splitting into different sheets, between which lie gradually thickening wedges of country rock. Also the phenomena of splitting and reuniting as shown in the different sections (Pl. XII) is not compatible with the idea that the form is due to movement. The richest stope in the mine, the Chiatovich stope, is formed by the uniting of several smaller quartz bodies, as seen both in horizontal and vertical section.

EXTENT OF LENSES.

The Drinkwater Crowning Glory group of quartz lenses lies in a zone 100 feet or more wide, which outcrops for a mile or more along the mountain side and dies out in both directions. From this it seems probable that the zone will die out also at a certain depth, though exactly where is uncertain. Assuming that the original vertical extent of the ore zone was about the same as that shown by a horizontal section, we must conclude that the zone would probably extend downward on the dip for less than a mile—perhaps very much less—for it is evident that the upper part of the zone—how much we can not tell—has been removed by erosion.

In general the lenses and the lens zones dip northward with the formation, which is a series of thin-bedded limestones and limy slates that have been intruded and somewhat altered.

NATURE OF WALL ROCKS.

Altered limestone and limy shale.—In the stopes of the Drinkwater tunnel the wall rock is usually schist mixed with quartz and granitic material. Sometimes it is alaskite and rarely unaltered limestone. In the lower or Hickey tunnel alaskite is the commonest wall rock, although limestone and schist are frequent. The schist has been found by the writer to be derived by metamorphism from a series of thin-bedded calcareous sediments, which may be classified as blue limestone and limy shale. Sometimes these rocks, especially the limestone, occur even in the wall rock of the quartz bodies in a practically unaltered condition. Often, again, the limestone is filled with siliceous material in the form of seams, lenses, and nodules, and is thoroughly altered, chiefly by silicification. (Pl. XIII, *A*.) Sometimes, near quartz or alaskite bodies, it is altered to mica schist, which wraps around the lenses of quartz or alaskite. Occasionally the microscope shows, mixed with the finely crystalline calcite of the limestone, green hornblende, epidote, quartz, and feldspar as products of metamorphism.

On the road in the canyon leading up to the Drinkwater mine a number of massive marble beds as much as 60 feet thick are intercalated with these dark-blue thin-bedded schistose slates. (Fig. 1.)

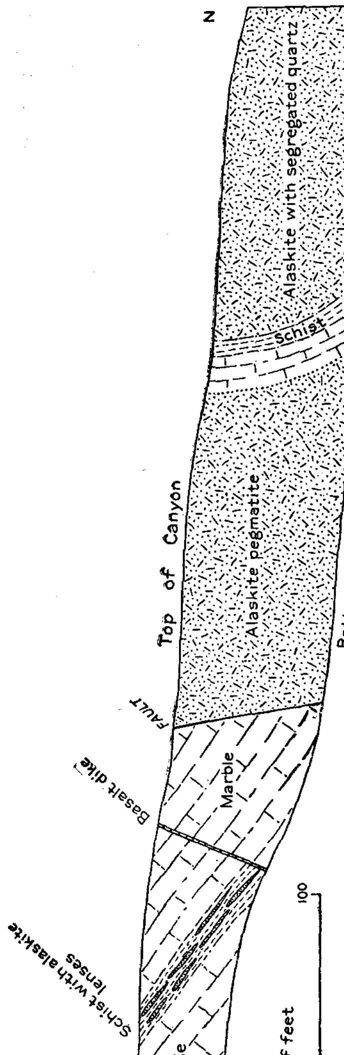


FIG. 1.—Sketch section in canyon wall below Drinkwater mine. The asterisk (*) indicates alaskite dike which is the subject of Pls. XIV and XV.

Alaskite.—Alaskite occurs in the mine workings, as shown in the figure, in about the same forms as the quartz lenses. The same facts are displayed by the outcrops. (Fig. 2.) The shape of these lenses is original, like that of the quartz lenses, and the same proofs are at hand. Thin intercalated sheets of alaskite often unite to form large lenses. In making a certain surface cross section (fig. 3) it was found that alaskite lenses which did not cross the section line were 2 feet in thickness at a distance of 10 feet from the line and became 20 or 30 feet thick at a distance of 100 feet. As seen on the surface the alaskite lenses are somewhat larger than those of quartz. These masses of alaskite and quartz have been intruded into the bedded limestone and are generally intercalated in the strata in large and small sheets, though they are in places cross cutting. The intruded sheets vary in thickness from many feet to the tenuity of a sheet of paper and are in places interlaminated with thin plates of schist, like the leaves of a book.

The alaskite has most frequently a typical granular structure like that of granite. In places it is fine grained or aplitic. Elsewhere it is coarse and passes into pegmatite, or it is fine grained or medium grained and is banded, possessing what may be designated as an original gneissic structure.

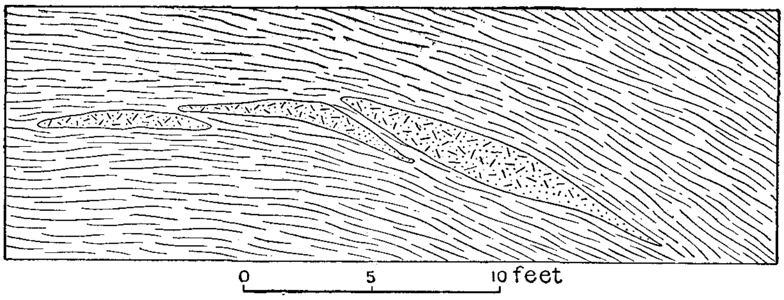
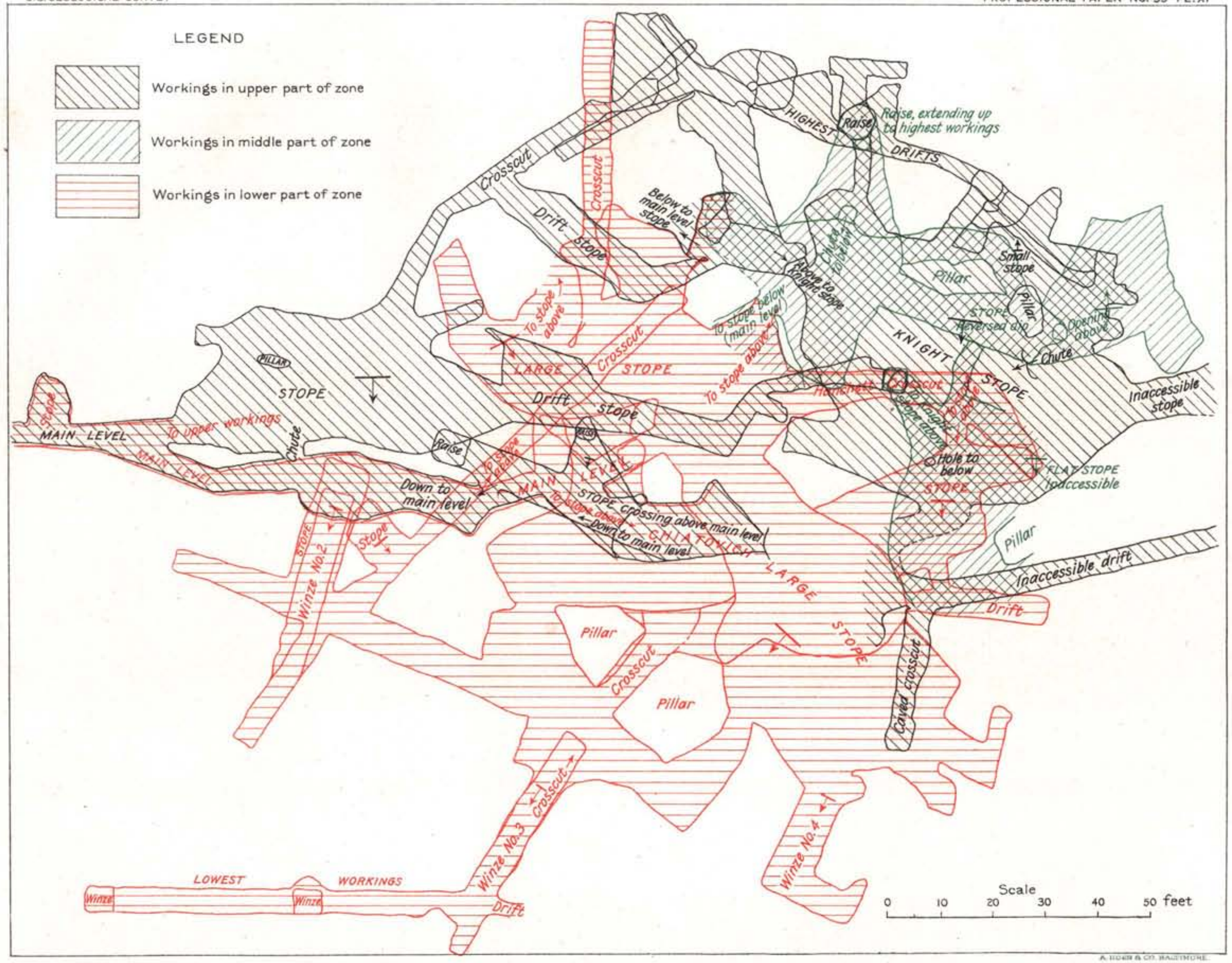


FIG. 2.—Vertical sketch section showing lenses of siliceous alaskite (passing into quartz) in schist (altered shaly limestone), from surface at Blair mines.

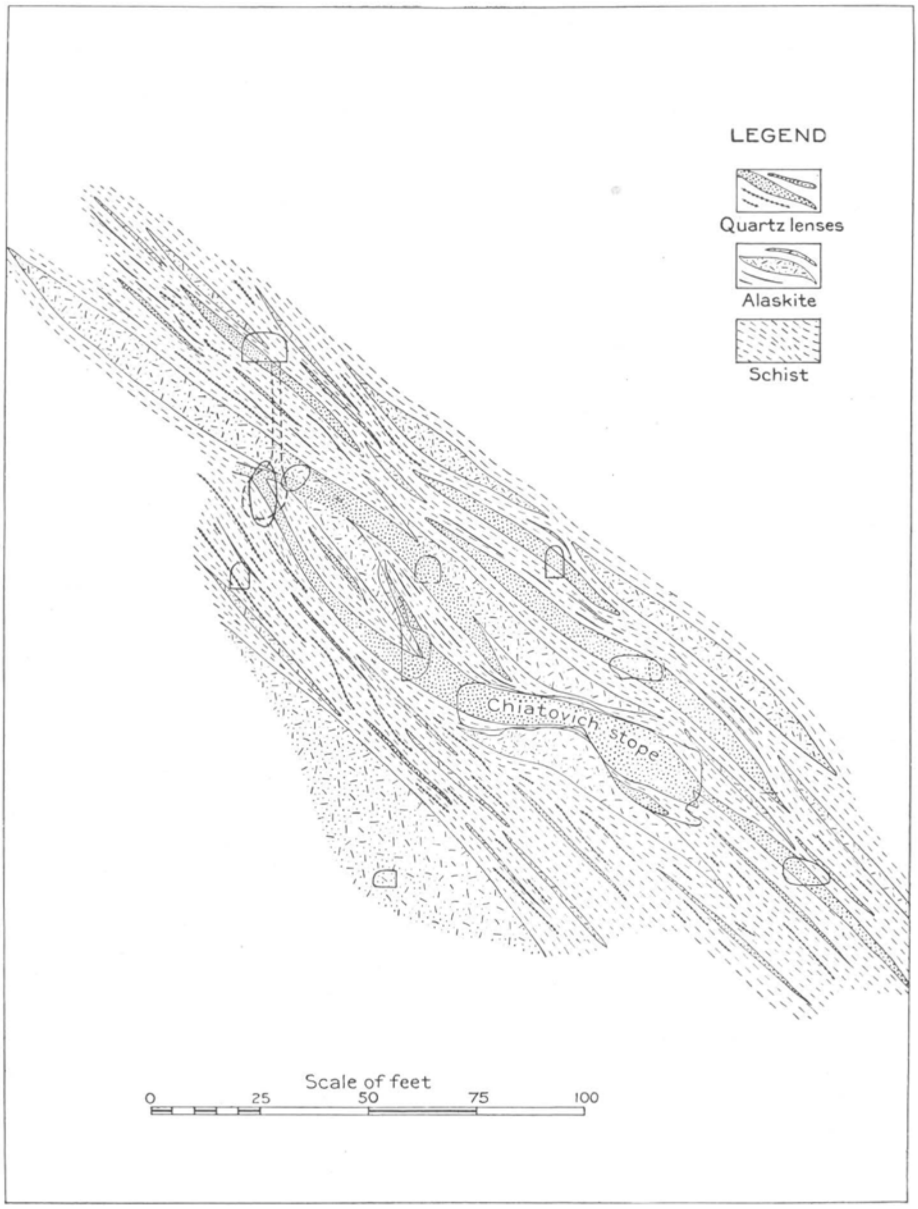
Mineralogically the rock consists of quartz and feldspar, including orthoclase, microcline, and a striated feldspar, which is sometimes an orthoclase, sometimes albite (or oligoclase-albite). Muscovite is an accessory, usually of small amount and in small flakes, although occasionally it becomes important. An occasional phase contains biotite and becomes therefor a siliceous biotite granite, but this phase passes by transition into alaskite and is unimportant in amount.

Microscopic study of the alaskite from these mines brings out the fact that the crystallization was rather slow and interrupted and is represented by more or less distinct generations. For example, a specimen from the Hickey tunnel shows a first generation consisting of coarse quartz, microcline, orthoclase, and an undetermined striated feldspar. The striated feldspar contains some fine muscovite along the cleavage lines. Similar muscovite is present in some of the orthoclase and quartz grains, while others are clear, as if these minerals consolidated at different periods. The microcline is always clear. The second generation of crystals occurs between these large grains and consists of a fine granular aggregate of the same minerals, including quartz, orthoclase, microcline, and oligoclase-albite, all fresh, with



A. HOEN & CO. BALTIMORE.

MAP OF CHIEF STOPE WORKINGS, DRINKWATER MINE.



VERTICAL CROSS SECTION OF CHIEF STOPE WORKINGS, DRINKWATER MINE.

numerous grains of calcite, which may also be contemporaneous. Fresh oligoclase-albite in one case was noted to contain an irregular geode-like inclusion of calcite. A very little chlorite is present in this second generation. A similar succession is seen in another specimen from the Hickey tunnel, but it is interesting that in this second case the amount of material of the second generation is very trifling, the rock being almost wholly made up of the first generation. Where this second generation does occur, however, the fresh quartz and feldspar include calcite rhombs and crystals of zircon. Another specimen from the mine shows a still more interesting succession of generations. The first generation consists of feldspar, chiefly idiomorphic. The interstices between the feldspar crystals are filled with allotriomorphic quartz, which sometimes cuts across the feldspar, following cracks.

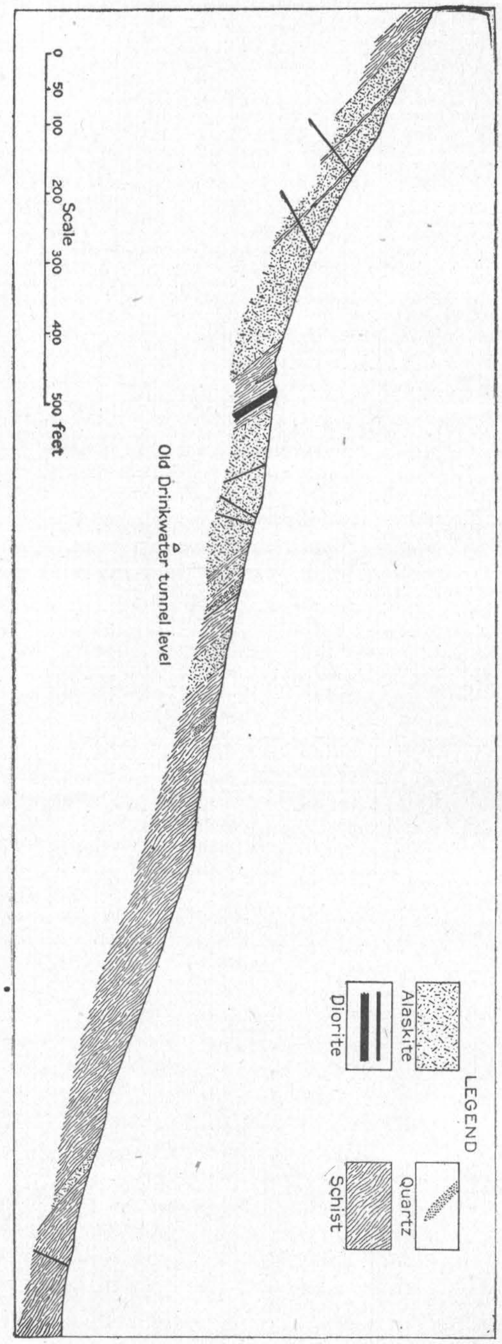


FIG. 3.—Vertical surface section at Blair mines parallel to section A—B, (Pl. X), and about 260 feet west of it.

As a rule the quartz in these rocks is both contemporaneous and slightly later than the feldspar, the two relations being shown almost always in a single slide. The orthoclase sometimes incloses quartz grains, and quartz may be found included in microcline as well as microcline in quartz, such cases showing contemporaneous crystallization. The quartz is in places segregated into irregular bunches, or into chains or strings more or less vein-like in appearance, though in the same sections the quartz and feldspar are intergrown and are practically contemporaneous.

The alaskite sometimes contains original pyrite and frequently small zircons. Both the quartz and the feldspar are characteristically filled with tiny liquid inclusions.

An interesting study is afforded by the muscovite in the rock. This grades in size from the larger flakes, always

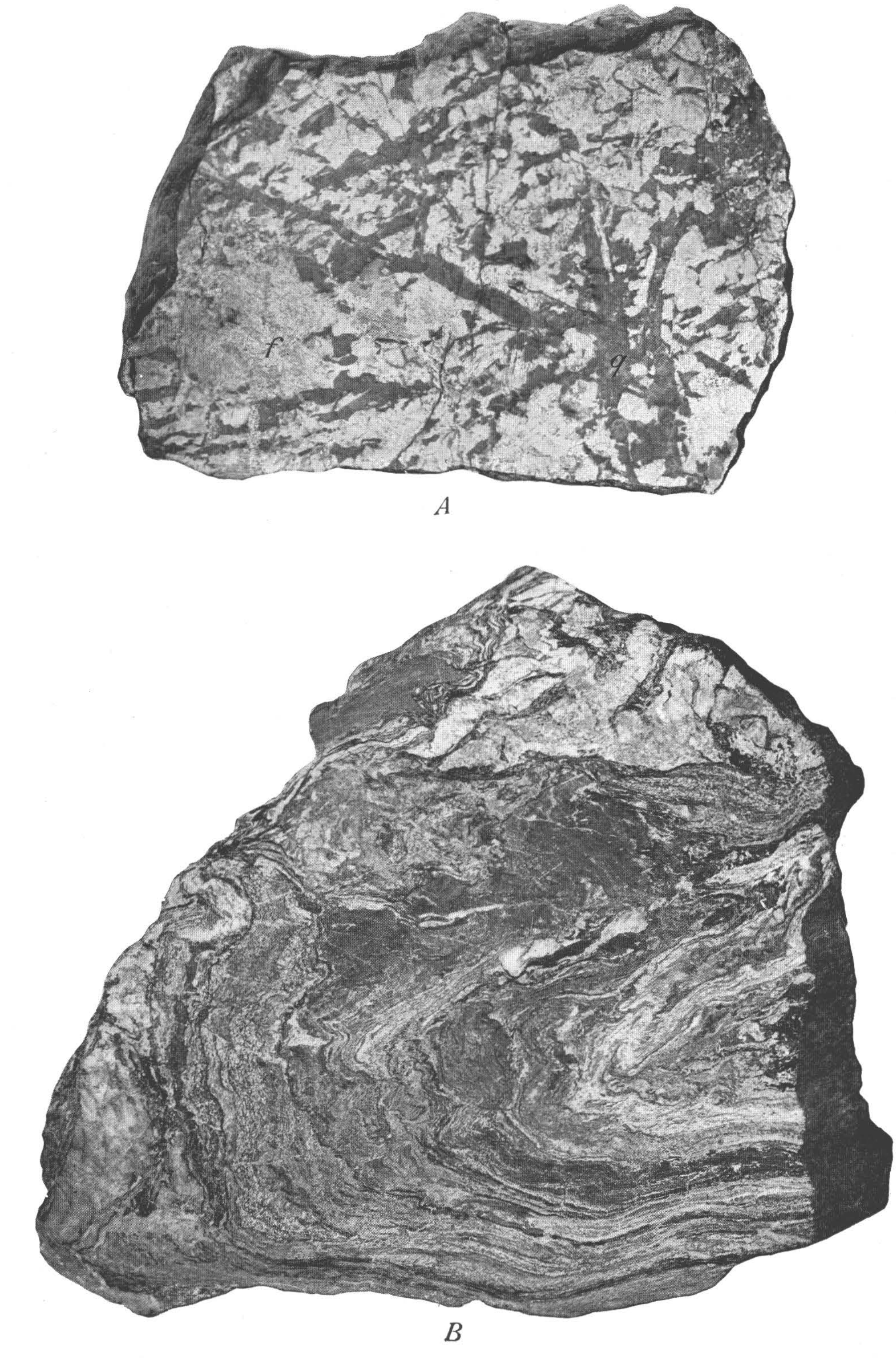
PLATE XIII.

PEGMATITE QUARTZ FORMING VEINLETS IN EARLIER CRYSTALLIZED FELDSPAR.

A, Reproduction of photograph, actual size, of polished specimen (No. 17) of alaskite pegmatite from a feldspathic portion of the Homestake veins. The light portions (*f*) are feldspar (microcline); the dark portions (*q*) are quartz. The quartz, while an essential rock constituent and an essential portion of the rock fabric, is of later crystallization than the microcline, in which it lies in part veinwise, in part in isolated grains.

GNEISS DUE TO INJECTION OF LIMESTONE SHALE BY ALASKITIC MATERIAL.

B, Reproduction of photograph, actual size, of polished specimen (No. 16) from the wall of the Crowning Glory vein. Shows gneiss produced by interposition of numerous thin sheets of alaskitic material (quartz and feldspar in varying proportions) between the laminæ of limestone shale, with attendant metamorphism of the latter.



A. PEGMATITE QUARTZ FORMING VEINLETS IN EARLIER CRYSTALLIZED FELDSPAR.
B. GNEISS DUE TO INJECTION OF LIMESTONE SHALE BY ALASKITIC MATERIAL.

recognized by the name of muscovite, to successively smaller proportions till it sinks gradually to the fine fibers which are ordinarily called sericite. Microscopic study, however, in many, probably most, cases shows a community of origin for the materials of different sizes, so that the writer will refer to all as muscovite.[a]

The coarser muscovite in some places occurs in grains of sizes equal to those of the grains of other minerals and is intergrown with them. As a rule, however, it is smaller than the quartz and feldspar, and occurs in characteristic flakes included in them, but especially in the feldspar. When it becomes very small, the feldspar which incloses it comes to have all the appearance of a sericitized feldspar in which the muscovite has arisen by a process of alteration. Indeed, in many cases the fine muscovite is so arranged, being parallel with the cleavages and even occurring along fractures in the feldspar, that the conclusion that it is an alteration product is inevitable, although the transition is perfect between this and increasingly coarser types and all seem to have a common origin. It is characteristic that in such a rock certain feldspars may thus contain fine muscovite, while adjoining ones are perfectly clear. The microcline of the rocks is almost always clear. This mineral, as is well known, is one of the last to crystallize from a granitic magma; indeed, it is known to be frequently later than quartz.[b] In several cases it has been noted that striated feldspar in a given thin section was considerably altered to fine muscovite, while the orthoclase was less altered and the microcline not at all. In such cases the secondary muscovite is not always fine, but becomes coarser and approaches the ordinary granitic variety, while retaining its relation to cracks and cleavages in the feldspar. In this connection the description already given of a phase of alaskite consisting of two generations may be recalled where the older generation of feldspars, which consisted of striated feldspar, orthoclase, and microcline, had been considerably attacked and altered to fine muscovite fibers—the striated feldspar most, the orthoclase less, and the microcline not at all; while the later generation, consisting of all these feldspar species, namely, microcline, orthoclase, and oligoclase-albite, were quite free from alteration, though they were associated with some contemporary muscovite. In another specimen from the Hickey tunnel the orthoclase was found to be considerably altered to fine muscovite, while the striated feldspar and microcline were fresh.

The conclusion from these facts is that the muscovite in the rock (which is usually of a fine variety) has been formed chiefly by alteration of the feldspar at stages of partial crystallization. Thus the early feldspars are altered, the later ones not. The crystallization of muscovite in general seems to be dependent upon the action of fluorine, and it may be that this factor determines whether in a given magma or solution an orthoclase molecule is formed or a muscovite molecule with a little quartz. Similarly, it is probable that the already formed orthoclase molecule may be easily decomposed to muscovite and quartz by the action of fluorine, with the help, perhaps, of other agents. Therefore feldspars in the vicinity of mineral veins are frequently muscovitized or sericitized. In the case now under consideration the alteration of those feldspars which formed first from the crystallizing magma has probably been accomplished by excess of fluorine in the residual granitic fluid. The alteration is therefore endomorphic.[c]

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[a] See Spurr, J. E., Geology of the Tonopah mining district, Nevada: Prof. Paper U. S. Geol. Survey No. 42, p. 232.

[b] Harker, Alfred, Petrology for Students, p. 28.

[c] Spurr, J. E., Quartz-muscovite rock from Belmont, Nevada: Am. Jour. Sci., vol. 10, Nov., 1900.

Besides the muscovite or sericite which has this origin it appears that some fine muscovite (sericite) may also be due to alteration subsequent to the crushing which the rock has frequently undergone (though none of the occurrences previously described were in crushed rocks). In certain places fine muscovite is seen to haev formed along a shear crack. In some cases, therefore, the portion of this mineral produced by endomorphic action may not be readily distinguishable from that due to metamorphism. Since the outcropping alaskite typically shows feldspars which are largely fresh, it is probable that weathering is unimportant as an additional factor in this change.

Diorite.—The limestone, limestone schist, alaskite, and quartz, which constitute the main mass of the rocks in the vicinity of the Drinkwater mines, are cut through by a considerable number of rather thin diorite dikes. These dikes frequently cut across the veins, without suffering any great deflection. Sometimes, however, they have followed the veins, these being in such cases along the zones of least resistance. The diorite is frequently intruded between the vein and its wall and so itself comes to form a vein wall. This, for example, is repeatedly found in the Hickey tunnel (Pl. VIII). Occasionally the vein is split by the diorite, which lies in the middle as a parallel intrusive sheet (fig. 4).

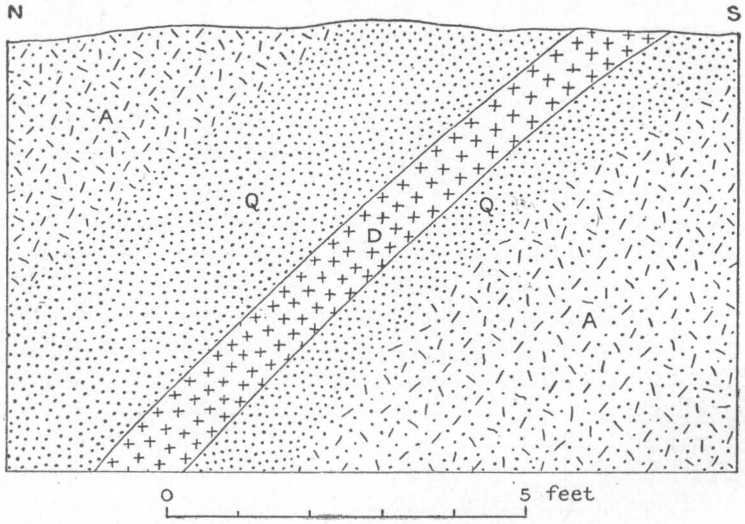

FIG. 4.—Vertical section in drift, Hickey tunnel, showing intrusive diorite splitting earlier quartz lens. A, Coarse alaskite (country rock of quartz); Q, quartz; D, diorite.

For field use the term greenstone is more descriptive of this rock than the term diorite, for the rock is generally entirely decomposed and is now an aggregate of secondary products, chiefly chlorite, calcite, pyrite, quartz, sericite, zeolites, etc. Originally the rock was composed chiefly of hornblende and feldspar, now recognized by pseudomorphs consisting of decomposition products. Ilmenite is abundant.

RELATION OF QUARTZ AND ALASKITE.

The typical quartz and typical alaskite form two ends of a rock series between which there is every gradation. All these intermediate stages are abundantly represented in and around the Drinkwater mines. The alaskite and the quartz have the same general appearance, and even on the outcrop it often requires close scrutiny to distinguish them. The alaskite becomes quartzose (both in the mines and on the surface), and passes from an even, granular condition to one characterized by large and small irregular or elongated blotches and veinlets of quartz, and thus gradually to typical quartz veins. Every vein or lens thus far mined or prospected shows, in places, mixed with the quartz, considerable feldspar, though in general it is found that with the incoming of feldspar in the ore body the values fall off quickly. The auriferous quartz in the mine, in the surface workings, in the Drinkwater tunnel, and in the Hickey tunnel often runs off laterally along the drifts into alaskite, chiefly pegmatitic. An example of this is found in the east end of the Hickey tunnel workings, as shown in the locality marked x in Pl. VIII. Here a strong quartz vein begins to contain scattered feldspar to the eastward, and farther on the feldspar begins to encroach more and more upon the quartz, until it becomes practically a pegmatite, which, however, contains irregular segregated bunches of solid quartz up to 2 or 3 feet in diameter. It is here demonstrated that the pegmatite and quartz masses are contemporaneous and are one and the same body. Sometimes, however, a stringer of quartz can be seen cutting across the pegmatite, showing that it was the last mineral to crystallize. This pegmatite consists essentially of quartz and feldspar and occasionally muscovite, and very rarely biotite. Pyrite, apparently arsenical, occurs in the pegmatite and more frequently in the quartz.

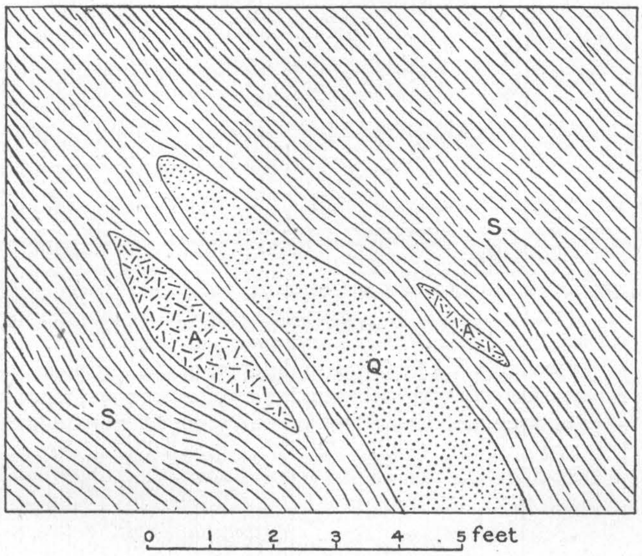

FIG. 5.—Vertical sketch section of surface open cut on Drinkwater ore zone, a short distance south of the mouth of the Drinkwater tunnel, showing lenses of quartz and alaskite. Q, Quartz (ore); A, alaskite (quartzose); S, schist (altered shaly limestone).

The general conclusion is that in and near these mines a series of fissile shales and thin-bedded limestone has been invaded by a very siliceous granitic intrusion, which has locally metamorphosed the sediments to schists. The quartz has plainly the same origin and nature as the alaskite, both being siliceous phases of a granitic magma. Both are intrusive, in lenticular elongated bands, chiefly along certain zones in the strata (fig. 5).

The exact relation between the quartz and alaskite may be understood by reference to the microscopic studies described under the head of Alaskite (p. 41). It is there shown that the crystallization of the intrusive granitic fluid has been slow and interrupted, and that the order of crystallization has been the same as that ordinarily

PLATE XIV.

ROCK SPECIMEN SHOWING ARRANGEMENT OF QUARTZ AND FELDSPAR IN ALASKITE DIKE.

Reproduction of photograph, actual size, of polished specimen (No. 172) of fresh and uncrushed alaskite from a dike in marble in a canyon below the Drinkwater mine (see fig. 1). The specimen shows the full width of the dike. The minerals are almost exclusively quartz and feldspar. Note the medium-granular structure, which locally (as in the upper part of the specimen) becomes more or less banded parallel to the dike wall, with the separation out of blotches and bands of magmatic quartz. In the lower end of the figure the feldspar (light colored) shows idiomorphic outlines against the magmatic quartz which runs up the right-hand side of the figure. The area within the rectangle is presented enlarged in Pl. XV.

ROCK SPECIMEN SHOWING ARRANGEMENT OF QUARTZ AND FELDSPAR IN ALASKITE DIKE.

observed in granitic rocks, namely, that the feldspars have crystallized first and the quartz last. There has been a great deal of difference, however, in the periods of feldspar crystallization, two distinct generations being easily recognized. Complete crystallization was evidently accomplished slowly, so that in many places the magma became first transformed to a mass of contiguous feldspar crystals whose interstices were filled by the residual granitic fluid. From this fluid there was crystallized out quartz, which occupied the interstices and completed the crystallization of the alaskite. Gathering together in larger bodies, the quartz formed solid masses, veins and lenses, of all sizes, ranging from particles determinable only under the microscope to lenses 8 or 10 feet thick and 100 or more feet in lateral extent. Such lenses sometimes occupy or follow fractures which were made in the semiconsolidated alaskite, or (where the solutions have traveled some little distance from their points of origin) they have formed veins in alaskite which was at the time practically entirely consolidated.

Microscopic demonstration of this origin is found by examination of some rocks from this mine, as has been already partially referred to. For example, a specimen from the Hickey tunnel shows a first generation of crystallization, consisting of fine allotriomorphic granular feldspar with quartz, the feldspar consisting of orthoclase, albite, and microcline. This first generation has been strained and broken, and the rifts are filled with granular or retiform unbroken quartz containing two idiomorphic feldspar crystals; one fully contemporaneous with the quartz, the other, though entirely inclosed within it, broken, and containing a quartz veinlet, marking it as a slightly earlier mineral. Other cases showing the same thing with slight variations were observed elsewhere. In the canyon below the Drinkwater mine there was examined a dike of alaskite 6 inches in thickness, which is intrusive into marble (see fig. 1). Both in the hand specimens of this dike and under the microscope the passage is consecutively shown from a moderate-grained uncrushed alaskite to little bunches and veinlets of segregated quartz, and even to larger quartz masses. These quartz streaks are apt to be elongated parallel to the sides of the dike (Pls. XIV and XV). A thin section shows feldspar (mainly orthoclase, with some striated feldspar) and quartz in about equal proportions. The feldspar has a definite tendency to group itself into thin parallel layers with alternating layers in which quartz is predominant. Thus an original gneissoid structure is obtained. The feldspar crystals are idiomorphic to hypidiomorphic; the quartz is allotriomorphic and distinctly later, but occurs in grains similar in size to the feldspar crystals.

INFLUENCE OF DIORITE ON VALUES.

The diorite dikes extend along the quartz lenses or cut them, as previously stated, but are of distinctly later age. They have sometimes been held to have an important connection with the rich ores. On this account the question was examined into carefully by the writer, in company with Mr. R. M. Geppert, of Denver, who was at that time engaged in a general sampling of the mine.

In the Hickey tunnel, where the diorite is more conspicuous than in the upper workings, it was noted that where it forms the wall of the quartz the quartz is traversed by parallel cracks for a few inches at its contact with the dike, these cracks being also parallel to the contact. Sometimes this cracked zone is a foot or

PLATE XV.

ROCK SPECIMEN SHOWING DETAILS OF ARRANGEMENT OF QUARTZ AND FELDSPAR IN ALASKITE DIKE.

Portion of polished specimen of alaskite dike (Pl. XIV) enlarged 3 diameters by photography and retouched to show the relative distribution of quartz and feldspar in the rock fabric. The light is feldspar (*f*); the dark, quartz (*q*). The texture varies from medium granular to fine pegmatitic.

ROCK SPECIMEN SHOWING DETAILS OF ARRANGEMENT OF QUARTZ AND FELDSPAR IN ALASKITE DIKE.

more thick. Along these cracks there is generally a dark substance which has penetrated the quartz from the cracks. The same dark coloring is noticeable in the quartz at the contact of the dike. Along such cracks pyrite is also found, sometimes forming only a crust and not filling the crack completely. The origin of the pyrite is evident, for the diorite itself is decomposed and richly spotted with pyrite which has formed at the expense of the iron silicates in the rock. This pyrite in the decomposed diorite, as might be expected, has not been shown to contain important values. To test the question as to whether the cracked quartz near the diorite had been enriched, a general assay sample of this quartz was taken by the writer and Mr. Geppert. This yielded to Mr. Vollmar gold 0.36 ounce; to R. H. Officer, gold 0.315 ounce, silver 0.475 ounce. As this sample was from a portion of a quartz ore lens, the value indicated is certainly not more than usual—in fact, probably somewhat below the average. The writer learned that Mr. Geppert found in another locality, as the result of his assays, that such a dark zone of quartz near the diorite contact, cracked and containing secondary pyrite, carried only about one-fourth as much gold as the unsheeted quartz below. In this case, at least, there was no enrichment, but probably an impoverishment. In other cases this cracked and pyritized zone runs higher than the main body of quartz, when it usually carries secondary galena, a mineral which is a highly favorable indication of gold values in this mine, whether it is of primary or of subsequent origin. In a small subsequent veinlet formed along a crevice near the diorite in the Hickey tunnel the writer found that the gangue material was mostly coarse calcite, probably derived from the decomposed diorite, with some quartz and green chlorite. The calcite contained considerable contemporaneous pyrite and galena. These occurrences are, however, exceptional, and are of little or no importance in considering the general values of the deposits. No diorite occurs in intimate connection with the rich ores which have been removed from the upper Drinkwater workings. It has been reported, however, that in these older workings the richest ore (now removed) came from near the hanging wall.[a] This report, in connection with the occurrence of richer subsequent ore near the hanging wall of the Mary mine (see p. 54) and other facts, suggests that these richest ores of the Drinkwater may have also been in part subsequent, though not dependent upon the diorites.

It seems from the facts presented that the fractured zones in the quartz, which have probably been formed by the intrusion of the diorite, have served simply as channels along which the original values in the quartz have been somewhat concentrated in some places at the expense of others.

VALUES IN WALL ROCKS.

Values in alaskite.—From a crosscut into the foot wall beneath the stopes in the upper Drinkwater tunnel workings a number of average samples were taken for assay by Mr. R. M. Geppert, and six of these were assayed by Mr. F. A. Vollmar. They were mostly solid alaskite, with some mixed alaskite and schist. Three of these samples contained 0.01 ounce of gold, two contained 0.03 ounce, and one contained 0.10 ounce.

In another crosscut from the Drinkwater stopes, the Hanchett crosscut, samples were taken from alaskite containing some small bunches of quartz. Four of

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[a] Report of the Mineralogist of the State of Nevada [Dr. A. E. White] for 1869 and 1870; published 1871.

these samples contained a trace of gold, one contained 0.05 ounce, one contained 0.06 ounce, and one showed no gold whatever.

At the lower end of the winze shown in Pl. IX, locality a, a general sample was taken of the harder portions of the alaskite pegmatite. This yielded to R. H. Officer & Co., gold, trace; silver, 0.025 ounce.

A series of general samples were taken by the writer and Mr. Geppert in the Hickey tunnel. At the point marked a in Pl. VIII the rock is a hard, fresh alaskite. On one side of the drift there is no quartz and the rock is shown by the microscope to consist of quartz and feldspar only, the texture varying from granitic to fine pegmatitic. The feldspar, which is largely finely striated, has an idiomorphic tendency, showing a crystallization earlier than that of quartz. A general sample of this yielded F. A. Vollmar, gold, trace; R. H. Officer, gold, 0.005 oz.; silver, 0.025 oz. On the other side of the drift in the same rock are small bunches of segregated quartz, often feldspathic, containing considerable pyrite and some galena, plainly contemporaneous and inclosed in good-sized separate bunches, up to the size of hazelnuts, in unbroken vitreous quartz. This locality is marked b in Pl. VIII. One such small quartz bunch was highly pyritiferous and contained only a few, pounds in all. This bunch gave Mr. F. A. Vollmar, gold, 4.15 oz.; R. H. Officer, gold, 3.810 oz.; silver, 0.840 oz.

At locality c, Pl. VIII, the rock is hard alaskite, consisting of quartz, orthoclase and striated feldspar. The microscope shows that it has undergone a very slight crushing. A general sample gave F. A. Vollmar, gold, trace; R. H. Officer, gold, trace; silver, 0.025 oz. At locality d, Pl. VIII, the rock is pegmatitic quartz, a sample of which yielded R. H. Officer, gold, trace; silver, 0.015 oz. A general sample of the less quartzose pegmatite in the same place gave gold, 0.005 oz.; silver, 0.017 oz. At locality e, Pl. VIII, the rock is alaskite with some small segregated quartz veins. Exceptionally some biotite is present; otherwise the rock contains quartz, fresh orthoclase, and microcline. A general sample of this gave F. A. Vollmar, gold, 0.0025 oz.; R. H. Officer, gold, trace; silver, 0.10 oz.

In the adit portion of the Hickey tunnel workings, at locality, e Pl. X, the rock is alaskite, generally coarse, with some small lenses of hard quartz and some layers of schist. A general sample gave F. A. Vollmar, gold, 0.06 oz.; R. H. Officer, gold, 0.06 oz.; silver, 0.095 oz. At locality g, on the outer edge of a large alaskite mass, a general sample gave F. A. Vollmar, gold, trace; R. H. Officer, gold, trace; silver, 0.020 oz.

Values in limestone schist.—In the Hickey tunnel adit, locality b, Pl. X, a general assay was taken of limestone slightly altered, with quartz seams. This yielded F. A. Vollmar, gold, 0.0025 oz.; R. H. Officer, gold, trace; silver, 0.020 oz. Farther in the tunnel, at locality d, Pl. X, is a rather massive bedded, altered limestone, consisting under the microscope of fine crystalline calcite with some secondary hornblende, epidote, quartz, and feldspar. A general sample gave F. A. Vollmar, gold, 0.0075 oz.; R. H. Officer, gold, 0.020 oz.; silver, 0.045 oz. Still farther in the tunnel, overlying the main alaskite mass in which the Hickey tunnel lateral workings lie, locality f, Pl. X, is a fine-grained limestone, shown by the microscope to contain scattered grains of originally detrital quartz. Of this a general sample gave F. A. Vollmar, gold, trace; R. H. Officer, gold, trace; silver, 0.030 oz.

FOLDING AND FAULTING.

Around the Drinkwater mine group the thin-bedded and schistose limestone and slates are folded and contorted on a minor scale, but have a general northeasterly dip. No large folds are noticeable. Some of this minor folding is probably subsequent in part to the intrusion of alaskite and quartz, and the disturbance may in general have accompanied the intrusion. Local reversed dips in the quartz lenses may be due to folding. Faulting of alaskite and quartz on a small scale may be seen in the outcrops (fig. 6). Small faults are also determinable underground, as shown in the east end of the Hickey tunnel workings (Pl. VIII), where quartz and alaskite are displaced. The slates have in many places become schistose and contain numerous laminæ of quartz and alaskite, and the resultant rock is usually contorted. In many cases these contorted laminæ, representing the siliceous intrusion, may be interpreted as veinlets which have followed the laminæ of the folded slate, but some of the contortions hardly admit of this explanation and are probably subsequent to the intrusion, as is indicated by the accompanying minute faulting which displaces the quartz-alaskite sheets.

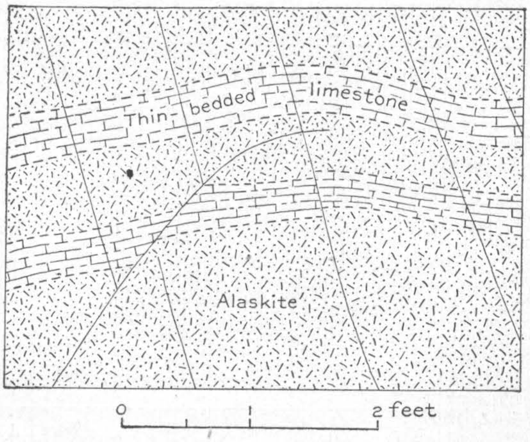

FIG. 6.—Sketch of vertical outcrop, Drinkwater Canyon, showing dying out of fault.

CRUSHING.

All the rocks under discussion, including the altered limestone and slate and the alaskite, quartz, and diorite, are frequently more or less crushed, as has been definitely determined by microscopic study. On the other hand, much of the material has not been crushed. All the specimens used to determine the composition, texture, and structure of the alaskite and quartz in the foregoing descriptions were taken from uncrushed rock. The amount of crushing varies from mere straining to complete granulation.

Remarkably little crystallization or metamorphism followed this crushing, and no subsequent vein action can be detected. In granulated alaskite the original minerals—chiefly quartz, orthoclase, and microcline—are as fresh as in the uncrushed specimens. Occasionally a little sericite has been developed along strong fractures, and even a little chlorite. Calcite in small veinlets is of more frequent occurrence and has evidently been transferred from the limestone to the crevices in the crushed alaskite. Where the quartz has been crushed, microscopic study usually shows that the pyrite also has been crushed. It is therefore beyond doubt that the mineralization preceded the crushing.

SUBSEQUENT ORES.

No decided enrichment of the ores by oxidation can be established. It is true that, so far as can be determined, the ores in the upper tunnel seem to have been locally richer than any found in the lower tunnel, but, as has been already noted, this localization and enrichment has no evident connection with the surface, but takes place irregularly along the surface and is probably an original difference. The character of the ore affords no ground for supposing any great concentration by surface waters, since the values are contained in finely disseminated gold and a small quantity of auriferous sulphides scattered through a mass of vitreous quartz. The minerals containing these values are not easily reached or attacked to any great extent by percolating waters. The quartz bodies are traversed by strong cross fractures, but no shoots corresponding to these are known, indicating that waters circulating along these subsequent fractures have had very little effect in redistributing values.

In the upper workings small specimens of cerussite (lead carbonate) are reported, evidently the result of the alteration of galena by surface waters.

WESTERN SOLDIER.

As shown on the map, the Western Soldier mine lies east of the Drinkwater, but on the same zone of lenses. The overlapping lenses are graphically shown in fig. 7. Each one averages 5 or 6 feet in maximum thickness.

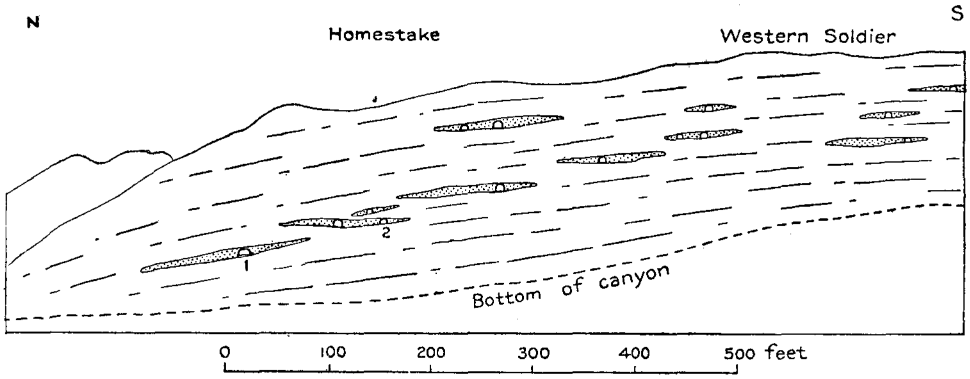

FIG. 7.—Rough vertical sketch of east wall of second canyon east of Drinkwater mine, showing the Drinkwater zone of quartz lenses. The position of various tunnels of the Homestake and Western Soldier mines is indicated; the number and position of the quartz lenses is approximately given.

The mine is credited with a production of 10,000 tons, valued at $20 to $22 per ton, making a total production of about $200,000.

One of the ore bodies in this property is said to have been the richest in the district. Specimens taken by the writer and examined under the microscope show galena, oxidized pyrite, and free gold, the latter separated entirely from the oxides and sulphides and isolated in small particles in the quartz. These ores appear to be primary and contemporaneous with the quartz. The quartz passes into a feldspathic quartz containing orthoclase, and this passes into a quartz-orthoclase rock or alaskite. The alaskite contains quartz, orthoclase, microcline, and probably albite, and a specimen studied microscopically showed that the orthoclase was much altered to fine muscovite, the albite considerably, and the microcline not at all.

These rocks as seen under the microscope are considerably crushed. In the specimen mentioned above the microcline, although fresh and clear, is broken, showing that the alteration to fine muscovite preceded the crushing. In one crushed specimen uncrushed and therefore probably secondary pyrite was observed.

Diorite dikes are numerous, and are generally parallel to the quartz lenses, though occasionally they cut across them or send tongues into them. No evidence of enrichment of the quartz near these diorite dikes was found. The quartz near the diorite seems to be in no way or degree different in value from that which is not near it.

One or two minor faults were observed in the dikes. At one place a diorite dike crosscutting a quartz lens is displaced by a slight reversed fault. At another place a small normal fault is seen.

HOMESTAKE.

As shown in fig. 7, the Homestake is the continuation on the same zone as the Western Soldier, being a portion lying farther down the canyon. It has a credited production of $60,000. Fig. 8 shows a general section at the lowest outcrop of the Homestake, where the ore has the usual characteristics and is closely associated with siliceous alaskite containing quartz veinlets. Into this siliceous alaskite it is distinctly transitional at various places. Farther up the hill, at locality 1, fig. 7, and at locality 2, a transition from the quartz lens into alaskite was also observed. At locality 1 a thin section of the feldspathic rock proves to consist essentially of coarse crystalline microcline, strained but unbroken and very fresh and clear. This incloses numerous irregular grains of a striated feldspar of high double refraction. In this microcline mass the cracks caused by breaking are filled with fine granular quartz and some orthoclase, with opaque carbonates and some gray-black metallic minerals. At locality 2 also the feldspathic rocks consist essentially of coarse microcline with some quartz. This chiefly microcline rock has been considerably broken and has been pierced by many small reticulating veinlets of quartz which have penetrated the microcline in every direction. (Pl. XIII, *A*.)

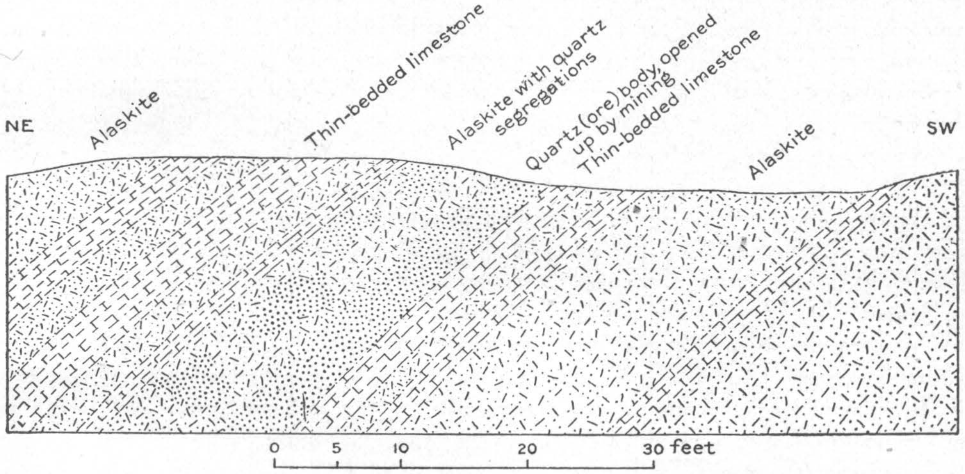

FIG. 8.—Diagrammatic sketch of section at lowest workings of Homestake mines, showing ore lenses and attendant sheets of alaskite intrusive into thin-bedded altered limestone.

In another thin section of alaskite studied the rock has undergone crushing since its final consolidation.

At locality 1, fig. 7, a 6-foot dike of relatively coarse diorite cuts nearly perpendicularly across a quartz lens at right angles to it without displacing it. At locality

2 diorite holds the same relation to the vein. No enrichment is known to occur at the contact of the diorite and quartz in either case. Near the contact of the diorite the quartz happens to be very barren.

MARY.

As shown on the map, the Mary mine lies near the Homestake and Western Soldier, and its workings are on the same zone of lenses as the above-mentioned mines. The Homestake and Western Soldier operate from the outcrops of the ore lenses on the side of the canyon, while the Mary reaches the lens zone by two tunnels running southwestward. Of these the lower one is the longest and was the means of working the mine at the time of the writer's visit. This tunnel runs in 450 feet to the zone and is 1,100 feet long in all (fig. 9).

The ore is in perfectly characteristic overlapping quartz lenses. Several parallel lenses may be on the same level. The lenses are associated with alaskite and run into this rock laterally, which is a fact known and recognized by the foreman of the mine. In the upper workings the ore was a free gold ore, carrying, it is stated, from $12 to $15 to the ton, and was free milling, with few sulphides. In the lower portions of the mine there is a considerable amount of sulphides, mostly pyrite, with some galena. It is of higher grade than that in the upper levels, but the values are harder to extract. The ore is milled and then concentrated, the concentrates being shipped for smelting and the tailings cyanided. The ore being mined at the time of the writer's visit was stated to assay about $26, of which milling extracted only about 54 per cent.

The sulphides in the lower workings are mainly in cracks in the quartz and are evidently subsequent—that is, they have crystallized since the crystallization of the quartz lenses. They even coat crevices in siliceous limestone partings in the quartz. The cracks in general run parallel to the upper wall of the lens near which they occur. In the lowest workings visited by the writer, in a winze 130 feet on an incline below the main tunnel level, this subsequent sulphide ore was about 5 feet thick next to the hanging wall, and the whole was said to assay $84. Beneath this was about 8 or 10 feet of poorer quartz, which, however, contained more free gold, though less sulphides. Throughout this mine it is said that the hanging wall portion of the lenses is better than the foot-wall portions, for while rich bunches occur near the foot wall they are not numerous.

The walls of the lenses consist both of alaskite and of limestone, the latter blue, dense, and slightly carbonaceous. Beneath the vein in the main crosscut tunnel is some limestone schist, and below this there is alaskite continuously to the breast. Above the vein zone the tunnel passes through limestone and alaskite alternately (fig. 9).

The alaskite in these workings is typically a pure quartz-feldspar rock, often pegmatitic. Muscovite occurs occasionally in the pegmatitic variety, and rarely biotite is present. Biotite also occasionally occurs in the granular alaskite, forming a granitic phase.

Specimens of the alaskite were examined microscopically. One specimen consists partly of coarse granular quartz, and partly of feldspar of similar grain, chiefly orthoclase. The quartz is slightly subsequent to the feldspar and locally intrusive into it, as previously noted in other localities, yet is an integral part of the rock. In another specimen having the same composition the quartz was more definitely contemporaneous, but was here and there segregated into very small, irregular bunches. Many of these bunches are elongated and so approach a vein-like form.

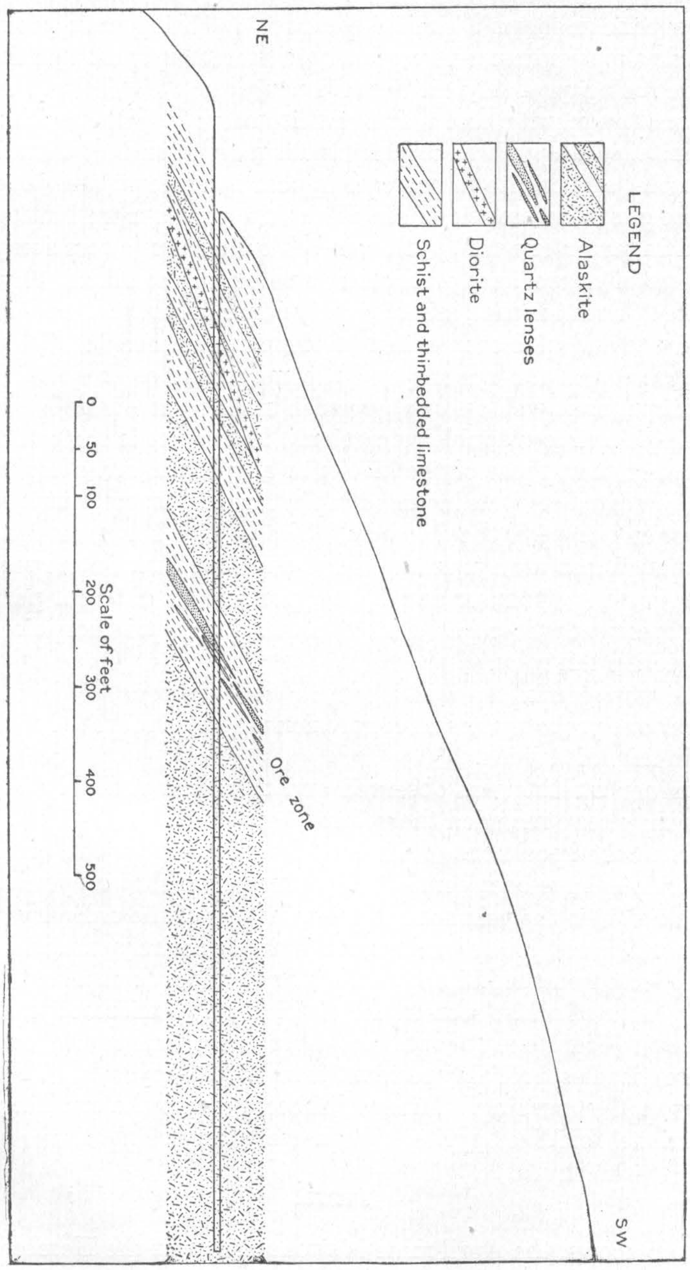

Fig. 9.—Section along Mary (Chiatovich) tunnel, showing rock formations and position of lens zone. Detail of ore lenses generalized.

In this specimen muscovite is present, varying from very fine (sericitic) to small separate crystals like the characteristic muscovite of granitic rocks. The complete gradation indicates a common origin. The larger grains are plainly an original rock constituent and the finer ones are probably the same, and yet the latter occur in isolated sheaves and bunches in otherwise fresh feldspar, sometimes completely replacing the latter. A process of magmatic alteration during crystallization is thus indicated.

Another specimen shows a similar composition, being mainly quartz and feldspar, but contains biotite in small irregularly scattered crystals. Chlorite is frequent in this section, being probably an alteration product of biotite. Apatite, zircon, pyrite, occasional muscovite, and a little calcite occur, together with magnetite and probably ilmenite. The pyrite is original and is more abundant than the iron oxides. Pyrite, muscovite, and calcite in one case appear intergrown and contemporaneous. Another specimen of this biotitic phase of alaskite shows more biotite than the first specimen, and in larger crystals, with some chlorite as an alteration product. The feldspar consists of microcline, orthoclase, and oligoclase-albite. Pyrite and magnetite (ilmenite?), both original, are extremely common, and are associated and intergrown with biotite and with each other. Sphene is common; and cloudy leucoxenic crystals often surround the sphene and the magnetite or ilmenite. Small apatite crystals are common, as well as long, greenish needles of an undetermined mineral having high single and low double refraction. Muscovite is scattered in small crystals, much smaller than those of the biotite or any of the other larger minerals. It occurs in small isolated crystals included in the large feldspars, but is strictly original and contemporaneous with the feldspar. The biotite has a tendency to uniform orientation, though not always in the same direction, but in curves. There is an irregular arrangement of darker and lighter portions in different parts of the slide, and quartz is frequently segregated into bunches of allotriomorphic grains. Tourmaline was noted in this rock.

No diorite was seen in the workings near the vein zone, so that the subsequent ore described above probably has no connection with this rock. One diorite dike was encountered in the adit tunnel.

A little minor faulting was observed and there has probably been some broad folding which may have included the veins.

Although all the specimens of alaskite described above are of uncrushed rock, some other portions have been considerably crushed, as shown by microscopic study. A specimen taken from the vein zone in the mine was of the ordinary type, consisting of microcline, orthoclase, albite, and quartz, but was entirely granulated by crushing. A specimen collected on the hill above the Mary mine was obtained from one of the most altered phases of schist seen in the district. The microscope shows it to be a crushed muscovite-granite. It contains quartz, coarse muscovite, and chlorite, with rutile (sagenite) needles, probably residual from biotite crystals. These minerals are all antecedent to the crushing. Minerals subsequent to the crushing consist of fine muscovite (sericite), oxidized pyrite, and quartz in tiny veinlets.

APRIL.

As the map shows, the April mine is situated east of the Homestake and on the same zone of lenses. The geology is similar in all details to that of the mines already described. Quartz and alaskite lenses occur in a thin-bedded limestone which is often schistose. The ore is generally accompanied by some diorite, usually an intercalated sheet. The mine is said to have produced 200 tons of ore having an average value of $50 to the ton. The ore was free milling and was worked in 1892–93 in Chiatovich's mill at Silver Peak.

LAST CHANCE.

The Last Chance lies east of the April and is the easternmost mine on the Drinkwater zone of lenses. Openings show a strong lens of quartz associated with pegmatitic quartz-feldspar veins in alaskite. The alaskite is sometimes crushed and contains secondary sericite, with infiltrated calcite. Besides alaskite, limestone—dark, usually thin-bedded, and siliceous—frequently forms the wall rock.

Greenstone or altered diorite occurs in a sheet a few inches to over a foot in thickness, which runs through the ore or along one of its walls. The rock is completely altered from its original form to calcite, quartz, kaolin, etc. It contains included fragments of quartz, some of them angular in shape. Along the contact of the greenstone dike with the quartz there is a strongly marked band of galena, with accompanying iron rust showing original pyrite. This galena has formed in part in the altered dike as well as in the quartz. Although this band is only a fraction of an inch in thickness there is no question as to its secondary nature. The ore containing galena in this mine as in others is usually relatively rich. The rest of the quartz near the dike is also usually good.

Small calcite veins, irregular and nonpersistent, occur in the greenstone, from which they have probably been derived by lateral secretion.

FRANK NO. 2.

The Frank No. 2 properties comprise a string of several small openings running in a north and south direction at the head of Echo Canyon. The quartz lenses here are probably on the same zone as those of the Drinkwater mine. The lenses lie flat, or approximately so, conforming with the general flattening of the limestone schist formation toward the south. The quartz bodies are of the ordinary type previously described, and make up lenses of various dimensions.

The quartz is associated with alaskite, which forms the usual country rock. A part of this alaskite is fresh and uncrushed and contains segregated bunches and veins of quartz. In places the main lens of quartz passes by transition along its margin into the alaskite country rock. Such quartz carries values, general assays from $3 to $14 being reported. Some of the bunches of segregated quartz within the alaskite show galena and carry values. Some of the galena sits upon free crystals of quartz, which line tiny druses.

A specimen of typical fresh and uncrushed alaskite, examined microscopically, shows a general granitic structure. It shows also two distinct generations of crystals. The first generation is represented by large hypidiomorphic grains of orthoclase and some of andesine oligoclase. Both, the orthoclase especially, are filled with muscovite fibers, in some places of relatively coarse grain, though still microscopic. The intensification of the amount and size of the muscovite along the edges of the feldspar crystals and along certain lines, evidently fractures in the crystals, shows the muscovite to be due to a process of alteration of the feldspar. The very irregular shapes of the coarse feldspar grains show that they were formed in place and were not caught up and included by the subsequently crystallized rock. This subsequently crystallized rock is represented by the second generation. It consists of perfectly fresh and unbroken quartz, orthoclase, some microcline, and some striated feldspar. These minerals are intercrystallized and contemporaneous. The quartz is relatively most abundant. It fills the interstices between the feldspar grains, intrudes, on a microscopic scale, feldspar grains of the earlier generation containing muscovite, and fills cracks caused by the occasional breaking of these. For all this, it is ordinary granitic quartz. The fresh feldspar sometimes invades the muscovitized feldspar of the older generation. Clear orthoclase incloses isolated idiomorphic small crystals of the older muscovitized orthoclase and also similar crystals of muscovitized striated feldspar. The coarser muscovite grains along the edges of the older feldspar are in some places intergrown with the edges of the quartz. The fresh feldspar of the second generation sometimes incloses quartz, sometimes is traversed by it. A single tiny quartz veinlet cuts straight across the slide. This is composed of quartz grains of the same size as the ordinary grains filling the spaces between the feldspar, and is actually everywhere connected with these grains. Zircon was observed in the younger feldspar and quartz.

The following history of the formation of this rock is therefore indicated: (1) Crystallization of orthoclase and andesine-oligoclase into a mass of adjacent crystals nearly filling the magmatic fluid; (2) alteration of the feldspar in part to fine muscovite, especially along the edges; (3) deposition of predominant quartz, orthoclase, relatively less microcline, and still less striated feldspar and tiny crystals of zircon, in the interstices. The movements of the fluid from which the second generation of crystals formed were sufficient to rupture the older crystals and to make tiny crevices in which the new minerals crystallized. Along a larger crack a quartz veinlet formed.

On the west wall of Echo Canyon, about 20 feet below the northernmost open cut on ore of the Frank No. 2, free gold occurs in unaltered alaskite pegmatite, which here forms a great mass constituting the whole country rock. This rock is composed essentially of quartz and feldspar, with some muscovite. At the place mentioned free gold is disseminated through the rock in small specks. In some places the gold is plainly derived from oxidized pyrite; in others it appears in small grains that are quite free from iron rust. It occurs principally in the quartz of the pegmatite but is also embedded in fresh feldspar. The area where this gold has been found is only about 3 yards in diameter and has no special form or other characteristic to distinguish it from the surrounding rock, which, so far as known, does not contain gold. A specimen of the auriferous pegmatite examined microscopically proves to consist of quartz, orthoclase, and microcline, all perfectly fresh. The rock has been cracked and in part crushed, although the crushed feldspar remains quite fresh. No gold was observed in the thin section.

Schist (probably altered thin-bedded limestone) also forms in places the wall of the Frank No. 2. Into this schist both quartz and alaskite are alike intrusive, in the form of lenses.

Greenstone or altered diorite is the latest rock connected with the ores. A dike of this rock 3 or 4 feet thick follows the ore zone, forking and reuniting so as often to cut out a portion of the vein, and sometimes splitting so as to leave a fragment of the vein included (fig. 10). The vein fragments in such a position seem to be richer than the average. The ore shows sulphides, consisting of galena and pyrite, filling parallel cracks. The miscroscope shows also the presence of calcite in these cracks. Such ore is undoubtedly subsequent. All the ore milled has been of this class. The galena here is the best indication of good values, which are in gold, accompanied in places by a very little silver.

Some portions of the alaskite are greatly crushed, the crushing being accompanied by the development of sericite; other portions are slightly crushed; while still others are perfectly intact. From an examination of outcrops it appears likely that this difference is due not so much to localization of the crushing stresses as to slightly different age of the different alaskites. Crushed alaskite and that which has undergone no stress occur in immediate contact and seem even to be transitional into each other. It is probable that some crushing occurred during the crystallization of this rock, and that the rock which was first formed was intruded by slightly later material of the same character. The diorite as a rule is altered but uncrushed, and the subsequent ore also is uncrushed.

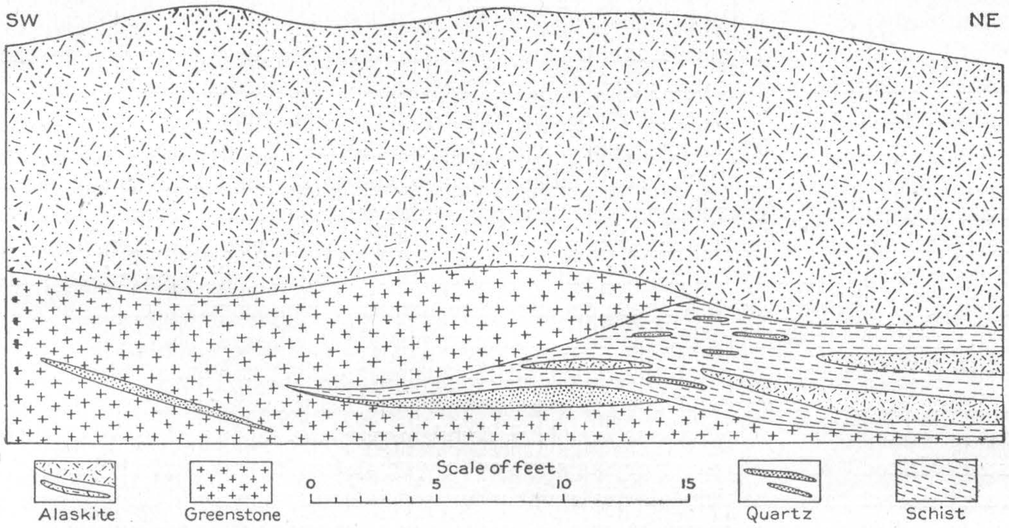

FIG. 10.—Vertical sketch section of open cut in northeast workings Frank No. 2.

Some slight faulting occurred subsequent to the diorite intrusions.

COLUMBUS.

The Columbus is a small mine or prospect separated by a little valley from the Frank No. 2. The valley is the continuation of the upper end of Echo Canyon but is not deeply cut. The Columbus is probably on the same zone as the Frank No. 2, the intervening portion having been removed by the erosion of the valley. The mine is said to have produced 200 tons of ore having an estimated value of $15 per ton. The ore was milled in a small stamp mill at Valcalde Springs.

The quartz which constitutes the ore occurs in flat-lying lenses, which pass into quartz-feldspar rock (alaskite) along the edges. Limestone schist also forms the walls in part.

The alaskite wall rock contains in places abundant quartz segregations and veinlets. Smaller bodies of alaskite are of lenticular form and are surrounded by schist in the same manner as the smaller quartz lenses.

Diorite is found near the ore, sometimes as a foot wall to the quartz lenses, or at some distance away from it, but generally parallel to the lenses and conforming to the general attitude of the schist.

There has been considerable crushing of the ore and the country rock. A specimen of the quartz viewed under the microscope is seen to be thoroughly crushed. It contains oxidized pyrite, which is uncrushed and therefore subsequent to the movement, and also fine granular calcite and a green amorphous substance, the latter two probably infiltrated.

SOLBERY.

The Solbery is a small mine, hardly more than a prospect, belonging to the Messrs. Valcalde and situated at the extreme head of New York Canyon, on the west branch. According to reports it has produced 100 tons of ore, valued at $20, making the production $2,000. At the mine opening, where there is a short tunnel and stope, the ore is quartz, 2 feet in thickness. It contains considerable feldspar. A specimen examined under the microscope is seen to be coarse quartz, with considerable coarse fresh orthoclase and microcline in some areas. In the outcrop the quartz seems slightly later than the quartz-feldspar rock or alaskite, but the vein passes into alaskite and is lost. Besides this vein or lens there are three or more parallel lenses, 100 to 150 feet apart. They have been worked to only a slight extent.

In the chief opening above mentioned the hanging wall of the quartz is alaskite, siliceous, and quartzose. A specimen examined microscopically was found to consist of coarse quartz, orthoclase, and striated feldspar, the feldspar being slightly muscovitized. These coarser crystals are cut by veinlets of finer quartz, with some fresh feldspar, and the veinlets are slightly faulted microscopically. The foot wall consists of 3 feet of green schist, with alaskite lying below it. The original nature of the schist is not certain. The microscope shows it to consist of quartz, sericite, and calcite, with subsequent uncrushed pyrite, now completely oxidized. The other parallel lenses mentioned have siliceous alaskite for both walls.

Both alaskite and quartz are locally strained and somewhat crushed. This crushing, as usual, has had slight metamorphic effect, the crushed feldspar remaining fresh. Some sericite has been developed as a consequence of the crushing, and subsequent pyrite was noticed both in the quartz and in the walls.

RED LIGHT.

The locality of the small mine known as the Red Light is shown on the map. It is the property of Mr. John Chiatovich. Work was begun on the mine in the spring of 1888 and it produced about 400 tons, which were worked in Mr. Chiatovich's mill at Silver Peak. The first 80 tons, it is said, milled $25 to the ton, the rest about $20. The property is mainly opened up at a single locality, by irregular flat drifts and stopes on quartz, and by a shaft 35 feet deep. The quartz constitutes the ore and occurs in the form of several overlapping lenses. A very little copper pyrite was noticed in the quartz. The general dip of the lenses is slightly east. When it is followed in from the surface along the vein, on the drifts and stopes, the quartz is found to pinch from 4 feet to 1 inch on the west wall of the drift; then it thickens again and at the face becomes very feldspathic. On the east wall of the drift, a few feet away from the west wall, the vein pinches out entirely long before reaching the breast, the limestone schist converging from both walls and meeting.

Limestone and limestone schist constitute the principal wall rock. Some of the rock is identifiable under the microscope as a kneaded limestone, somewhat carbonaceous and containing broken quartz veinlets and subsequent unbroken pyrite. In this limestone schist there are lenses of alaskite as well as of quartz. Some of the schist is also apparently a sheared alaskite, as near as can be judged from the microscopic examination.

The first 80 tons of somewhat richer ore noted above were taken from the outcrop of the quartz lens. This is important in considering the effect of weathering and oxidation on original values.

SODA.

The Soda claim is hardly opened up and is little more than a prospect. It contains small lenses of quartz, each several inches thick, embedded in limestone schist. The lenses strike north and south, and dip eastward with the formation, at an angle of 25°. The best streaks of ore are said to assay $40.

MISSOURI.

Only a little work has been done on the Missouri prospect. It has been developd by several inclines and open cuts along the strike and by one tunnel. It has not been worked for about twenty years, and the period during which it was operated is uncertain. At the main opening, the only place where any stoping has been done, there is a quartz lens having a maximum thickness of 5 feet, which dwindles to 18 inches a short distance downward. So far as seen the vein is free from feldspar.

The wall rock is a schistose altered limy slate containing lenses of alaskite and alaskite-quartz.[a]

A thin section of the alaskite shows some interesting features. Two generations of crystals are observable. The older generation is represented by coarse feldspar, chiefly orthoclase, with some striated feldspar. These feldspars have been fractured and cemented by veinlets of quartz intergrown with contemporaneous, smaller, but still good-sized crystals of feldspar, of the same species apparently as the older crystals. The younger feldspar mostly grows out from the edge of the older crystals, but is differently oriented. Many of the smaller fresh feldspar crystals are included in the greatly preponderating quartz.

A lens of harder rock, which is included in the schist and whose shape is probably due to crushing, proves on microscopic examination to be greenstone. It is completely altered and consists of a mixture of calcite, muscovite, and quartz, with pyrite, chlorite, and other decomposition products.

A slight fault displaces the vein and the inclosing rocks a few feet.

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[a] This term is used for quartz-feldspar rock containing so much quartz that it is a transitional phase between typical alaskite and typical quartz.

GOLDEN EAGLE.

The workings on the Golden Eagle consist of open cuts and short tunnels made at various places for 200 or 300 feet along the west face of a steep canyon and near the bottom. These openings are on a strong line of quartz lenses which in general strike N. 15° W. and dip 10° SW. In places the quartz is as much as 5 feet thick, but it always pinches out and is succeeded by other lenses. One tunnel, which started on a 2-foot vein of quartz, continued only 40 feet to a point where the lens pinched out and disappeared.

This property was located in 1875 and has since been abandoned and relocated several times. In 1900 Bonifacio Aguilar, operating a lease from H. W. Barton, took out about 30 tons of ore valued at $30 a ton, and worked it in an arastra at Coyote Springs. This is the only production with which the mine is credited. The rest of the ore is said not to be so rich, an average value of about $18 being reported.

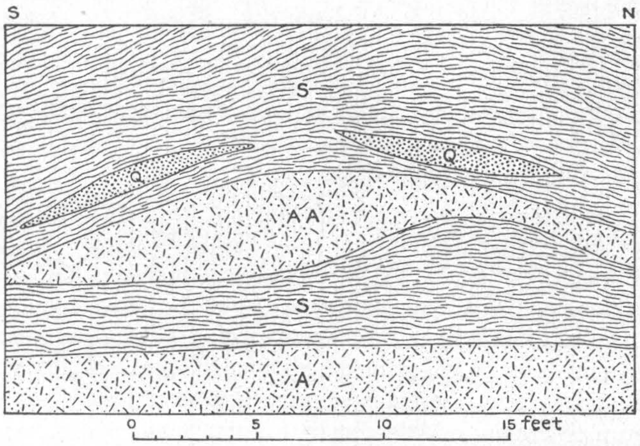

FIG. 11.—Vertical sketch section of open cut of Golden Eagle prospect. A, Siliceous alaskite country rock; AA, siliceous alaskite, principal ore body; Q, quartz (barren); S, Schist (altered shaly limestone).

Some of the quartz lenses are free from feldspar; others, again, contain so much as to be classed as alaskite-quartz. The ore lens from which the production given above was taken is of the latter class (see fig. 11). It contains small streaks or veinlets of quartz, sometimes distinct and sometimes grading into feldspathic rock. Such rock contains scattered pyrites and galena, plainly contemporaneous in origin with the rest of the rock. A typical specimen from this ore lens shows two generations of crystals. The first is coarse orthoclase. This has been considerably broken, and fine muscovite has been developed along the crushed zone. The feldspar has been cemented by crystalline quartz. A specimen of the ore containing pyrite and galena, taken from the pile which had been sorted out for shipment, is of practically the same character as the specimen previously described, but in this case the quartz of the second generation is intercrystallized with fresh orthoclase. In places the subsequent feldspar cements a whole crevice in the older feldspar, excluding the quartz of the second generation.

The walls of the quartz lens are generally schist, containing small lenses of alaskite and quartz. Heavy masses of alaskite overlie and underlie these schists.

In this locality there are a number of diorite or greenstone dikes, both intercalated in the schist and crosscutting it, but they have no connection with the ore. In one place an intercalated sheet of such greenstone forms the hanging wall of the quartz lens. In this greenstone there are some secondary veins of small size, containing quartz and ferruginous calcite, both cutting across the greenstone sheet and running along its upper contact.

Some specimens of alaskite show crushing subsequent to all crystallization, with the development of sericite.

ESMERALDA.

The Esmeralda prospect has been opened by a cut 35 feet long, which shows moderate-sized lenses of alaskite and quartz in stratified limestone and shaly schists. Fifteen feet above the lens zone is a bed of thin-bedded limestone shale which is comparatively little altered. This may be on the same lens zone as the Golden Eagle, for quartz can be traced most of the distance between the two prospects. The strike of the beds and vein is N. 15° W., the dip 25° NE. The quartz contains disseminated galena and pyrite, both original. Three or four tons of ore taken from the prospect were packed on a man's back to Tarantula Springs, where it is said to have milled $100 to the ton, but no more of this kind was found.

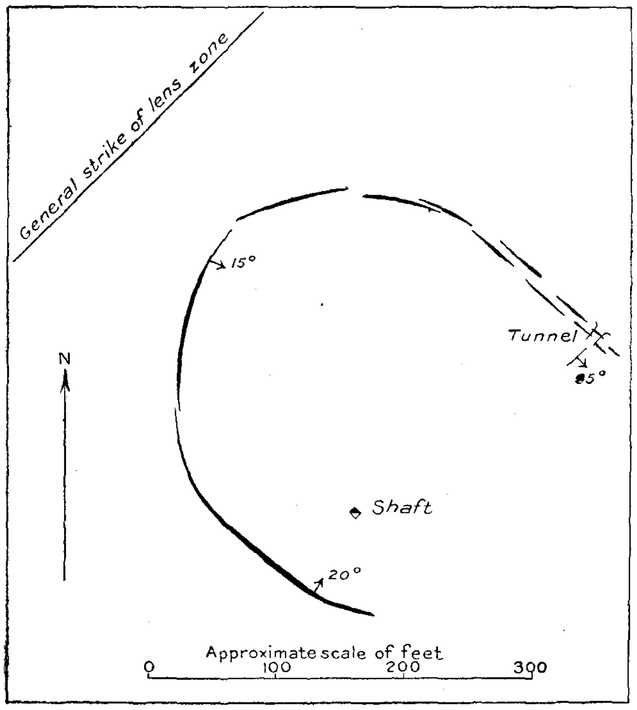

FIG. 12.—Sketch on horizontal plan showing outcrop of Crescent lens zone.

CRESCENT.

The Crescent mine is located, as shown on the map, on the southwest side of this mineral district. It was worked desultorily from 1887 to 1893. Between 200 and 300 tons of ore, valued at $10 to $12 a ton, were extracted and were milled at Tarantula Springs. A mining engineer who has sampled the remaining ore states that it averages $12 or $13. The property has been opened up chiefly by a short tunnel and a shallow shaft.

The geology is exactly like that of the similar properties previously described. The so-called vein is a zone of aligned lenses. The outcrop of this zone, as the name indicates, is crescentic, following around the edge of a small hill. The cause of this curved outcrop is that the vein is flat, with a slightly scoop-shaped depression (fig. 12). The strike is east-northeast, the dip southeast, but the latter is locally reversed.

The solid quartz in the lens zone is about 7 feet thick in its strongest or southern portion, but changes rapidly at the other or northeast end to separate smaller lenses. At the tunnel near where the ore has been stoped some primary galena was noticed, and here the ore is richer than at the other end, where it is thicker, but barren and white.

The quartz lenses are accompanied intimately by alaskite and by rocks which show various gradations between alaskite and quartz. One specimen of this alaskite shows, as usual in this rock, two generations, the first consisting of quartz, orthoclase, and oligoclase-albite. These have been somewhat broken, strained, and penetrated by a second generation consisting of the same minerals as the first, namely, orthoclase, oligoclase-albite, and quartz. The quartz and feldspar of the later generation are intercrystallized and contemporaneous, though sometimes small idiomorphic crystals of the feldspar are included in the quartz. Among these crystals albite and orthoclase were recognized. The feldspar of the first generation, both the orthoclase and the oligoclase-albite, is partly altered to scattered blades of fine muscovite, especially along the edges, while the feldspar of the second generation is clear. The younger generation of minerals forms irregular veinlets, sometimes all quartz, sometimes all feldspar; the latter can often be recognized as younger only on account of the contrast produced by the muscovitization of the older feldspar. This younger material also fills spaces between the larger orthoclase crystals or penetrates these crystals, sometimes appearing as isolated grains in the section. On the walls of vein-like channels the older orthoclase has been added to by clear orthoclase of secondary growth having the same orientation. One such veinlet is characterized by zonal feldspar parallel to the walls, the fine zones being due to differently oriented stripes with a coarse, massive center of orthoclase and some albite. In this case the zonal part is muscovitized, the central part not, showing that the muscovitization succeeded the fracturing, while it preceded the general cementation.

The quartz streaks and lenses occur chiefly in shaly limestone, altered in the lens zone to a bluish schist, and here containing small lenses (augen) of granitic material, but a few feet away from the lens zone the limestone is comparatively unaltered. The whole zone is capped by blue limestone, which is the bottom of a limestone series that is more massive than the limestone-shale series marked by the copious intrusion of alaskite and quartz and hence characteristic of the mineral district.

Some of the alaskite has been crushed subsequent to the formation of both generations of crystals. In certain thin sections of such crushed rock some secondary crystallization was noted, which, apart from the common development of fine sericite in such cases, was the first observed instance of recrystallization following crushing. In such specimens the crushed orthoclase and microcline can be seen in process of irregular alteration to probable albite, although the alteration is not important. In another specimen the feldspar has been largely replaced by fine granular quartz, giving a structure suggesting quartzite and resembling the structure of the "bull" quartz of the Drinkwater mine.

VEGA.

The Vega property was worked about 1892, and a short time after its discovery produced about $3,000, the ore being treated in a custom 2-stamp mill, which at that time was running at Tarantula Springs. Some of the ore taken here contained $100 to the ton. This ore contained galena and also altered pyrite. The rest of the quartz in the lens was not extracted. The lens is 4 feet wide at the center of the outcrop (fig. 13), but when followed in by a tunnel diminishes to nothing in about 50 feet (fig. 14). It also dwindles and disappears in both directions along the outcrop, so that it is a lens well defined in three directions.

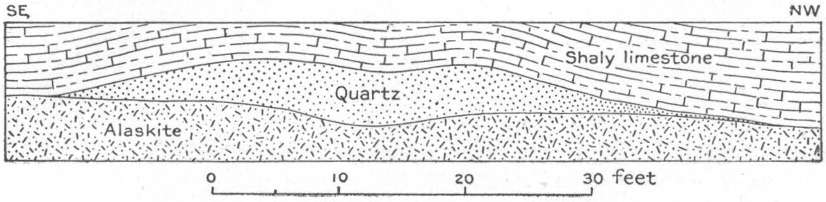

FIG. 13.—Vertical longitudinal section of Vega ore lens at outcrop, taken at right angles to fig. 14.

The geology is identical with that in the Blair mines and others like them on Mineral Ridge. As shown in the sketch (fig. 14), the location is at the contact of the blue shaly limestone characteristic of the mineralized area with the conformably overlying marble, which, so far as known, does not contain ore deposits. The foot wall of the lens is alaskite, the hanging wall schistose limestone overlain by alaskite. The last-named alaskite is quite uncrushed and is fresh. As is almost invariable in the alaskites of this district, it shows two distinct generations of crystallization. The first generation is represented by large grains of orthoclase, the second by a finer granular mosaic, consisting of quartz, microcline, and orthoclase, the first predominating. The crystals of this mosaic sink to fine dimensions. Some of the orthoclases of the rock are altered to fine muscovite, while some are clear. In one case

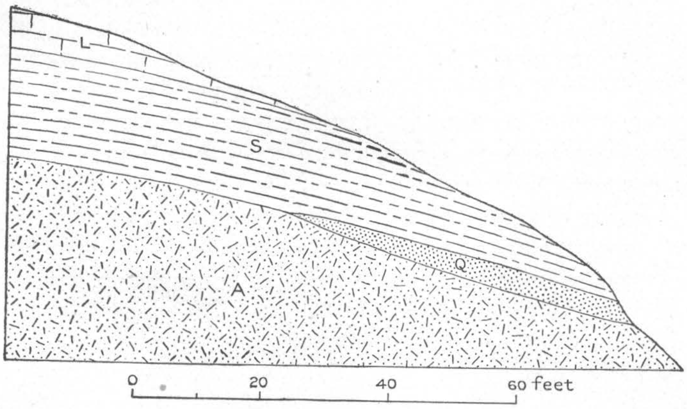

FIG. 14.—Vertical cross section at the Vega mine. A, alaskite; Q, quartz (ore body); S, dark shaly limestone; L, brown marbleized limestone or dolomite.

a crystal of the former is included in the latter, as if the alteration preceded total crystallization.

The alaskite of the foot wall is somewhat crushed, but shows the same composition and structure as that just described, and the crushing has not injured the freshness of the last crystallized feldspars. In this rock some of the quartz is very full of fine muscovite, similar to that in the older feldspars. In this case also the muscovite fibers are arranged along certain lines.

Microscopic examination of the fine blue limestone of the hanging wall shows it to be an ordinary dense limestone with carbonaceous streaks and a sandy streak marked by fine quartz grains.

A diorite dike, 4 feet thick, cuts across the alaskite. The microscope shows this to be entirely altered to quartz, chlorite, etc. Original ilmenite is abundant.

RED MONSTER.

This prospect is situated somewhat apart from others of its kind on Mineral Ridge, lying, as is shown on the map, farther northwest than these. The geology is of the Drinkwater type. Like most of the mines of the district, it is abandoned, and has been for some time. It is reported to have been worked a little in 1899, and at that time one carload of ore was shipped to the Selby smelter. Nine tons were milled at the Silver Peak mill in 1892. The workings consist of an incline 13 feet deep and a drift 60 feet long at the bottom. The ore bodies are quartz lenses in schist, the main lens varying in thickness from several feet to a few inches. Some of the quartz has been stoped to a thickness of 2 feet, especially near the surface.

Alaskite, sometimes muscovite bearing, is associated with the quartz at one point in the workings. A general section of the hillside shows different sheets of alaskite alternating with limestone schist. A specimen of coarse alaskite pegmatite, examined microscopically, shows two periods of crystallization, the first having resulted in coarse feldspar, largely orthoclase, with a little microcline and some striated feldspar. This feldspar incloses many small blades of muscovite, which are much coarser than the usual fibrous or sericitic variety, but have probably a similar origin. These feldspars have been strained and partly crushed and cemented with quartz and some feldspar.

GREAT GULCH TYPE

GREAT GULCH MINE.

This is a gold-producing property of a different type from those previously described. It is located near the bottom of a deep gulch, southeast of the area of gold mines and prospects already described, and between these and the Pocatello-Vanderbilt group of silver mines. The mine is said to have produced $6,000 to $7,000. Ninety-eight tons of the ore, it is said, netted the owner $57 to $58 per ton. This ore was treated in Chiatovich's mill at Silver Peak, and the tailings were chlorinated. The property is opened by several cuts and tunnels, the longest being about 220 feet. These all follow streaks of ore. Below these, at the bottom of the gulch, a prospect tunnel was run in, under the direction of Tonopah parties, in 1903, but did not reach any ore. The tunnel, which is very tortuous, is about 240 feet long in all.

The property is situated on the east side of the gulch, near the bottom. The rocks forming the side of the gulch here consist of a thick series of stratified thin-bedded limestones, considerably altered and schistose, and dipping north at a moderate angle. This series contains frequent interbedded lenses of alaskite. In places also the alaskite, contrary to its usual custom, cuts across the bedding of the limestone (fig. 15). The openings of the Great Gulch mine show that the general alignment of the ores is parallel with the strike and dip of the general formation.

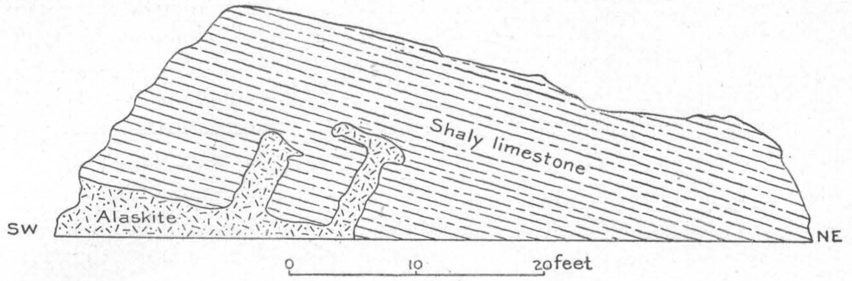

FIG. 15.—Sketch section of portion of northwest side of canyon at Great Gulch mine, showing alaskite cutting across bedding of shaly limestone.

At the mine the general geology is similar (except for the ore) to that of all the other mines previously described. Lenses of white vitreous quartz occur interbedded in the limestone schist. The quartz often becomes feldspathic and passes into siliceous alaskite, which also occurs in separate lenses. The distinctive feature of this mine, however—the one that distinguishes it from all the preceding—is the

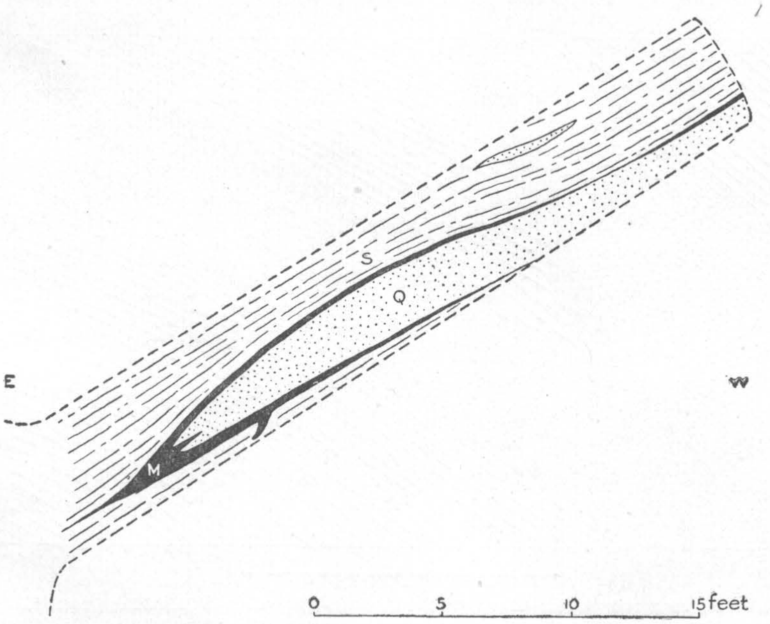

FIG. 16.—Vertical section along raise in upper tunnel, Great Gulch mine, showing occurrence of ore. Q, Quartz (lens); S, shaly limestone, somewhat altered; M, auriferous mispickel (ore). Dotted lines show outlines of raise.

character and relative age of the mineralization. The ore is mispickel or arsenopyrite, and is subsequent in age to the quartz and alaskite with which it is generally associated. The mispickel occurs in streaks of all thickness up to 1 or 2 feet locally, but usually much less. The streaks are of very uncertain size, shrinking in places to small seams and again expanding into lenticular masses of solid ore. The largest masses of ore are noticeably associated with the alaskite and quartz lenses, especially with the latter, and occur occasionally as cross-cutting streaks, but usually as bands parallel to the walls of the lenses and to the attitude of the limestone schist (fig. 16). The hanging wall of a quartz lens is an especially favored location, and in this case the ore lies either in the fractured quartz, or above in the limestone, where it generally forms seams between the laminæ of the sedimentary rock (fig. 17). The ore has originated partly by replacement, not only of the limestone schist, but also sometimes of alaskite. Cases were noted where an alaskite lens is locally almost completely

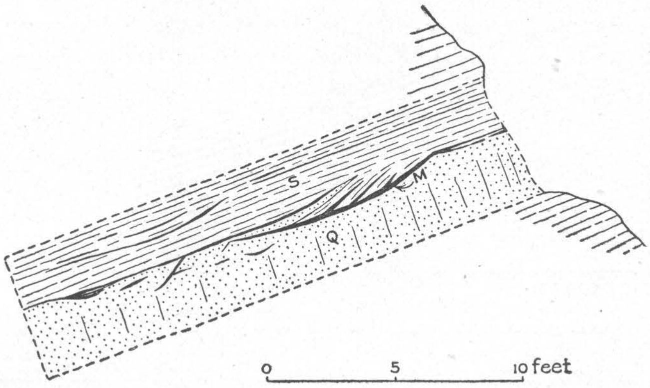

FIG. 17.—Vertical section of incline from surface following on ore, Great Gulch mine. Q, Quartz in cross fracture; S, shaly limestone; M, mispickel (ore). Dotted lines show outlines of incline.

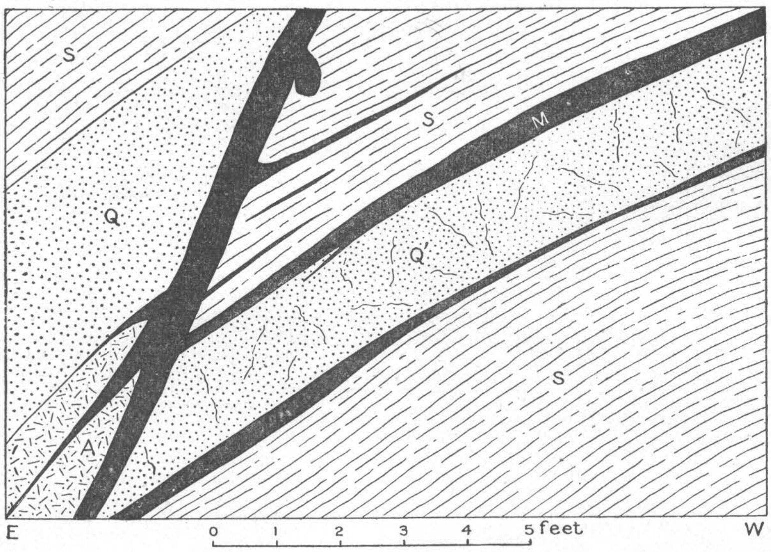

FIG. 18.—Vertical section in short drift near end of upper tunnel, Great Gulch mine. A, Alaskite; Q, quartz; Q′, quartz (feldspathic), much broken; S, shaly limestone, considerably altered to schist; M, mispickel (ore). Mispickel occurs along a fault zone on both sides of the crushed quartz, especially on the hanging-wall side.

replaced by mispickel, except for residual portions here and there. Frequently the arsenopyrite streaks follow both the hanging wall and the foot wall of a quartz lens (fig. 18). The general situation is well expressed in the accompanying figures.

It is evident that the preferential association of the arsenopyrite with the quartz and next with alaskite is due to the fact that these afforded better fractures when subjected to stress than the inclosing schist. The solutions which deposited the arsenopyrite followed fractures created by stress subsequent to the consolidation of the quartz, and only in the rigid and brittle materials, such as the quartz, and to a less extent the alaskite, were the openings produced by fracturing sufficient to allow vigorous circulation and ore deposition. It is therefore easy to understand why the ore streaks are nonpersistent, and become faint, split, and die out in the schist. The preferential location of the ore at the hanging wall of the quartz lenses indicates rising solutions. These ascended through the fractured quartz till their progress was impeded by the relatively impervious overlying schist, and beneath this impervious contact the ore deposition took place.

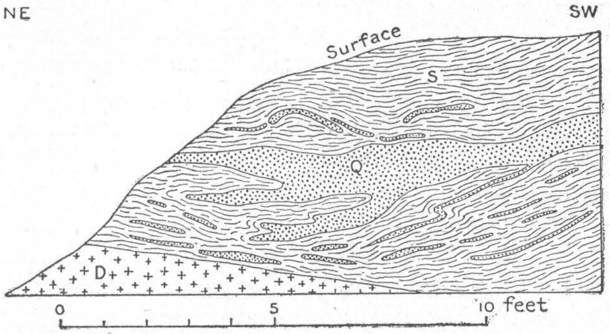

FIG. 19.—Vertical section at opening of chief tunnel, Pocatello mine, showing quartz in schist. D, Greenstone (altered diorite); Q, quartz; S, blue schist (altered shaly limestone).

SILVER MINES AND PROSPECTS OF MINERAL RIDGE.

POCATELLO.

At the Pocatello silver mine the ore follows a zone of rather small and nonpersistent quartz lenses which are similar in every way in appearance, age, association, and origin to the quartz bodies which form the ore in the typical gold mines of the district. The lenses lie in a blue schist, which represents a more or less altered shaly limestone (fig. 19). The lens zone is flat, lying with the formation, but is undulating and somewhat faulted (fig. 20), and this fact, in connection with the variations in the topography, brings about very irregular outcrops. What is probably the same zone outcrops about 100 yards southeast of this point on top of the ridge overlooking Silver Peak.

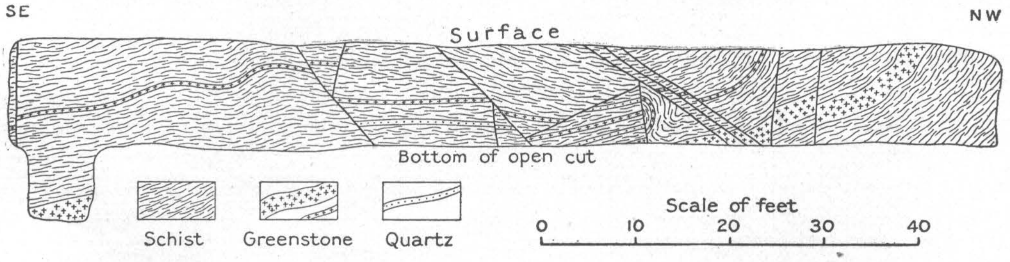

FIG. 20.—Vertical sketch section of open cut on ore zone at Pocatello mine, showing faulting.

The ore is later than the quartz. It consists largely of a black metallic mineral occupying cracks in the quartz—the "black metal" of the miners. This is rich in silver and yields a stain of copper carbonate.

The alaskite is in lenses, which are associated with the quartz lenses in the typical way so often described for the gold mines. Locally this alaskite has a granitic phase. A thin section of this biotite-bearing alaskite, or biotite granite, proves to be uncrushed and nearly fresh, with a structure and texture like that of the ordinary alaskite. The biotite is a sparse essential and is extraordinarily full of rutile needles. Some of the orthoclase is altered to fine muscovite or sericite, while some is not. In one case a sericitized core of probable orthoclase is surrounded by clear orthoclase, as if there were two periods of crystallization. The microcline also, which is more abundant than the orthoclase, is absolutely fresh, and thus seems subsequent in origin to the sericitized feldspar. In several cases the microcline was observed to inclose small idiomorphic crystals of partly sericitized orthoclase. Included biotite crystals were also noted in a similar situation, as if the small orthoclase and biotite crystals had floated free in the fluid from which the microcline crystallized. The sericitized feldspars are sometimes microscopically fractured, and in these fractures veinlets of quartz and orthoclase are formed. The fresh orthoclase of the later period of crystallization sometimes incloses idiomorphic quartz grains.

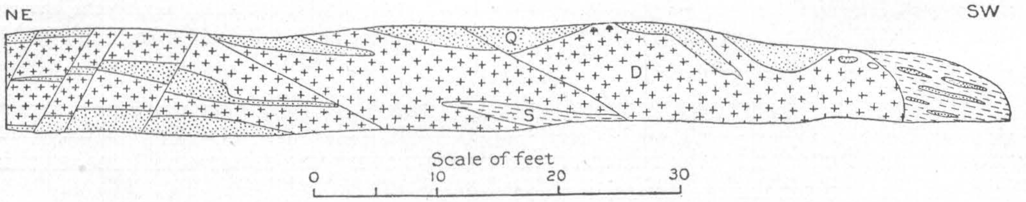

FIG. 21.—Vertical sketch section along open cut on ore zone of Pocatello mine, showing diorite cutting and inclosing earlier schist and quartz. The ore is contained in cracks in the quartz near the diorite contacts. Q, Quartz; D, greenstone (altered diorite); S, schist (altered shaly limestone).

A specimen of the schist from near the vein proves to be intensely altered. The microscope shows it to be an aggregate of fine sericite pierced by subsequent veinlets and nests of fine intercrystallized granular quartz and calcite. Fresh grains of feldspar (chiefly microcline, sometimes orthoclase) occasionally occur.

Southeast of the main vein outcrops on top of the ridge that overlooks Silver Peak village there is an interesting section showing the relation of the schistose, thin-bedded limestone in which the quartz lenses occur to the overlying brown crystalline limestone or dolomite which does not contain ores. The marble overlies the thin-bedded, shaly limestone series conformably, and there is a transition between the two which, although it occupies only a few yards, is gradual. Alternating layers of brown marble and dark thin-bedded schist occur for a few yards below the contact, the thickness of the layers of marble gradually increasing upward until the massive marble formation is reached. The phenomena are those of a change of sedimentation, and the change indicated is that from a shaly thin-bedded, calcareous sediment to massive limestone. Alaskite seams are especially numerous toward the top of the schistose series, but do not extend into the brown marble. However, a number of small alaskite lenses and quartz lenses are found above the lowest strong band of marble which is intercalated with the schistose bands. Evidently the shaly series has been selected for intrusion by alaskite and accompanying quartz because of its easy fissility, and for this reason this formation is ore-bearing, while the overlying massive limestone is barren.

The ore zone is frequently cut by greenstone dikes, which are in general parallel with the zone, but are occasionally transverse. Thus the greenstone divides, underlies, or overlies, as the case may be, the quartz which constitutes the ore (fig. 21).

Frequently the quartz near the greenstone intrusions was noted to be especially cracked, blackened, and mineralized. From one locality two general samples were taken from the same quartz mass; one of the blackened quartz within 2 inches of the greenstone contact, the other of the whiter quartz several inches away from it. The first assay yielded gold, 0.34 oz.; silver, 2.5 oz.; the second, gold, trace; silver, 0.2 oz.

Some connection of the greenstone with the localization of the ore is thus indicated, and it is probable that the connection is that the intrusion of the greenstone has fractured the adjacent quartz so as to provide here channels for the circulations which accomplish the later, and in this case the main, mineralization.

Under the microscope the greenstone proves to be an altered diorite of the usual type. The present constituents are secondary quartz, chlorite, calcite, etc., with much ilmenite and a little pyrite.

VANDERBILT.

As shown on the map, the Vanderbilt mine is a short distance southeast of the Pocatello and is probably on the same zone of lenses. The outcrops of the Vanderbilt extend down the east side of the ridge for about a quarter of a mile, and along this outcrop the ore zone has been developed and worked by open cuts and tunnels.

The ore zone has a general strike of N. 60° E. and dips 20° SE., but varies considerably. Although the zone is persistent, as noted above, and is probably continuous with the Pocatello ore zone, it is doubtful whether any through connection could be traced between the different veins or leads in this zone.

The general geology is like that of the Pocatello. Thin-bedded, bluish limestone, somewhat metamorphosed to schist, is here intruded by more or less lenticular sheets of alaskite (with granitic phases) and of quartz, which is directly transitional into the alaskite. In this quartz the ore occurs, but in such a way as to prove that it is of subsequent origin, like the ores of the Pocatello and the Great Gulch mines. The location of the ore is essentially determined by two conditions—first, the quartz lenses; second, the proximity of the greenstone or diorite sheets or dikes. These sheets are abundant and vary in thickness from a few inches to 3 or 4 feet. They generally lie parallel to the stratification, although they may leave it and crosscut the formation. By preference they follow the series of aligned quartz lenses which constitute a definite zone in the altered shaly limestone. The diorite overlies or underlies the lenses so as to form a hanging or foot wall, or both, or even splits the quartz and divides it (figs. 22 and 23). The quartz near the diorite is strongly fractured parallel to the contact, and in these fracture cracks the black silver-copper mineral which forms the ore has been deposited. Thus the rich ore is oftenest most closely associated with the diorite, and may occur along both the hanging and foot walls of a dike. Where such a dike leaves the zone of quartz lenses, however, as it frequently does, the ore does not follow it, but continues within the lens zone along the contact of some other diorite sheet which has followed the zone more closely. The diorite sheets show a tendency to keep a straight course, so that where the quartz lens zone alters its position rather suddenly by folding or faulting the diorite is apt to keep straight on, and so leave the zone.

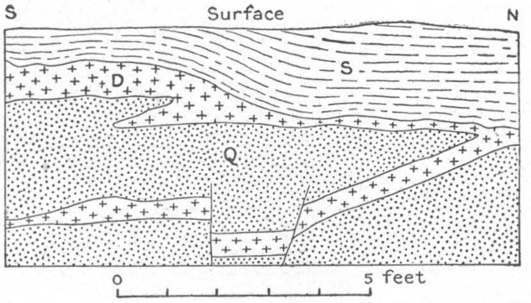

FIG. 22.—Sketch of outcrop, Vanderbilt ore zone, showing greenstone (altered diorite) cutting quartz. S, Limestone schist; Q, quartz (ore); D, greenstone.

A specimen of the altered limestone into which the alaskite and quartz is intruded proves on microscopical study to be a true limestone, containing, however, scattered isolated fresh grains of quartz, orthoclase, and oligoclase-albite, which have probably formed by replacement and are the result of metamorphism due to the siliceous intrusions.

A thin section of a granitic phase of the alaskite contains muscovite and biotite in relatively small amount. Both muscovite and biotite are inclosed in microcline, and the muscovite is inclosed in orthoclase. An interesting feature of this rock is that the quartz grains are sometimes arranged in strings, showing a commencement of segregation which, if carried further, would form a small veinlet. The whole rock is perfectly fresh and uncrushed.

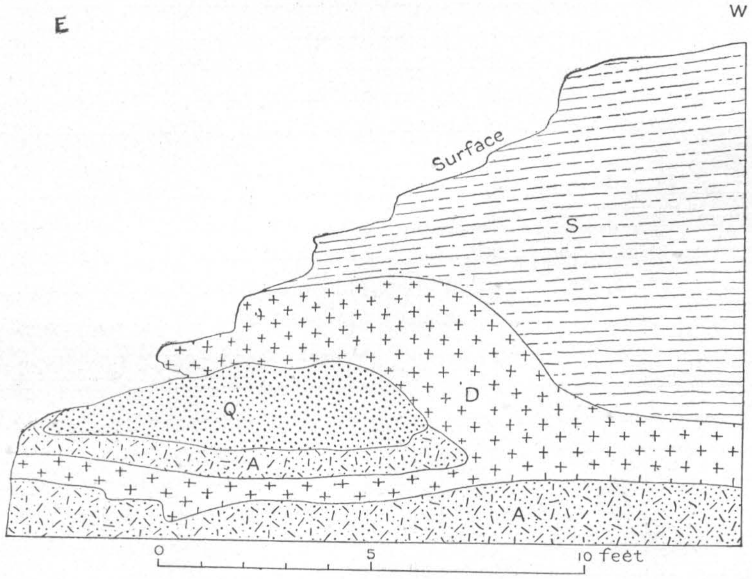

FIG. 23.—Sketch of vertical side of open cut, Vanderbilt mine, showing greenstone (altered diorite) surrounding a small quartz lens. S, Limestone schist; D, greenstone; Q, quartz (ore); A, alaskite.

A specimen of the quartz which constitutes the ore shows under the microscope the peculiar structure noted in the granitic alaskite just described and in almost every specimen of alaskite from Mineral Ridge that has been studied microscopically. The rock is made up of large grains, interstices between which are filled with a cement of much smaller grains, of apparently a later generation. The only difference between this and the alaskites seems to be that here the grains are all quartz; otherwise the texture and structure are similar.

BLACK WARRIOR.

As shown on the map, this abandoned mine is situated in a formation that is different from any of those previously described. It is located in the brown crystalline dolomite which overlies the shaly limestone series of Mineral Ridge. The outcrops of the Black Warrior veins extend west-northwest along the face of the foothills for 100 to 150 yards; they have been opened by considerable workings.

The deposits consist of veins or bands of quartz and jasperoid or silicified marble, running parallel to the bedding planes of the dolomitic marble or occasionally crosscutting them. The veins are irregular in form, without straight walls, and are evidently chiefly due to the replacement of the marble. The jasperoid is a dense-textured rock and is white, like the marble whence it is derived. The microscope shows various stages of silicification between crystalline dolomite and entirely silicified rock, the change being accomplished by the growth of interlocking idiomorphic quartz crystals, which form a typical retiform structure or network like that characteristic of rocks of this origin.[a] The quartz containing the ore is coarser, but has in general the same structure and may be termed a jasperoidal quartz or a semijasperoid. The veins are believed to be the result of replacement of dolomite by waters obtaining access along fracture planes and spreading out also along convenient stratification planes.

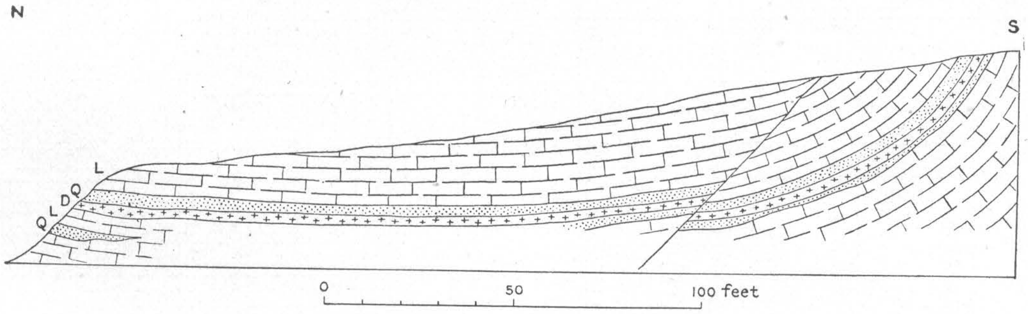

FIG. 24.—Vertical cross section showing relation of vein in main Black Warrior workings. D, Greenstone (altered diorite); Q, quartz (ore); L, brown crystalline dolomite.

The main vein, which is considerably developed by a tunnel, is, like most of the rest, a bedded vein with an average thickness of 3 or 4 feet. Other veins of much the same character are exposed at different places. These veins are only locally productive of high-grade ore. The good ore is characterized by the presence

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[a] Mon. U. S. Geol. Survey, vol. 31, p. 219.

of a black metallic mineral in disseminated streaks in the quartz. This mineral is plainly primary and contemporaneous with the quartz, so that the ore deposit belongs in a somewhat different class from the Vanderbilt and Pocatello silver mines. The values are irregularly disseminated in the quartz vein, and often are especially abundant near the hanging and foot walls. The black ore mineral is evidently the same as in the case of the Pocatello and Vanderbilt, and is rich in both silver and copper. It yields azurite and malachite on oxidation. Disseminated galena also is associated with this "black metal."

Greenstone dikes or sheets occur in the dolomite, chiefly parallel to the bedding. In the main tunnel, where most of the ore was found, a greenstone sheet constitutes the foot wall of the chief vein. The greenstone is a much-altered rock, the microscope showing it to consist entirely of secondary materials like quartz, carbonates, etc. It is of the same character as the greenstone or altered diorite dikes which have been described in connection with nearly every other ore deposit of Mineral Ridge. The relative age of the diorite and of the ore deposit is, in this case, not clear from the observed phenomena. There is no ore in the greenstone, however, (fig. 24).

FOLEY'S AND PALMETTO COMPANY'S PROSPECTS.

These two prospects lie 200 or 300 yards apart, on the extension of the Black Warrior zone. The country rock is brown Cambrian dolomite. The veins consist of white quartz and white or brownish jasperoid, forming regular or irregular bodies, which in several observed cases cut across the faint stratification of the dolomite. None of these veins are traceable very far, but die away along their strike into silicified dolomite. They are evidently largely the result of displacement.

Some of the veins are accompanied by greenstone or altered diorite, which may occur both on the foot or hanging wall or both. It is somewhat uncertain here, as in the Black Warrior, whether the greenstone or the quartz is the older. The accompanying sketch section (fig. 25) shows an exposure which gives the impression that the quartz is the later and has followed and cut a greenstone dike.

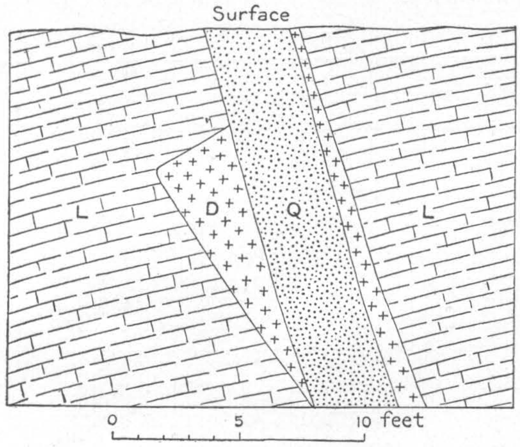

FIG. 25.—Vertical sketch section showing relations of veins at Foley's prospect. Q, Quartz; D, greenstone (altered diorite); L, crystalline dolomite.

The ore is of the same nature as that at the Black Warrior, the values consisting in disseminated sulphides, especially the black metallic mineral, which yields copper on oxidation.

MINES AND PROSPECTS IN THE VICINITY OF LONE MOUNTAIN

ESPERANZA.

The Esperanza is situated on the extreme edge of the area shown on the map. The vein lies in rather thin bedded, often shaly, green and blue limestones, weathering brown. The strata are highly folded. In this formation are small, cross-cutting, irregular veins, and there are also quartz seams following the stratification. These interstratified seams are apt to be of irregular size, not traceable for any long distance, and to be represented rather by irregular quartz veinlets within a given bed or zone than by a regular, well-defined vein.

At the time of the writer's visit the main workings on the Esperanza consisted of a short incline. At the surface the vein showed somewhat over a foot of quartz and was fairly well defined. Along the strike, however, the vein could not be traced far in the same strength. In the quartz the values consist of copper, lead, silver, and gold, especially silver. The ore-bearing minerals consist of the black complex mineral mentioned in previous descriptions (containing all the four metals mentioned) and galena, with pseudomorphs of limonite after pyrite. There is some calcite in parts of the gangue. Secondary chrysocolla was noticed.

PAYMASTER.

The Paymaster is a half mile east of the Esperanza and is outside of the area shown on the map (Pl. XXI, *A*). It is in the same green shaly limestone as the mine previously described. Its rocks are of Cambrian age; the writer collected lower Cambrian trilobites between the Paymaster mine and the Paymaster camp. Some ore has been shipped from both this mine and the Esperanza. The character of the ore is very much alike in the two mines. The upper part of the Paymaster ore was fully oxidized and iron stained, and contained some native silver of secondary origin. The Paymaster vein where opened up near the surface shows 12 to 14 inches of white, rusty, and shattered quartz, with a regular and well-defined wall. About 100 feet southwest of the shaft what is probably the same vein outcrops, only a few inches thick. The thickness also varies vertically, as is shown in the inclined shaft by which the vein has been opened.

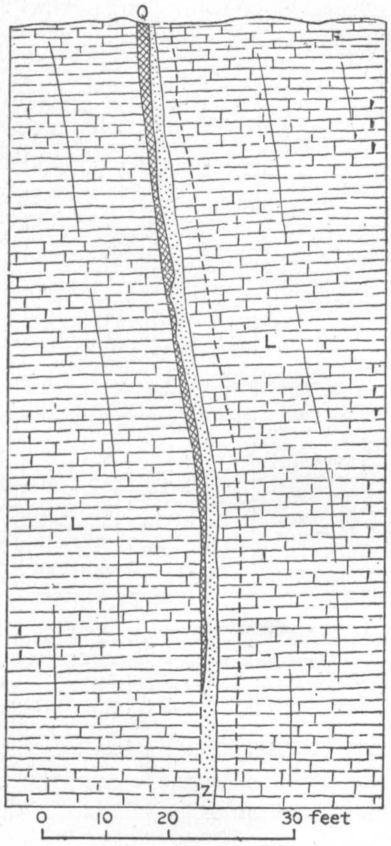

FIG. 26.—Vertical cross section of Paymaster vein at shaft. Dotted lines show shaft; L, shaly limestone (country rock); Z, crushed and decomposed zone; Q, quartz (ore).

The character of the vein zone is more persistent. This is essentially a crushed or fractured zone in limestone, but the amount of quartz which has formed in it is variable and in places the quartz may even disappear (fig. 26).

UTOPIA.

The Utopia is also located outside of the area included on the map, being about a mile and a half north of the Paymaster camp. The country rock is light-colored dolomite (often white), thin bedded, and brown weathering. The mineralized zone, as developed at the time of the writer's visit, was about 500 or 600 yards long and 100 to 200 feet wide and has a general north-south course. In this zone are small, weak, and nonpersistent quartz veins. Usually these veins are less than a foot thick and none of them are traceable far. The general strike of the veins is parallel to the stratification of the Cambrian beds in which they lie, and the general dip is easterly with the dip of the strata. Thus most of the veins are parallel to the stratification, but many cut across the dip and some across the strike. The quartz which constitutes the ore is to be considered as an accompaniment of certain zones of crushed rock which have pretty well defined courses and walls. In these zones the quartz may be scattered or may follow the hanging or the foot wall, but is not usually persistent (figs. 27, 28).

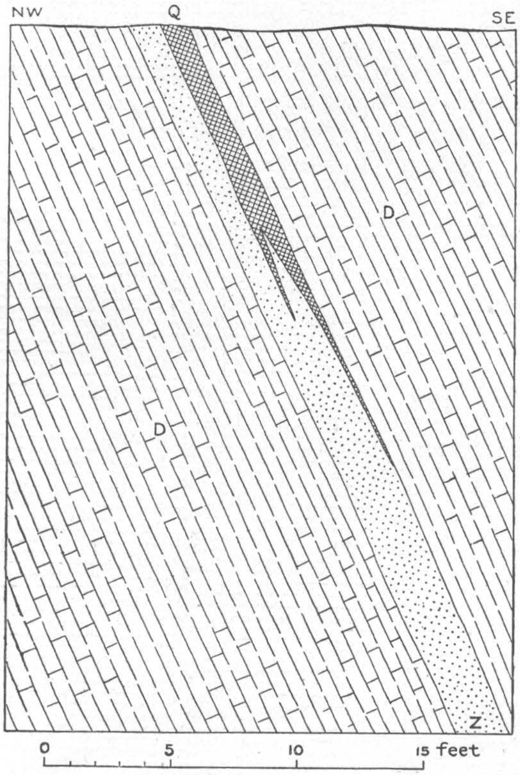

FIG. 27.—Vertical cross section of typical interbedded vein, Utopia prospects. D, Shaly altered dolomite; Z, crushed and decomposed zone; Q, quartz (ore).

These prospects belong in the same geological group as the Paymaster and Esperanza mines previously described. All are small and nonpersistent veins in Cambrian limestones and slates, generally, but not always, parallel with the stratification. All followed similar crushed zones, evidently due to disturbances in the limestones, which afforded channels for the circulating mineralizing solutions; but the supplies of such solutions were certainly very scanty. In all the character of the ore is the same, consisting of a quartz gangue carrying small amounts of rich silver-bearing sulphides with some galena, pyrite, and secondary minerals, such as chrysocolla, probable chloro-bromides of silver, limonite, etc.

At the Utopia the dolomite which forms the walls of the veins becomes characteristically altered and spotted. A specimen of this examined microscopically is found to consist mainly of a fine fibrous mineral, probably sericite, with some quartz.

ENTERPRISE GROUP OF PROSPECTS.

In the northeast corner of the area shown on the map, south of Lone Mountain and also farther east, off the area mapped, there are a number of prospects which have many characters in common. The name is given from the prospects of the Enterprise Company, which are typical.

The Enterprise prospects are situated along a metamorphosed zone in calcareous sediments. This zone, which trends N. 36° E., was followed by the writer for over 1,500 feet and is said to extend for over a mile. The dip is nearly vertical, in general steeply west, with the inclosing formations. A typical cross section of the metamorphosed zone is shown in fig. 29. The zone varies in width, averaging about 60 feet and has sometimes rather indefinite boundaries. It is marked by the coarsely crystalline minerals which are characteristic of metamorphosed impure limestones, principally epidote and garnet. The garnet is usually green in thin section and is optically anomalous, being decidedly doubly refracting, especially the coarse crystals. Other minerals which occur more or less abundantly are magnetite, specular iron, quartz, and calcite. Zoisite, chlorite, actinolite, hornblende, and probable orthoclase, albite, and wollastonite were also found in the thin sections. In one section large idiomorphic crystals of an altered mineral, probably originally andalusite, now entirely decomposed to sericite, quartz, etc., were seen. In places along the zone any of the commoner minerals may become very abundant, so as to form the greater part of certain bands. Thus there are bands of magnetite, epidote, and garnet, respectively, and in one place quartz is abundant to the exclusion of other minerals, forming a "vein" which, however, gradually changes to epidotic rock. Besides the metallic minerals above mentioned pyrite, chalcopyrite, and galena occur in limited amounts, and this ore contains a certain amount of gold and silver. Some of it has been reported to contain tin, but tests of two samples made in the laboratory of the U. S. Geological Survey do not show any. Some silver ore from a point farther north on this same zone is said to have been hauled to Columbus and milled over twenty-five years ago.

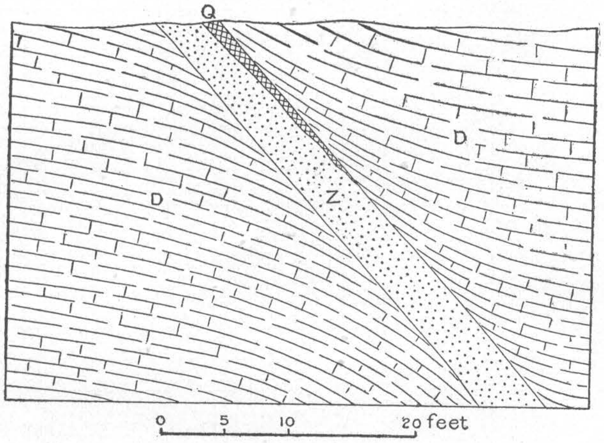

FIG. 28.—Sketch of vein in open cut on Utopia property. D, Altered white dolomite; Z, crushed and decomposed zone (probably sheer or fault zone); Q, quartz (ore).

Bands of white crystalline marble alternate with the bands composed of the other metamorphic minerals just mentioned and also occur above and below these bands.

West of the zone, stretching between it and the contact of the granite, which lies at its nearest point about two-fifths of a mile distant, are thin-bedded slates, considerably metamorphosed and resembling in a general way the calcareous slate series of Mineral Ridge. A specimen of these slates examined microscopically proves to be very fine grained. It consists of lighter portions and slightly darker bunches, which give the schist and hand specimen a spotted appearance. The first-named areas are chiefly sericite, while the spots are more complex, consisting of quartz, sericite, some magnetite, and occasional glaucophane.

On the eastern side of the coarsely crystalline metamorphosed zone which contains the ores the rock is typically dark-blue crystalline limestone, often metamorphosed along certain interstratified bands or along irregular, vein-like, cross-cutting seams to white marble. In some of the marble near the coarsely metamorphosed zone a little tremolite was found by microscopic study.

The situation of the coarse metamorphosed zone which contains the ores and is characterized by coarsely crystalline epidote, garnet, etc., between the metamorphosed slates and the metamorphosed pure limestones indicates that it represents a sedimentary bed of a composition differing from and probably transitional between the rocks on either side—that is to say, probably an impure calcareous sediment. The continuation of metamorphism to the granite contact indicates that the alteration has been due to the granitic intrusion. Such metamorphism, affecting a series of sediments of varied composition, such as we have here, would naturally produce these varied results, and the original composition of a sedimentary bed transitional between a limestone and argillaceous sediment might be sufficient to account for the crystallization of a distinct metamorphic zone marked by its own peculiar minerals, such as occurs here in the zone characterized by epidote and garnet. Within this zone bands of epidotic rock, of pure marble, and of dense metamorphic rock like the metamorphic schist which constitutes the east wall are sharply divided from one another, frequently by absolutely clean and straight lines, as if the different bands represent layers originally different (fig. 30). On the other hand, irregular veins of marble cut across the dark-blue limestone which lies east of the zone under discussion, showing that the metamorphism of the limestone to marble in such cases was accomplished by solutions circulating along cross-cutting fractures (fig. 31). Moreover, within the garnet-epidote zone veins of coarsely crystalline epidote cut and include bunches of denser rock, pointing to the same action as in the case of the marble veins. The frequency of these phenomena indicate that this zone has been also a zone of fracturing.

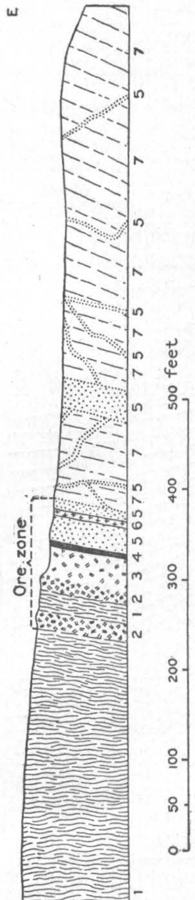

FIG. 29.—Cross section of Enterprise ore zone, showing relations to adjacent strata, taken from a point just within the quadrangle. 1, Black-spotted schists; 2, hard, coarse epidote (chiefly) rock; 3, fine silicified and epidotized rock; 4, chiefly magnetite; 5, dolomite marble (white); 6, altered diorite; 7, dark-blue crystalline limestone.

An intercalated intrusive sheet of diorite about 10 feet thick runs along this ore-bearing metamorphosed zone at one point. It is composed chiefly of feldspar and hornblende and is considerably altered to epidote, cloudy carbonates, and quartz. Throughout most of the zone, however, no diorite was encountered.

The general conclusion reached is that at the time of the intrusion of the near-by granitic mass fractures sufficient to permit an unusual facility of water circulation were formed along a zone of sediments transitional between limestones on the one side and slates on the other. Solutions emanating from the granite penetrated the strata and metamorphosed them for a considerable distance from the contact. Along the fracture zone in impure limestone the circulation was especially vigorous, producing a coarser crystallization. Many of the elements in the metamorphic minerals produced in this zone were probably derived from the original sediment, helping to make the garnet, epidote, etc. On the other hand, various elements were probably introduced into the zone from the granitic solutions—as, for example, the lead, copper, silver, gold, much of the iron, and many other elements in part or in whole.

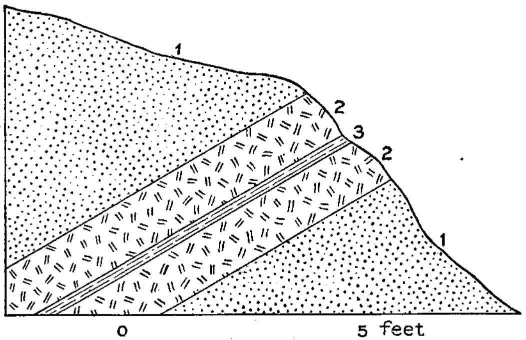

FIG. 30.—Vertical cross section of outcrop of a portion of Enterprise ore zone at one point, showing origin of different bands by alteration of chemically different strata. 1, Pure, coarse, white dolomite marble; 2, green rock containing much epidote; 3, probably metamorphosed calcareous slate (fine-grained mat of quartz, actinolitic amphibole, carbonates, etc.).

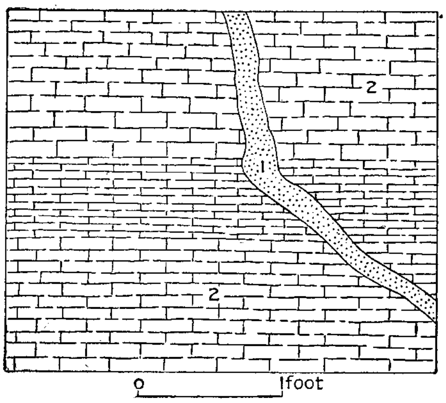

FIG. 31.—Sketch of outcrop near Enterprise ore zone, showing derivation of dolomite marble (1) through solutions circulating along a cross-cutting fracture in blue, sometimes thin-bedded, limestone (2).

The Lone Mountain Syndicate is a prospect having geological conditions similar to those mentioned above but is not on the same zone. Its location, as shown on the map, is over 2 miles northwest of the locality just described. Between the two localities the rocks consist of fine dense quartzites, often containing some epidote, interbedded with crystalline schists which represent altered slates and with some beds of white marble. Bands of epidotic rock also occur. These are distinct from the other rocks, but often associated with marble bands, suggesting again that the original composition of these beds was largely responsible for the formation of epidote by recrystallization during metamorphism. Diorite dikes occur rather sparingly in this series. One which was examined microscopically is different from all the other diorites previously described, in that both the hornblende and the feldspar are comparatively fresh.

In the Lone Mountain Syndicate property a short incline was seen which goes bearing metamorphosed zone at one point. It is composed chiefly of feldspar and hornblende and is considerably altered to epidote, cloudy carbonates, and quartz. Throughout most of the zone, however, no diorite was encountered.

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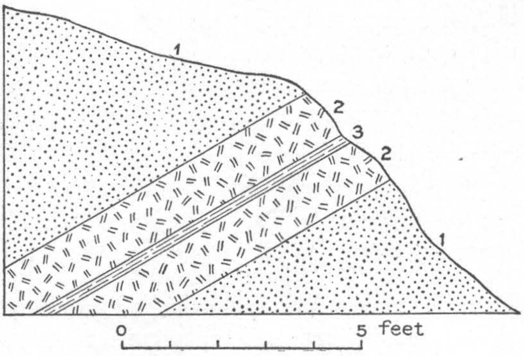

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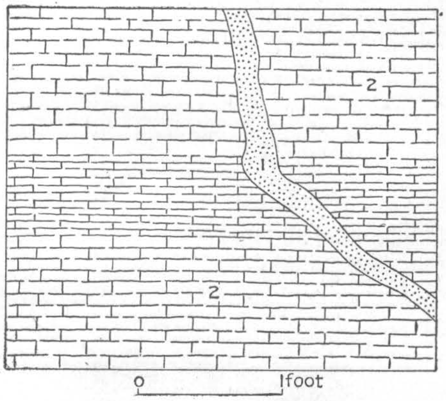

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In the Lone Mountain Syndicate property a short incline was seen which goes consist of a number of prospect shafts and inclines. Some of these are in pegmatite, which contains areas of segregated quartz. Others are in alaskite, generally fine grained and siliceous. These rocks are intrusive into limestone, which has been changed to marble and into beds of silvery mica schist—metamorphosed slate. The alaskite when seen in thin section resembles certain phases of the alaskite from near the Drinkwater mine on Mineral Ridge. It consists, essentially, of quartz and feldspar, the latter with a strong idiomorphic tendency, the former a later crystallization. The feldspar is mostly orthoclase and some oligoclase. There are occasional small primary pink garnets and some primary muscovite, usually in small grains. In places this alaskite has been so altered that the feldspar is entirely changed to sericite. This alteration is associated with fine-grained cellular quartz, which constitutes the mineral exploited in these prospects. Examined microscopically, the quartz is a moderately fine-grained idiomorphic aggregate containing some pyrite. It is reported that this ore was of very low grade, so low as not to be available for mining.

Several hundred feet east of these prospects in the alaskite and associated rocks there is a lens of quartz somewhat over 100 feet in length and 25 feet in maximum thickness, conforming to the stratification of the limestone in which it lies. This quartz wedges out and disappears in both directions along the strike. In its neighborhood is a smaller lens of the same kind, about 25 feet long. The quartz sometimes contains galena and is reported to be a low-grade gold ore.

About 350 feet west of the quartz vein mentioned above is the locality whence the rich ore which created the excitement was taken. The country rock here is gently dipping limestone which has been altered to a fine-grained marble and in places more or less silicified, especially along certain zones. In this limestone there are small bunches of bluish quartz which show a faint copper stain. Calcite is also present. A thin section of the ore shows it to have the typical retiform structure of jasperoid. It has been formed by replacement of the original limestone by silica. This ore contains a black sulphide showing red, yellow, and green alteration products. It is very likely that this is the "black metal" which contains copper and silver in considerable amounts and is one ot the characteristic ore minerals of this whole district. Under the microscope free gold was observed, both intergrown with the black mineral and separate from it. This gold is inclosed in the quartz and is apparently original.

ALPINE.

The Alpine mine is located almost due north of Weepah, over 1 mile beyond the northern edge of the area included within the map. It was, however, visited by the writer and is of some importance, being the only mine among those described from the Lone Mountain region that has produced any considerable amount of ore. This mine shipped $209,000 worth of ore and paid dividends amounting to $70,000 on the results of its first year's work.

The mine is situated in a district which lies near the intrusive contact of the Lone Mountain granitic mass with the Paleozoic limestones and interbedded slates. Near the granite a broad belt of the intruded limestone has been altered to white dolomite marble, while the slates are altered to crystalline schists. This belt is over half a mile wide at the point examined. The strata are folded and faulted and in general dip away from the Lone Mountain granitic mass. The prevailing strike is northerly. The dip is westerly at a rather low angle. At the Alpine mine the prevailing strike is N. 70° W., and the dip is gently south, though the strata are rolling. A short distance farther north, at the Alpine Eagle prospect, the strata strike N. 30° W. and dip 18° SW.

A specimen of a slightly impure bed in the limestone examined microscopically showed biotite, a little quartz, epidote, and serpentine, all developed as the result of metamorphism.

A thin section of one specimen of the Lone Mountain granite shows it to correspond with the granitic phase of the Mineral Ridge alaskite. It consists mainly of feldspar and quartz and very subordinate biotite. Sphene, magnetite, and zircon also occur. The structure of the quartz and feldspar, broadly speaking, is allotriomorphic, but certain turbid portions of the feldspar which show the form of idiomorphic crystals are surrounded by clearer feldspar, the whole being intergrown with quartz. The idiomorphic cores and the clear later growths of feldspar are usually similarly oriented. The cores contain small blades of included original muscovite, while the clearer feldspar does not. The feldspar is mostly orthoclase, both in the case of the earlier and the later crystallizations. Microcline is frequent, but is always fresh and belongs to the later period of crystallization, being contemporaneous with the quartz. This structure is interpreted to mean that after the usual first crystallization of magnetite, sphene, biotite, zircon, etc., idiomorphic feldspar crystals, now occupying about one-fifth of the section, separated out and floated free and detached in the magma. Subsequently these were corroded and partly altered to fine muscovite, for since the cores and the clear margins of the feldspar are both usually orthoclase, the theory of differential weathering or other alteration is not admissible. The phenomena indicate that the spaces between these original idiomorphic feldspar crystals were subsequently filled by crystallization of fresh orthoclase, which, joined on to the older feldspar, produces the present allotriomorphic grains. Subsequent, in general, to this later orthoclase some microcline and quartz crystallized out.

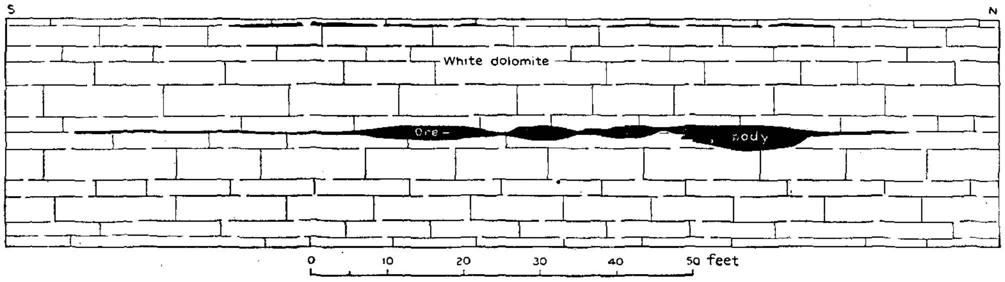

FIG. 32.—Sketch of hillside outcrop of ore body following bedding plane of white dolomite; vertical section, Nevada Alpine mine.

In the metamorphosed belt of sediments near the contact of this granitic intrusion there are numerous seams of ore lying conformable to the strata and, according to prospectors, extending up as far as the granite, but not into it. The ores consist in part of small quartz seams containing galena. These contain silver, but are of low grade and are not mined. However, they lead to bodies of mixed galena and sandy lead carbonates, which often show copper and iron staining, due to oxidation. These ore bodies are the result of the replacement of the dolomite. They widen to irregular pockets or rough lenses and occur separately or strung together along bedding planes in the dolomite. Their general shape and size is best seen by diagrams (figs. 32 and 33). Where examined in the vicinity of the Alpine mine, they are confined to a certain zone in the bedding—that is, the bedding planes which the ore bodies follow are comparatively close together. Thus the three chief ore bodies of the Alpine mine outcrop on the same zone, and farther north the prospects of the Alpine Eagle are at about the same stratigraphic position. Above and below this horizon, however, are lesser lenses of ore, following other stratification planes. These different ore horizons are called "floors" by the miners. In some cases the ore extends to a slight extent away from an interbedded lens, along perpendicular fracture planes at right angles to the bedding, but this is relatively unusual and unimportant. The ore bodies are of limited size and are separated from one another by much longer stretches of barren rock. The prospects which have been found outside of the horizon upon which the Alpine mine is situated have not yielded any considerable amount of pay ore. There is very little quartz in the rich ore, but along the edges of the pockets galena-bearing quartz comes in, similar in nature to the low-grade quartz seams noted above.

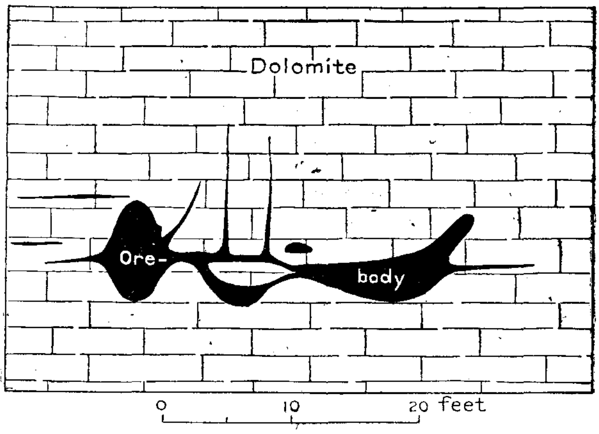

FIG. 33.—Sketch (vertical section) of outcrop of ore body (chiefly cerussite) in dolomite marble, Nevada Alpine mine, Lone Mountain district.

In and near the ore bodies the dolomite is characteristically altered to talc, evidently by siliceous solutions acting upon the dolomite. This talc is sometimes stained green by copper. This characteristic alteration occurs both near the low-grade quartz veins and the richer replacement deposits, indicating a common origin for both.

In the ore of the replacement deposits the lead carbonate is several times richer in silver than the galena. The shipping ore at the time of the writer's visit was said to carry 100 ounces of silver and up to 50 per cent of lead. The superior richness of the carbonate is probably due to an enrichment of the original values during alteration in the weathered zone. The galena found in the quartz on the edges of the richer ore is not altered to carbonate, which is probably due to the fact that the inclosing quartz has protected it.

Diorite sheets, and to a less extent cross-cutting dikes, are abundant in the marble and occasionally in the granite, but do not seem to be in any way associated with the ore and are propably of later origin.

PROSPECTS IN THE SOUTHERN HALF OF THE QUADRANGLE.

DYER DISTRICT.

The Dyer district is located a mile east of Dyer's ranch, in Fish Lake Valley. It lies a short distance beyond the western edge of the area shown on the map just west and northwest of the small area of granitic rocks south of the junction of the southeastern edge of Fish Lake Valley with the foothills of the range, at the point where this junction is cut by the western boundary of the area mapped. In this district, within a space of about 1 square mile, are a number of prospects, which, it is reported, were worked upon in 1863 and 1864, though no ore was shipped. Later on these and other prospects were worked, especially between 1884 and 1887. From one of the prospects a few tons of ore are said to have been shipped to the Monte Diablo mill in Sodaville in 1887, and from another prospect some ore is said to have been shipped to Columbus. At this period a mining camp sprung up here, which, however, was short lived. Since the discovery of Tonopah these claims have been relocated, but when visited by the writer in the summer of 1903 nothing had been done, in most cases not even assessment work.

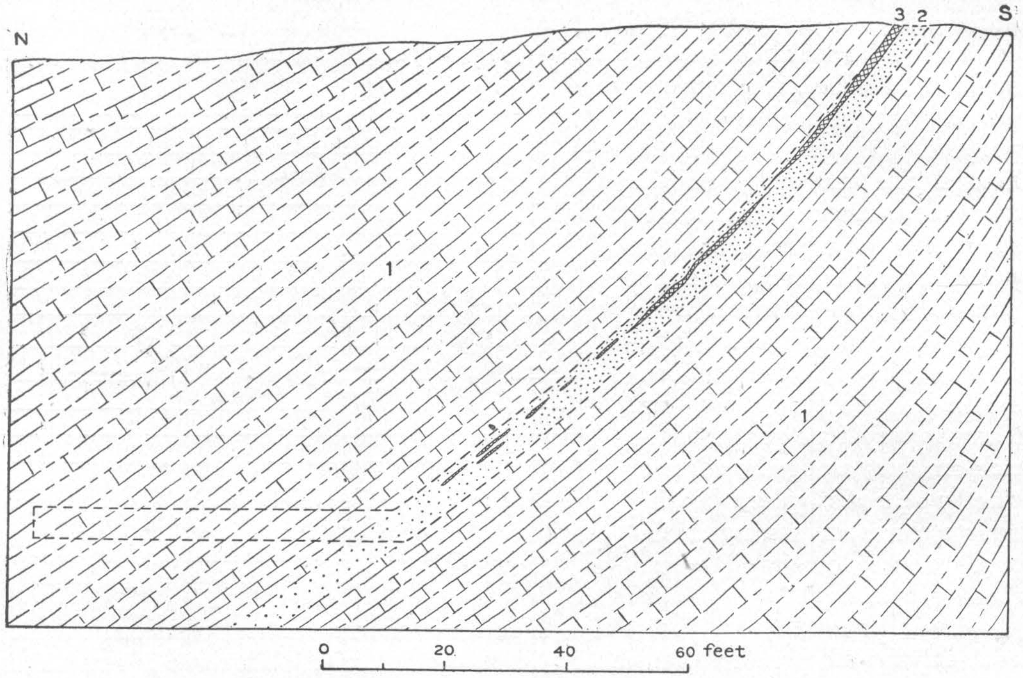

FIG. 34.—Vertical section of chief prospect in Dyer district. 1, Thin-bedded slaty limestone; 2, crushed and decomposed zone along bedding, growing less in depth; 3, quartz (ore); short dash lines show incline and cross cut.

The prospects are on zones of crushed and decomposed rock, almost always parallel to the stratification of the thin-bedded, siliceous, shaly limestones in which they occur. Separate crushed layers of this sort sometimes unite by thickening up. Within these crushed zones there are discontinuous, irregular, and small stringers of quartz, carrying the black silver-copper sulphide ("black metal") that is characteristic of the silver ores of the quadrangle. When oxidized, these ores are crumbling and show iron and copper stains, and a yellow-green stain that is probably silver chloride. Both vertically and horizontally the ore is apt to peter out rapidly and disappear, giving place to the soft gouge of the crushed zone, exactly as in the case of the group of veins of which the Paymaster, Esperanza, and Utopia are examples. In fact the group of veins just mentioned is identical in every geologic feature with those in the Dyer district, except that those last named are weaker. The crushed zone also, though more persistent than the argentiferous quartz which it contains, frequently becomes weak in a short distance and passes into fractured limestone. Fig. 34 gives a cross section of the most important of these prospects visited. Throughout the district examined the limestone is full of bunches of quartz similar to those described, but discontinuous as to horizontal and vertical extent, and changing very rapidly to absolutely nothing. They are nearly all bedding-plane deposits.

The values in these ores are silver, the picked ore in one or two of the most important prospects being claimed to assay from 74 to 120 ounces silver. A few hundred yards south of one of the principal prospects mentioned above there is an outcrop of specular iron ore, opened up by an open cut and a little incline. This ore is in sandy siliceous limestone and seems to be essentially a bedding-plane deposit, from which tongues cross cut the formation irregularly. The ore deposit seems to have no definite shape, and the ore does not seem to be in any considerable quantity.

GOOD HOPE PROSPECT.

This was not visited by the writer. The following description is by Mr. H. W. Turner:

> The abandoned Good Hope mine is situated about 7 miles south of Piper Peak. The country rock is slate, presumed to be of Ordovician age. The beds strike northwest-southeast and dip NE. 40°. In these slates is a layer of a light-colored quartzite, and along the contact of the quartzite with the underlying slates there is more or less quartz containing galena and showing copper stains. There are several cuts and tunnels and a stone cabin in the gulch to the south. The ore is said to have been worked for silver and reduced in a little furnace on Furnace Creek in the foothills of the Inyo Mountains.

WINDYPAH, OR FESLER, DISTRICT.

GENERAL FEATURES.

In this district there are a number of prospects, but at the time of the writer's visit, in the summer of 1903, there were no developed mines. The district is located in the southwestern part of the area included in the map. Geologically the prospects are centered around the intrusive granitic body which is found in that region, the deposits occurring either in the granite or in the contiguous Paleozoic limestones and slates into which the granite is intrusive. The district was discovered in the winter of 1903 by J. E. Fesler.

Some of the granite of the district is similar in appearance to the granite of the Lone Mountain district in the northeastern part of the quadrangle. Other phases are coarsely porphyritic, with phenocrysts of feldspar, some as much as 3 inches in length. In this granite and in the limestone near the granite contact are frequent aplitic dikes, usually of alaskite, often containing nests of segregated quartz. These dikes are regarded as a phase of the granitic intrusion, later in consolidation than the main mass of the granite, and are believed to have been separated from the granitic magma by the crystallization of the less siliceous typical granite. In the portion of the granite exposed at the present surface the aplitic dikes of alaskite usually cut the granite and show the ordinary phenomena of intrusion. In this case they have evidently not segregated directly from the granite with which they are in contact, but were probably derived from a lower horizon, whence they have ascended to cut the overlying cooler and earlier consolidated granite.

VEINS.

The veins found in this district are divisible into four distinct classes:

1. Segregations in alaskite. These consist of lenses and bunches of quartz of very limited size, directly segregated out of and contemporaneous with surrounding alaskite. The lenses have not been proved in any case to be of large size or abundant or to have any regular connection between themselves. The quartz, as well as some of the alaskite, contains original pyrite and sometimes shows good values in gold.

2. Quartz veins following along shear zones in granite. These veins are locally xenogenous, having penetrated the granite along crushed or shear zones. The supplies of mineralizing solutions have evidently not been copious, nor were the channels strong. This is shown by the fact that the walls are ill defined and the amount of quartz variable. The mineralogical character is like that of the veins of the first class, the quartz carrying scattered auriferous pyrite. Locally good assays in gold are obtained, but as all the workings are near the surface the values in this and other classes have probably been concentrated during oxidation. The veins, however, are in general better defined than those of the first class and are occasionally traceable some little distance. Often, however, they have the form of numerous stringers in the granite whose extension is uncertain. These ores also probably have a genetic connection with the granitic intrusion. It is believed that highly siliceous residual material segregated from the consolidating granitic intrusion at a somewhat lower horizon has ascended and penetrated and mineralized the already consolidated granite along available channels caused by fracture.

3. Veins in the limestones and slates at or near the contact of granite. These belong mineralogically in the class of noble silver-quartz veins or quartz veins containing highly argentiferous minerals with relatively small amounts of baser minerals. They are characterized by rich black auriferous sulphide of silver and copper—the "black metal" of Nevada miners. The nature of this mineral, which has previously been frequently referred to, will be discussed further on (p. 91). Veins of this sort are very persistent, following at or near the granitic contact sometimes for miles, or extending in a direction away from the contact almost or quite as far. A favorite location for these veins is along the contact of alaskite dikes with limestone. These veins, though persistent in length and probably in depth, do not as a rule have well-defined walls and are to be regarded as replacements of the wall rock along fracture zones. Frequently an alaskite dike has such a vein on both sides, though

more or less intermittent. The ore oxidizes to silver chloride, copper carbonate, and free gold.

4. Lastly comes a type of veins intermediate between the second and third described above. These are veins in the granite carrying, so far as studied, almost entirely gold values, but having a mineralogical composition intermediate between classes 2 and 3. Besides pyrite, they contain more or less black metal, as well as chalcopyrite and galena, and alteration may produce characteristic oxides and carbonates, such as malachite, cerussite, probable black oxide of copper, etc.

These four classes of veins are all believed to have been due to different forms of the same mineralizing agent, namely, the siliceous fluid which was segregated out of the granitic magma by the crystallization of the earlier granitic materials that form the true igneous rocks.

The first class has segregated directly from the alaskite, which is a phase of the granite; the ore has the same relation to the alaskite that the latter has to the granite. The alaskite is a granite without biotite; the quartz is an alaskite without feldspar. The segregated quartz, as is shown elsewhere in this report, is in this case of the same age and generation as the granules of quartz which make up a large proportion of the alaskite and granite.

The second class has probably segregated from the granitic magma in the manner above noted, but at a lower or slightly different locality, and has found its way into or near the granite, veinwise.

The third class represents the work of similar magmatic juice, which has penetrated the intruded limestones and slates near the granitic contacts and has deposited silica and metals chiefly by the process of replacement.

The fourth class, which is believed to have had a similar origin to the first three, is valuable as illustrating a mineralogical connection between the gold veins in the granite and the silver veins in the limestone, and so favoring further the theory of common origin.

The quartz veins in the limestone are marked by relative abundance of quartz with rather sporadic mineralization, while those in the granite are usually smaller and not so well defined, but frequently carry better values, at least near the surface.

DIVIDEND TYPE.

The class of deposits due directly to segregation is illustrated by the Dividend and similar prospects. The Dividend lies near the center of the granitic area, within a zone of alaskite 150 yards wide, which is itself intrusive into the granite and runs off several miles at least in a northwesterly direction. At the Dividend the alaskite contains small bunches and veinlets of quartz. These are irregularly distributed, having no definite trend and forming no definite vein. In the quartz and in the neighboring alaskite there is some original pyrite mainly oxidized to hematite. In both cases the pyrite is claimed to be auriferous. Some perfectly fresh alaskite was seen, which was claimed to be second-class ore, but an assay made for the writer by Mr. R. H. Officer showed traces only of gold and silver. Microscopic examination of this material shows a perfectly fresh and unstrained typical quartz-feldspar rock. A specimen of first-class ore, which is claimed to run up to $250 per ton when sorted, was found to be alaskite similar in original composition to the fresh alaskite just mentioned, but with its feldspar entirely decomposed to sericite. In some of this ore free gold is visible, probably the product of oxidation of the pyrites. It is probable that there has been near the surface some enrichment by the process of oxidation. The values are all in gold.

The alaskite here is fine and even grained and contains quartz and feldspar in about equal proportions. The feldspar is both orthoclase and striated feldspar probably albite. In form the feldspar is idiomorphic to hypidiomorphic, and the quartz occupies interspaces. Sometimes the feldspar is broken into and separated by the intrusion of the quartz. Both of the above-mentioned phenomena indicate that the quartz crystallized as a rule decidedly subsequent to the feldspar. Some portions of the alaskite mass, as seen under the microscope, contain much more quartz than others, so that typical granular vein quartz results usually in parallel bands, this quartz being perfectly contemporaneous with the intergranular quartz of the quartz-feldspar rock. Besides the original pyrite, which is frequently found in the alaskite and also in the segregated quartz and which is altered to limonite or hematite, there are small specks of magnetite and occasionally some probably original crystals of hematite. Biotite is occasionally found, and a little sphene and zircon. In some cases the feldspar is partially altered to sericite, and sometimes it is entirely decomposed.

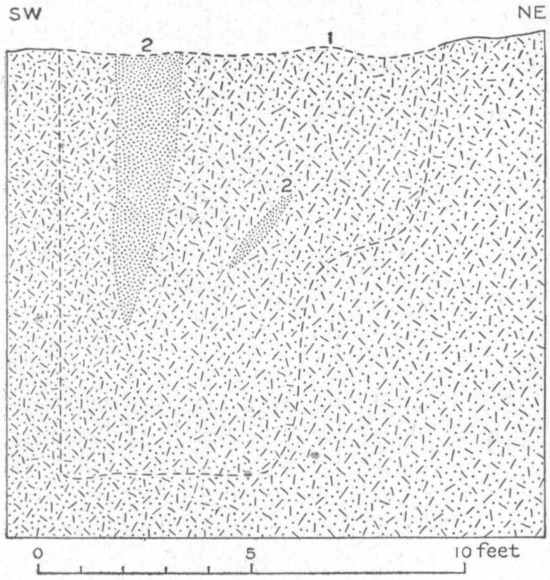

FIG. 35.—Sketch vertical cross section of prospect hole on Arroyo Grande claim, Windypah district. 1, Alaskite; 2, quartz, auriferous; dotted outlines show pit.

A quarter of a mile northwest of the Dividend, in the same alaskite dike, is a prospect called the Magpie, showing an open cut on some small quartz lenses. The geology is the same as at the Dividend. Here the quartz veins are mixed in places with coarse feldspar, indicating their origin. The inclosing alaskite, when examined microscopically, is found to consist of quartz and feldspar in varying proportions. In some thin sections the contemporaneous crystallization of quartz and feldspar is shown, which is unusual for this region. In some portions of a certain slide, for example, the feldspar is idiomorphic; but in other portions the quartz has an idiomorphic tendency against the allotriomorphic orthoclase. As a rule, however, the feldspar is distinctly older, and in other slides the quartz is seen in the process of segregation, showing beautifully the genesis of segregated quartz veinlets (Pl. XXII). By this process typical vein quartz forms in places, having near the edges frequent small idiomorphic crystals of feldspar, like those of the adjacent alaskite, entirely surrounded by the quartz. In these rocks also original pyrite is present. The feldspar consists of orthoclase and probable albite, and becomes turbid from sericitization or kaolinization.

About 1,500 feet northwest of the Magpie, along the same alaskite dike, is another unimportant prospect called the Arroyo Grande. The alaskite here is more or less silicified and iron stained, with small areas of fine granular, quartzite-like segregated quartz. There are several quartz lenses, the largest observed being 1½ feet thick and 6 or 8 feet long at this point, but they have no definite extension (fig. 35). The values here are said to be entirely gold.

HECTOR TYPE.

The Hector vein is a decomposed shear zone in the granite, about 1,000 feet away from the contact. This shear zone is partially and irregularly occupied by decomposed, friable, and iron-stained quartz. The walls of the vein are poorly marked. It has a strike of N. 45° W. and a dip of 60° SW., and was opened up at the time of the writer's visit by an incline shaft 55 feet down (fig. 36). The granite of the walls is decomposed. It is a coarse, chiefly feldspar-quartz rock with little biotite. Some apatite, sphene, and magnetite are present. The feldspar is sericitized and kaolinized to a variable extent. The vein quartz contains scattered pyrite, and assays are reported to show values in gold, with only traces of silver.

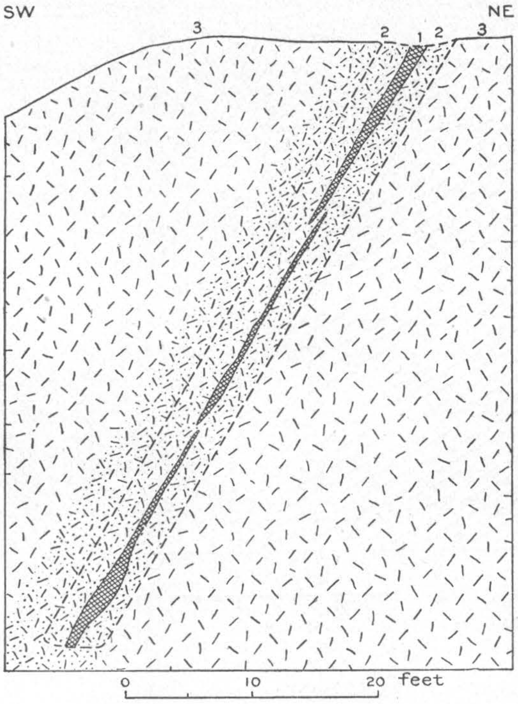

FIG. 36.—Vertical cross section of Hector vein. 1, Quartz (ore); 2, white decomposed granite; 3, gray partly altered granite.

North of the Hector, on the same hill, are similar smaller veins, being stringers of pyritiferous quartz in decomposed granite. They have a general west to northwest strike. Some of this material shows free gold.

The Hunkidori prospect is located about 1,200 feet west of the Hector and a little south, and is also in granite. This rock is a medium-grained biotite-granite, having a different texture from that at the Hector in that it contains very large feldspar phenocrysts. In this granite there is a crushed zone 2 feet wide, with no clean wall. It contains mixed quartz and iron-stained granitic material, the quartz being especially abundant near the foot wall of the zone. This vein is said to have gold values and to horn free gold.

A few thousand feet southeast of the above prospect is another called the Richmond Chief. This is in granite of variable texture, changing from a granular form to one that is coarse and almost pegmatitic, with extremely large feldspar phenocrysts. This granite contains areas of decomposed basic rocks which are probably dioritic dikes. A quartz vein cuts across the granite and is exposed for some distance along the hill. This is probably subsequent in origin to the diorite. In places this vein shows pyrite, largely oxidized, with some faint copper stains. It is said to assay gold.

CHLORIDE TYPE.

A prospect called the Chloride is located north of the Hector, in calcareous sediments, a few hundred feet from the northern contact of the granite. The vein here has a general strike of N. 58° to N. 70° W. It is situated on the contact between the altered calcareous strata on the southwest and an alaskite dike on the northeast. This alaskite is of a type similar to that at the Dividend, consisting of quartz, orthoclase, probable albite, etc., but the structure is finely porphyritic rather than evenly granular. The alaskite is decomposed near the vein and in places contains subsequent pyrite, indicating that the vein is subsequent in origin to the alaskite. In places there are similar veins on both sides of the dike. This vein or vein zone is said to be traceable for several miles, in general parallel to and near the contact of the granite.

The vein at the point examined is variable in width, with irregular walls. It consists of quartz and brown jasperoid mixed with altered wall rock, with chalcedony and calcite coatings on the cracks (fig. 37). It contains black metal or copper-silver sulphide, some of which, it is reported, assayed over 1,500 ounces. The values throughout are chiefly in silver, with some gold.

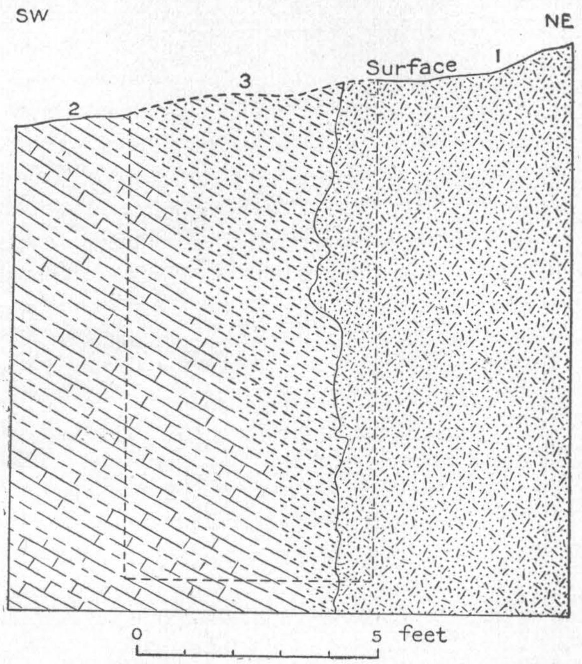

FIG. 37.—Vertical sketch cross section of Chloride vein. 1, Alaskite; 2, thin-bedded slaty limestone (altered); 3, silicified limestone (hornstone) and quartz containing metallic minerals (ore); outlines of prospect pit shown by dotted lines.

Southwest of the Chloride, on the opposite or south side of the granite, a similar quartz vein occurs at the contact of the granite with calcareous strata. The extension of this vein is marked by prominent though irregular outcrops of quartz several feet across. The vein has been opened up only by a few pits. The values are said to be chiefly silver, with some gold. On this ledge two claims have been located to the west of the point examined and six or seven to the east, thus covering a length of over 2 miles.

In the sedimentary rocks about 2 miles east-southeast of the point where the above vein was examined a similar vein-zone outcrops at intervals along a generally north-northeast line, running nearly perpendicularly to this granite contact and crossing the strata to another granite contact farther south. At several points along this vein zone prospects were visited. At the northernmost locality, not far from the granite, there is a quartz vein several feet thick, sometimes brecciated, containing cavities left by the dissolution of pyrite. The country rock is a metamorphosed slate, consisting chiefly of quartz with fine lamellar green biotite, with some tourmaline, magnetite, epidote, and scattered crystals of dark red, probable rutile. There is a parallel and larger quartz ledge 150 yards away from this one. Farther south along the same general zone, at the Victoria prospect, there are small irregular stringers of quartz in metamorphosed slate. This quartz shows galena and copper pyrite, the latter partly altered to malachite and chrysocolla. The ore is said to contain gold and silver. There are chalcedony coatings on some of the cracks. The country rock here is like that just described. Somewhat over 1,000 feet still farther southwest on this zone, at the Fesler prospect, the character of the vein is like that last described. Some of the formation here is a knotted schist, which, when examined microscopically, proved to be practically the same as the country rock farther north. The knotted portions are irregularly segregated bunches of biotite.

From this point southward along the zone similar outcrops occur at several places. About 1¼ miles farther southwest is the Sib prospect. This shows a quartz vein about 4 feet thick, outcropping in an arc-shaped form for about 90 feet, then passing under the Pleistocene drift on both sides. The vein has a general N. 55° W. strike, and dips 65° NE. The country rock is white and brown crystalline limestone or dolomite. The property is opened up by a shaft 20 feet deep and a pit 6 feet deep. The pit shows nearly 4 feet of solid quartz, with limy streaks. In the shaft the quartz is found next to the unaltered country rock, and the solid portion of the vein is 1 foot thick, but is not persistent, fading away above and below. This weakening and dying out indicates that the veins have originated largely by replacement.

These veins contain, scattered in the quartz gangue, small bunches of metallic mineral. Galena is often present, and chalcopyrite, the latter usually largely altered to black massive secondary oxides or sulphides. The most important ore mineral, however, is dull black and massive. It is usually partly altered to red and blue copper minerals, probably both carbonates and silicate (malachite, azurite, chrysocolla), and it is perhaps on this account that even where the alteration is not perceptible to the eye the mineral gives a greenish streak. This material is highly argentiferous, and is usually called by the miners "black metal." It also contains gold. Specks of free gold were observed in one of the specimens collected. Dr. W. T. Hillebrand, who examined this mineral, found that it consisted principally of some of the oxides of antimony, colored by undecomposed sulphide. This sulphide may be either a residual portion of an original copper-antimony-silver sulphide or may be some secondary sulphide. The silver, of which considerable is present, is not in the form of chloride, but whether as sulphide or antimonate was not determined. The material is evidently partly oxidized and altered from its original condition. The margin of blue-green copper staining around the areas of the black mineral shows that the latter has lost some copper; while the antimony and silver would be less likely to have been removed. The original material was probably a sulphantimonate or sulphantimonite of copper and silver. In its present form the mineral appears very similar to stetefeldtite, a substance that has been described from various of the older mining camps of Nevada, such as the Empire and Philadelphia districts, though probably not containing as much silver as the latter.[a] Analyses show that stetefeldtite is a mixed oxide and sulphide and probably an alteration product. Materials more or less similar to stetefeldtite have been described as due to the alteration of sulphides. The most likely original sulphide from which such an alteration material as the Silver Peak ore under consideration could come is argentiferous tetrahedrite; and the material described as stetefeldtite may have had a similar origin.

One assay from this prospect is said to have yielded 1,186 ounces of silver, 31 per cent copper and 3.8 ounces gold. This was probably pure "black metal."

CONFIDENCE TYPE.

The Confidence prospect is located nearly 2½ miles southwest of the Sib. It shows a persistent vein 6 or 8 inches thick, with granite on both walls, that strikes N. 87° E., dips 78° S., and has been traced for 2,000 feet. The quartz is iron stained and shows cavities left by the dissolution of pyrite. It also contains small spots of coarsely crystalline galena; also some "black metal" or copper-silver sulphide. At some places the quartz is mixed with much jasper, and chalcedony coatings line cavities. Secondary cerussite, malachite, etc., occur. The values in this prospect are said to be chiefly gold, but on account of the mineral constituents it forms an interesting link between the veins of the Hector type and those of the Chloride type.

Over 2 miles north of the Confidence is the Widow prospect, in coarse granite cut by altered diorite. The diorite now consists entirely of secondary minerals, such as epidote, quartz, and brown-green biotite. The vein lies on the under contact of the diorite dike with granite and has a strike N. 85° W., nearly parallel to that of the Confidence. The dip is 34° south. The vein is fairly regular, a foot or 14 inches in thickness, but in places opens out irregularly to as much as 3½ feet (fig. 38). It is said to carry considerable values of gold and a very little silver. The ore shows more or less decomposed pyrite and chalcopyrite, with some probable "black metal." The chalcopyrite is altered to malachite, and in part also probably to black copper oxide.

PALMETTO DISTRICT.

The portion of this district comprised within the quadrangle lies in its southeastern part, on the north slope of the Palmetto Mountains. In the same general region are more important districts which, since they are outside of the area examined, were not visited and are not described. They lie south and southwest of the district which has been investigated. The deposits within the quadrangle are all prospects, and are in and near a body of intrusive granitic rock, with aplitic facies, which cuts the Paleozoic sediments. The geological conditions and the nature of the ores are very similar to those in the Windypah district.

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[a] Dana, E. S., System of Mineralogy, 6th ed., p. 204.

MACNAMARA.

The MacNamara group of prospects is located near Indian Garden, on claims located by Matthew MacNamara in 1880. The two principal claims are the Bullion and Mammoth. Assessment work was done upon these for twenty years, but there has been no real production. In the spring of 1903, Messrs. Lynch and O'Meara, of Tonopah, worked the prospects somewhat on a bond, but did not take it up.

This deposit is situated not far from the contact of the main granitic intrusion, in a locality where the calcareous and siliceous sediments are cut by a complex of alaskite dikes, which probably represent a later phase of the granitic intrusion. Although quartz with some copper staining and considerable iron is found at various points in the intruded sediments, generally in streaks having a northwesterly direction, only the one vein opened up in the above-mentioned prospects has developed any quantity of ore. Where this vein is most productive it consists of quartz, replacing and penetrating the altered calcareous sediment on the under side of an alaskite dike.

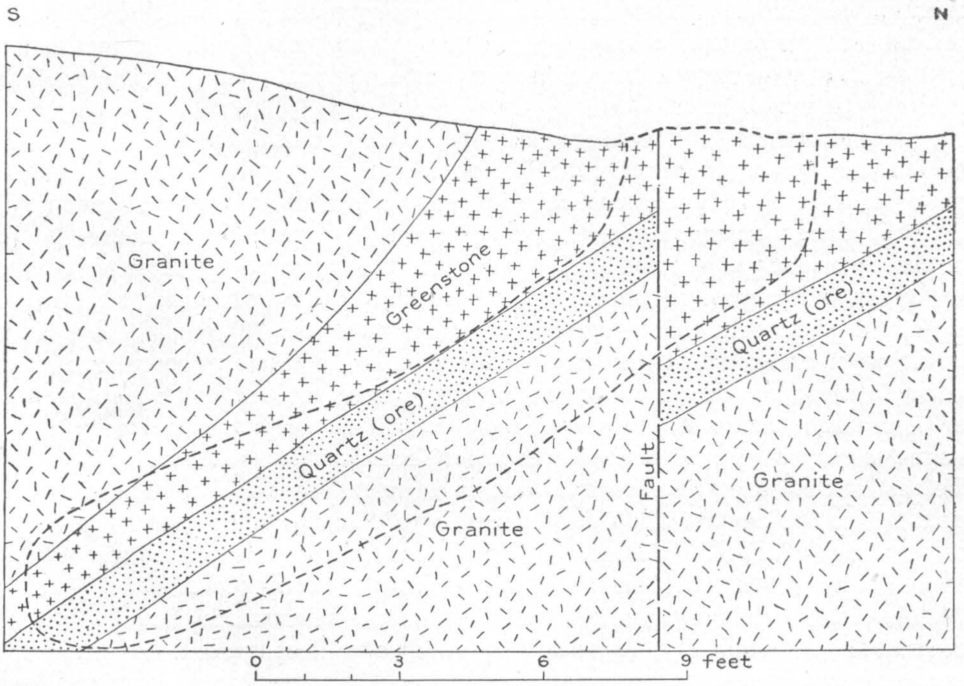

FIG. 38.—Vertical cross section at Widow prospect, showing relation of vein to greenstone dike. Dotted lines show outlines of incline.

The unaltered impure limestone of this region is rather thin bedded and light blue, with cherty bands. Within the area cut by the alaskite dikes it becomes metamorphic, showing silicification, in extreme cases leading to the production of hornstone or jasperoid and also containing garnet and epidote. In some of the garnet-bearing bands are white quartz veinlets, which have apparently the same origin as the other metamorphic minerals. A number of thin sections of these metamorphic sedimentary rocks were examined microscopically. One, which appears to be an altered shale, is now composed chiefly of fine cherty quartz, sericite, chlorite, and garnet, with accessory magnetite, orthoclase, and tourmaline. A number of other thin sections showed variations of a single kind of metamorphic rock, consisting chiefly of quartz, with abundant clear, translucent, greenish garnets, which often show beautiful optical anomalies. Sometimes dark-brown opaque garnets of smaller size, of a different variety from that mentioned, are abundant. In the garnet in every case are abundant tabular crystals with a moderately high single and double refraction. In some cases these are colorless, in other cases they are red, and still others green, or the red and green coloring may be mottled. In certain crystals where the coloring matter is bunched or segregated, however, the red coloring is seen to be due to disseminated hematite and the green coloring to disseminated chlorite. The mineral is probably malacolite. Other constituent minerals are magnetite, calcite, and in some cases muscovite. A metamorphic rock of different variety is fine grained and consists mostly of quartz, epidote, and brucite, with some zircon.

The vein which has been prospected is locally strong, but has no good walls and is rather weakly mineralized. The outcrop is marked by frequent bunches of brown jasperoid. It is also marked by a conspicuous red iron-stained zone running N. 50° W. for an observed distance of half a mile, and probably farther. The prospect is opened by a shaft 100 feet deep on the vein and by three adit tunnels, the lowest and longest of which runs in 230 feet to the vein and a little distance beyond it. The vein as opened in the workings shows 10 feet of ledge matter, consisting of cracked and decomposed limestone. In this are irregular streaks of quartz, some of which show galena, chiefly coarse grained, with lead carbonate and some slight malachite stains. It has also a little pyrite and chalcopyrite. The gangue is quartz. Some barite is reported, but was not observed by the writer. The best of the ore, carefully sorted out, is estimated by a local prospector to yield about $50 to $80 per ton, the values consisting of $2 in gold, 80 ounces in silver, and the rest lead. Mr. H. W. Turner had some of the galena from this mine assayed, which showed $11 in gold, 54 ounces of silver, and 76 per cent lead.

The alaskite dike along whose under surface the vein runs is about 10 feet thick. Examined microscopically, the rock was found to be decomposed, the original feldspar being represented by masses of fine sericite. In some places the original quartz showed a tendency to be strung along in chains. Some limonite, seen in the thin section, was probably due to the oxidation of original pyrite.

The crushing which formed a channel for the mineralizing solutions that deposited the vein was very likely accomplished at the time of the alaskite intrusion and perhaps by its agency. This will explain the localization of the vein along the alaskite dike, which is a relation similar to that observed for similar veins in the Windypah district. Some of the movement, however, appears to have been subsequent to the alaskite intrusion, and the alaskite itself is in places partially affected and is frequently decomposed.

A dike of fine altered diorite, of the familiar type noted in all other mining districts in this quadrangle, was observed in this neighborhood, but has no connection with the principal prospect or with the veins in general.

PAYMASTER ZONE.

This is shown on the map as a long zone of veins, all probably occupying the same fracture zone, but not known to be entirely connected. The entire extent is about 4 miles, and part of the zone lies in granite or alaskite and part in the intruded sediments. The general strike is west-northwest, parallel to the long axis of the granitic intrusion.

The westernmost part of the zone visited is that where the Nevada and California claims are located. These were located in 1880, and, having lapsed, were relocated in 1903. The veins lie in alaskite, which constitutes a considerable mass on the border of the granite. A specimen of the alaskite from the wall of a vein at one point was found to be quite fresh, consisting of quartz and feldspar in about equal proportions. The feldspar shows a tendency to idiomorphism, while the quartz is subsequent. In some cases the quartz cuts across the older feldspar. Quartz grains have a tendency to segregate in connected and elongated areas; definite quartz veinlets may thus result. The straight walls for part of the course of such veinlets indicate that the mass was in part brittle enough to be fractured and forced asunder even while the crystals of the quartz veins were filling the interstices between the feldspar crystals. A connecting spongy mass of contiguous feldspar crystals is thus evidenced, saturated with the residual magma which deposited the quartz. The feldspar here is orthoclase, microperthite, and oligoclase-albite. There is accessory zircon and magnetite. Another specimen of the alaskite taken from the vein wall at a different locality was similar but was altered, the feldspars having changed to very fine sericite.

On the whole the quartz veins are slightly later locally than the alaskite, but the relations indicate that the quartz has segregated from the alaskite. The separate quartz bodies along the vein zone are not persistent, often running into portions which become mixed with feldspar and appear to give way to alaskite. The thickness of the quartz is variable, but it attains a maximum of several feet. On the outcrop the ridges of quartz are offset one from another, and both this and the observed fact that the quartz may diminish in thickness going down, as observed in a small incline here, indicate that the quartz bodies are roughly lenticular in form.

The quartz shows copper and iron pyrites. The values are said to be in gold, but to be low. In one place the highest assay is said to have been $6 in gold, while at another picked samples are said to have gone from $10 to $30 in gold.

The Reliance is another abandoned property, on the same trend as the California and Nevada and about 1 mile east of these claims. The Reliance and the adjoining. Helpmeet claims are located on an east-west striking lode zone in alaskite and granite A specimen of the granite here is coarse grained, containing quartz, orthoclase, oligoclase, microperthite, biotite, ilmenite, and sphene, with some chlorite secondary to the biotite. The order of crystallization has been (1) oligoclase and orthoclase, (2) orthoclase and quartz. The oligoclase is sometimes included in the orthoclase, and an inner growth of oligoclase is sometimes completed by an outer zone of orthoclase.

At one point here a vein 15 feet wide is opened by an incline 30 feet down. The gangue is quartz and barite, carrying some copper pyrite largely altered to black copper oxide and malachite.

By following the trend indicated by the above-mentioned lodes, what is apparently a further extension, covered by the Paymaster, Porto Rico, and Richmond claims, may be reached. These lie not in the granite but in the metamorphosed calcareous sediments into which the granite is intrusive. Of these prospects, the one lying farthest east is the Paymaster. There was an old location here made ten or twelve years ago, called the Mountain Lion, but this having lapsed it was relocated in 1902 by E. H. Rose. From here east and west along a zone 4,000 feet long or more, there is a weak lead marked at intervals by large masses of black hornstone, specular iron, garnetiferous and rather coarsely crystalline metamorphic rock, and associated quartz veinlets. Crystalline limestone appears at many points along the zone. The quartz, which is present in rather small quantities, is iron stained, and some of it is said to yield gold on horning. The lead seems to be a long band in the metamorphosed sediments, marked chiefly by a special segregation of quartz and by some gold. It is probable that the lead may follow a fault or fracture zone, for at one point on the Paymaster claim a shaft 40 feet deep shows a decomposed, soft, ground-up material containing rounded pebbles which probably owe their origin to attrition. This soft material is said to be the best gold ore, some of it carrying $40 in gold, but very little silver. Some of the whiter quartz, copper stained, is said to carry some silver.

Specimens of the metamorphic rock along this zone were examined microscopically. One is a dense hornstone, which under the microscope proves to be in part a dense carbonaceous chert. Interstratified layers in this contain probable orthoclase, greenish garnets, and abundant probable malacolite, with fine carbonates, quartz, hematite, epidote, and zoisite. Another specimen is mostly diopside, largely altered to calcite and serpentine, with iron and some quartz. Other primary minerals are magnetite, quartz, orthoclase, albite, and zoisite.

At one place a 2-foot dike of basaltic diabase cuts the metamorphosed strata. This consists of partly altered feldspars and colorless augite.

BARREL SPRINGS.

At Barrel Springs the writer noted in 1899[a] that the limestone is decomposed along a vertical zone 10 yards wide and stained with iron and copper. The rocks here have a honeycombed and cavernous appearance. Mr. H. W. Turner took at this point a sample of a piece of siliceous rusty material which assayed $1.24 in gold and 11 cents in silver per ton. A little copper pyrite was noted.

AURIFEROUS SAND DUNES.

Of the areas of sand dunes shown on the map, that occupying the center of the south side of Clayton Valley is the largest. This consists of typical white sand, with no vegetation. In detail the sand is continually shifting, but the general position of the dunes is said not to change materially from year to year. The dunes have been several times staked out and assayed with the idea of cyaniding the material for gold which it is supposed to contain.

These dunes may be considered to represent a rough average sample of all the quartz in the district, including that from the veins, from the granitic rocks, and

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[a] Bull. U. S. Geol. Survey No. 208, p. 186.

from the rhyolites. Since the quartz veins weather largely in small, heavy fragments, and since the granite yields small grains, it is probable that altered rocks furnished by far the larger proportion of this sand. From all sides—north, east, south, and west—the detritus pours down from the mountains into the Clayton Valley basin. It is partly sorted by water, but chiefly by wind, which has blown away the fine particles derived from the decomposition of the aluminous minerals and left the quartz clean, and, having collected it from all over the valley, has piled it up in these heaps.

Information concerning the reputed gold contents of the dunes was obtained from Mr. F. A. Vollmar, of Silver Peak. Mr. Vollmar says he first sampled these sand dunes several years ago, and eight assays gave him an average of $1.80 per ton, while some were as low as 40 or 50 cents. Later other parties sampled the dunes thoroughly and 1,500 assays were made, for which an average of $1.50 per ton was claimed. The matter, however, was dropped. Later Mr. Vollmar took sixteen assays for another party and got only traces of gold. Still later two other samples, collected by another person, were assayed by Mr. Vollmar, giving again only traces. Mr. Vollmar advances the explanation that the first high assays may be due to material which was derived from the tailings from Chiatovich's mill at Silver Peak, particles of gold having wandered across to the sand dunes along with other windswept material. The present writer took a large sample of the sand from the northern end of the dunes, which was assayed by R. H. Officer & Co., of Salt Lake City, and gave only traces of gold and silver.

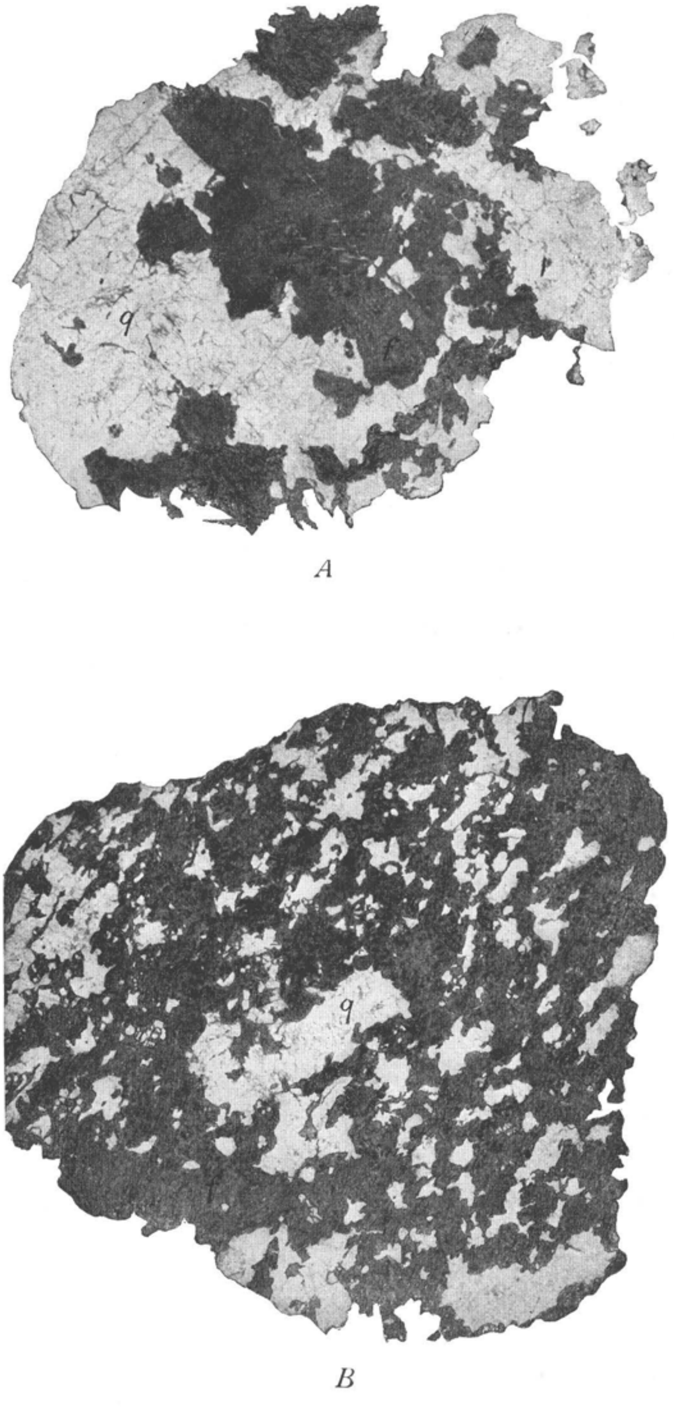
From the shifting movement continually going on within these dunes, it is likely that the lower portions may contain more gold than the rest.

PLATE XVI.

THIN SECTIONS SHOWING SEGREGATION OF QUARTZ AND ALASKITE INTO BUNCHES.

A, Segregation of magmatic quartz (and also of feldspar) and alaskite into comparatively large bunches. Feldspar is chiefly orthoclase; the quartz is subsequent and intrusive into the feldspar crystals, yet is an essential part of the rock fabric. Light portions are quartz (*q*); dark portions feldspar (*f*). Specimen 163, from cross-cut tunnel of Mary mine. Photograph of thin section as viewed against a clear sky. The feldspar being largely altered to sericite becomes semiopaque; enlarged 4 diameters.

B, Segregation of magmatic quartz and alaskite into bunches of varying size. Light portions quartz (*q*); dark portions feldspar (*f*). Specimen 164, from cross-cut tunnel of Mary mine. Photograph of thin section as viewed against a clear sky. The feldspar is somewhat altered and so becomes semiopaque; enlarged 4 diameters.



THIN SECTIONS SHOWING SEGREGATION OF QUARTZ AND ALASKITE INTO BUNCHES.

CHAPTER III.

GENETIC RELATIONS OF METALLIFEROUS ORE DEPOSITS.

THE DRINKWATER TYPE OF GOLD MINES OF MINERAL RIDGE.

OCCURRENCE OF GOLD IN QUARTZ.

The typical auriferous quartz of Mineral Ridge is white and crystalline and is seen under the microscope to be crowded with liquid inclusions. Its appearance and nature is that of the characteristic gold quartz found in so many districts in the world. Occasionally this quartz contains original muscovite and rarely original chlorite crystals. Contemporaneous sulphides are sparsely disseminated, principally pyrite, more rarely galena. Occasional copper pyrite has been observed.

The quartz throughout contains gold and a little silver, the proportion of the latter to the former being about 1 to 100. The gold is finely disseminated in the free state through the quartz and is also contained in the scattered sulphides. It is estimated that about 87 per cent is in the free disseminated form and about 13 per cent in the sulphides. The gold values are irregularly concentrated into certain groups of lenses and certain lenses within those groups. Thus in some portions it is relatively high grade, while other portions are low grade or nearly barren.

RELATION OF QUARTZ TO QUARTZ-FELDSPAR (ALASKITE) ROCKS.

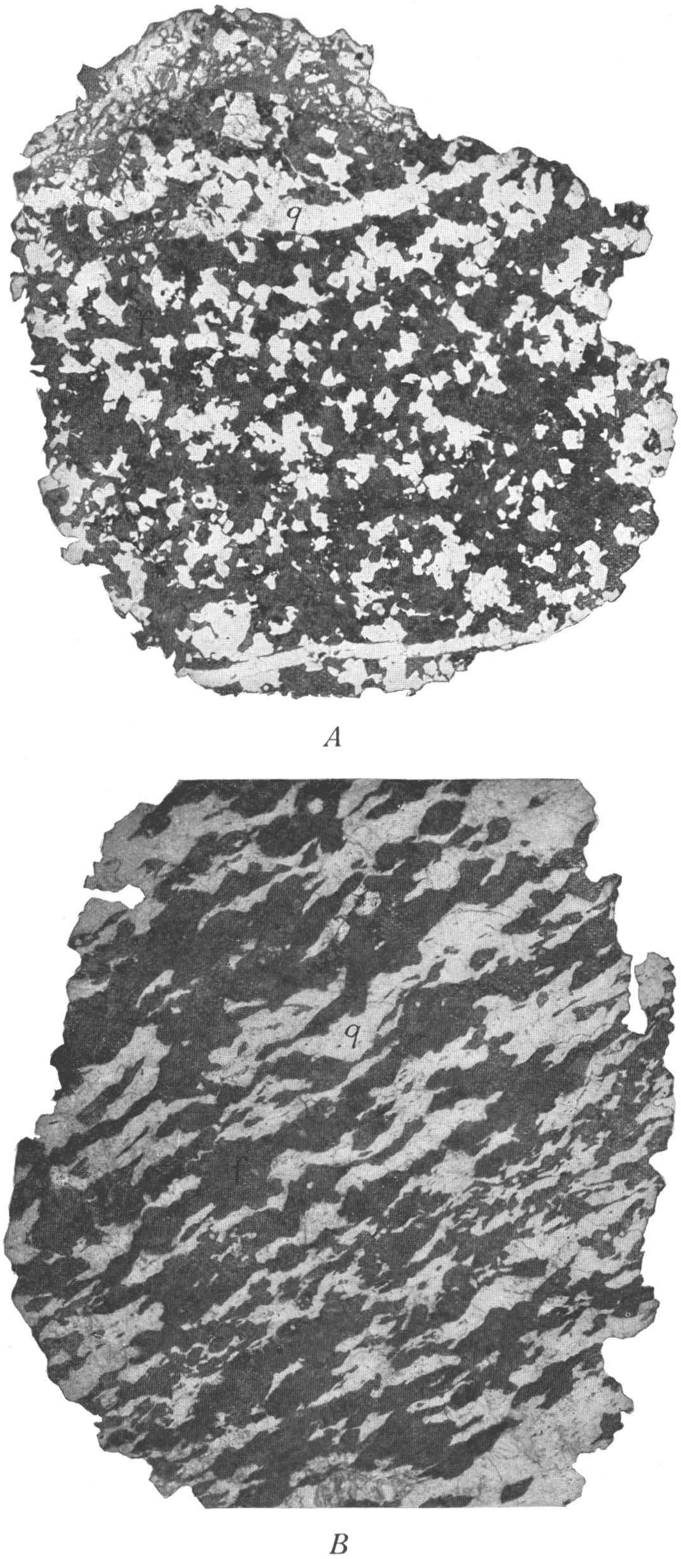
The quartz lenses are intimately associated with alaskite intrusions on Mineral Ridge, one not occurring without the other. Petrographically the typical quartz and the typical alaskite form two ends of a rock series, between which every gradation is abundantly represented. The alaskite and quartz have very nearly the same dense, milk-white appearance, and even on the outcrop it often requires close scrutiny to determine the difference between the two. The alaskite becomes quartzose and passes to a state where it contains quartz blotches and veinlets (Pl. XVI, *A*, *B*, and Pl. XVII, *A*), and so gradually passes over into typical vein quartz. Nearly every quartz lens which has been mined or prospected shows in places considerable feldspar mixed with the quartz. The auriferous quartz frequently runs off laterally into alaskite, chiefly pegmatitic. As a rule, the contained gold grows rapidly less with incoming feldspar, although occasionally feldspar-bearing rock carries good values. Under the description of the Frank No. 2 prospect, the occurrence of primary free gold in pegmatite has been described. Also, in one place in the Hickey tunnel, a small bunch of sulphide-bearing quartz segregated in the midst of pegmatite showed on assay the relatively high result of $76 in gold. The Golden

PLATE XVII.

THIN SECTIONS SHOWING MAGMATIC QUARTZ AND GNEISSOID STRUCTURE IN ALASKITE.

A, Veinlets of magmatic quartz in fine-grained alaskite. Light portions quartz (*q*); dark portions feldspar (*f*). Specimen 288, alaskite in quartz vein, Nevada prospect, Palmetto district. From photograph of thin section as seen against a clear sky, without microscope. The feldspar is altered and turbid and is hence semiopaque; enlarged nearly 5 diameters.

B, Original gneissoid structure in uncrushed alaskite. Light portions quartz (*q*); dark portions feldspar (mostly orthoclase, less finely striated feldspar). Specimen 172, from dike in canyon below Drinkwater mine. From photograph of thin section as seen by transmitted light against the sky without the microscope. The feldspar (*f*) being somewhat turbid from weathering is semiopaque; enlarged 5 diameters.



THIN SECTIONS SHOWING MAGMATIC QUARTZ AND GNEISSOID STRUCTURE IN ALASKITE.

Eagle ore lens, which is said to average $18 to the ton, also contains a good deal of feldspar throughout. This lens contains small streaks of segregated quartz with primary pyrite and galena.

NATURE OF GRANITIC MAGMAS.

It was long ago recognized that granitic rocks had originated from magmas essentially different in nature from those which form the more basic plutonic rocks and from those which produce surface lavas. The relative order of crystallization and the nature and association of the chief granitic minerals are decidedly against the explanation of cooling from a simply fused condition.

The relative order of crystallization in granites is (1) ferromagnesian minerals (chiefly biotite and hornblende), (2) feldspar, and (3) quartz. Of these quartz, the last to crystallize, is the least fusible. Hornblende can ordinarily not be formed at a great heat and at a sufficiently high temperature passes over into pyroxene.[a] Biotite on elevation of the temperature is fused to a glass. The contradiction between the fusing points and the relative order of crystallization is clearly seen in the case of the feldspar and quartz. According to Vogt[b] the fusing point of orthoclase is 1,190° C., of albite 1,140°, of quartz 1,700° to 1,800°.

Many granitic minerals when the granite is heated red hot change their optical properties, showing that they were formed at a relatively low temperature; under such conditions they often decrepitate.[c]

The experimental reproduction of granitic minerals has thrown further light upon the condition of the rock's crystallization. Quartz, orthoclase, microcline anorthoclase, albite, muscovite, and amphibole have never been artificially formed by the cooling of dry melts, in spite of many attempts. All these, however, have been formed artificially in the presence of "mineralizers," such as water, fluorides, boron compounds, tungstic acid, etc.[d]

Above a certain high temperature, but before the melting point is reached, quartz passes over into other opal-like modifications of silica.[e]

Muscovite is not a volcanic mineral.[f] It is not found in any of the plutonic rocks save in granites, nor is it present in the volcanic rocks whose chemical composition corresponds to that of the granites. When subjected to heat, it fuses to a glass, showing it has been formed in the wet way.[g] According to Brauns[h] mica can easily be formed by melting a mineral containing its elements with a metallic fluoride under 800°. At higher temperatures mica is unstable and passes over into olivine, augite, scapolite, etc. In this case fluorine shows its property of being able to crystallize amorphous substances.[i] That the presence of this

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[a] Vogt, J. H. L., Mineralbildung in Silikatschmelzlösungen. Christiania, 1903, pp. 6 and 7. Hornblende has been formed by long heating with water at 550° C. Above 500° to 700° augite is formed instead of hornblende.

[b] Op. cit., pp. 141 and 190.

[c] Bischof, Gustav, Lehrbuch der chemischen und physikalischen Geologie, vol. 2, pp. 865 and 866.

[d] Brauns, Reinhard, chemische Mineralogie, p. 245. Vogt, Mineralbildung in Silikatschmelzlösungen, Christiania, 1903, p. 6.

[e] Bischof, Chem. und phys. Geologie, vol. 2, pp. 866 and 868.

[f] Rosenbusch-Iddings, Microscopical Physiography of the Rock-Making Minerals, 2d ed., p. 264.

[g] Zirkel, Lehrbuch der Petrographie, 2d ed., vol. 1, p. 340.

[h] Chemische Mineralogie, pp. 247, 248.

[i] Doelter, C., Allgemeine chemische Mineralogie, p. 176.

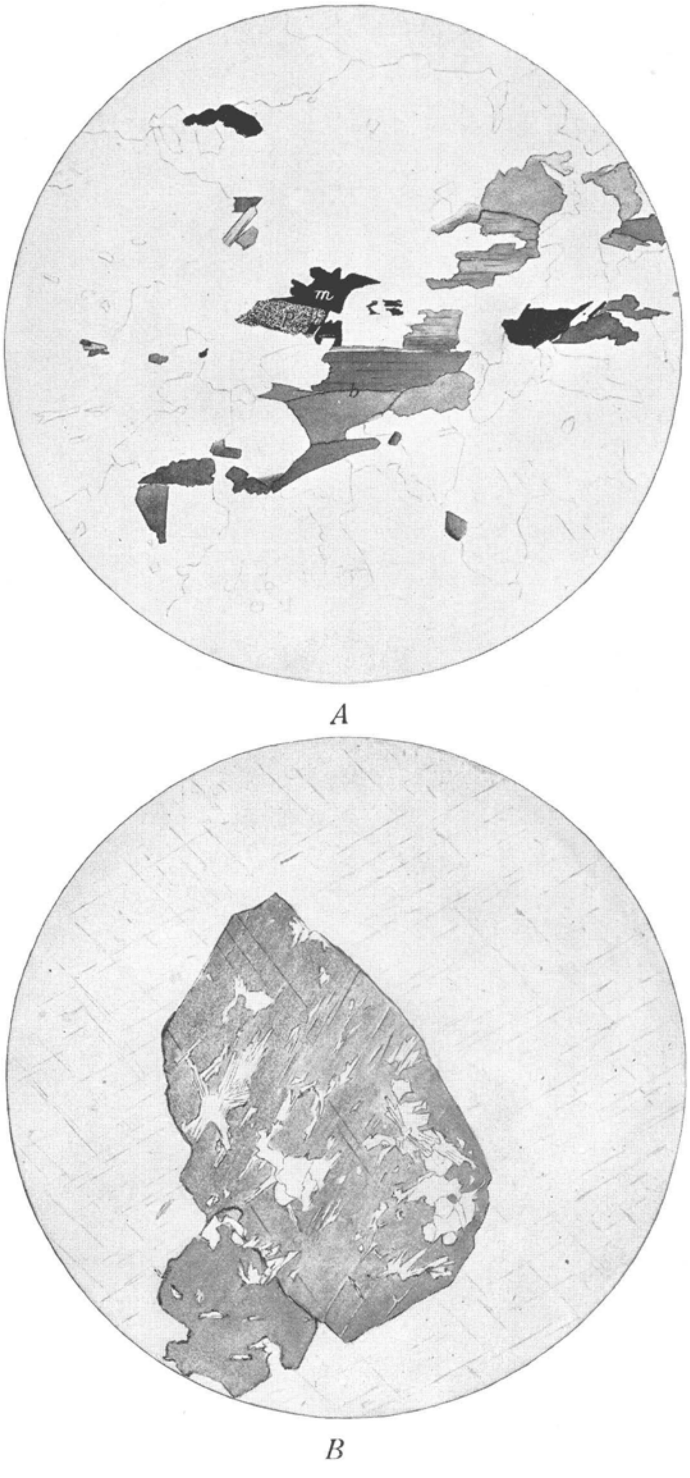
PLATE XVIII.

ORIGINAL PYRITE IN GRANITIC PHASE OF ALASKITE.

A, Original pyrite in granitic phase of alaskite associated with magnetite (ilmenite ?) and pyrite. Drawing from thin section 165, granitic phase of alaskite from Mary tunnel. *b*, Biotite; *m*, magnetite (ilmenite ?); *p*, pyrite. Enlargement about 60 diameters.

MUSCOVITIZED ORTHOCLASE CRYSTAL INCLOSED IN FRESH ORTHOCLASE

B, Older idiomorphic orthoclase crystal partly altered to fine muscovite and inclosed in fresh, unaltered orthoclase of the second period of consolidation. Drawing from thin section 184, fresh alaskite from the Vega prospect. Illustrates formation of muscovite by the action of the residual magma on earlier formed feldspar during consolidation. Enlarged about 180 diameters.



A. ORIGINAL PYRITE IN GRANITIC PHASE OF ALASKITE.
B. MUSCOVITIZED ORTHOCLASE CRYSTAL INCLOSED IN FRESH ORTHOCLASE.

mineralizer is essential to the formation of natural as well as artificial muscovite is indicated by various facts. The best crystallized muscovite occurs abundantly in cavities in granites and in pegmatites, associated with minerals like tourmaline, which is the result of the action of another mineralizer—boron.[a] Fluorine is also present in the composition of muscovites. On heating muscovite gives off water, which reacts for fluorine. According to Bischof,[b] the best characterized micas, for example, those from granite, are richest in fluorine.

Finally the contact metamorphism which intrusive granitic rocks exert upon the rocks which they cut is of such a character as to show the presence of mineralizers. Minerals like tourmaline, scapolite, muscovite, etc., frequent in the contact metamorphic aureoles of granites, testify to the emanation of boron, chlorine, fluorine, water, etc., from the consolidating granitic magma, these mineralizers leaving the magma and playing the same crystallizing rôle in the intruded rock that they have already played in the formation of the granite.

From these considerations it is plain that ordinary granitic rocks have crystallized at relatively low temperatures, which, from the experiments made in the production of granitic minerals, we can suppose as having a maximum of 500° to 800° C., and that at such temperatures, which are below the fusing point of most of the granitic constituents, the granite magma remained mobile on account of the intermixture of water and other mineralizers. In this process it is likely that water was one of the most abundant and efficient factors. From analysis of the fluid inclusions in granitic quartz we know that these inclusions, which represent the final fluid residual from the consolidation of the granite (since quartz is usually the last mineral to crystallize), consist mostly of water with alkaline salts and carbonic acid. The quantity of water in the magma has never been even approximately determined. Scheerer[c] estimated it as between 1 and 50 per cent, but believed that the actual quantity approached much nearer the minimum than the maximum of these figures.

NATURE AND COMPOSITION OF THE ALASKITE.

The alaskite of Mineral Ridge is made up essentially of quartz and feldspar, with some muscovite. Its structure is variable. In general it may be described as allotriomorphic granular or granitic, but it varies frequently on the one hand to fine grained or aplitic and on the other to coarse grained or pegmatitic. It sometimes has a parallel banding or gneissic structure, which is original. (Pl. XVII, *B.*) The feldspars consist of orthoclase, microcline, anorthoclase, albite, and oligoclase-albite. All of these except anorthoclase are present in nearly every section. Rarely andesine-oligoclase has been identified. Muscovite is usually present in small amount and in small flakes. Accessory minerals frequently found are zircon, pyrite, and calcite. In one place alaskite pegmatite was found to contain, apparently, arsenical pyrite. By the accretion of sparse biotite the alaskite passes into a granitic phase. (Pl. XVIII, *A.*) On the other hand, by the withdrawal of the feldspar it passes into a common quartz phase. Where biotite is present, additional accessory minerals

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[a] Dana, E. S., System of Mineralogy, 6th ed., p. 616.

[b] Chem. und phys. Geologie, vol. 1, p. 79.

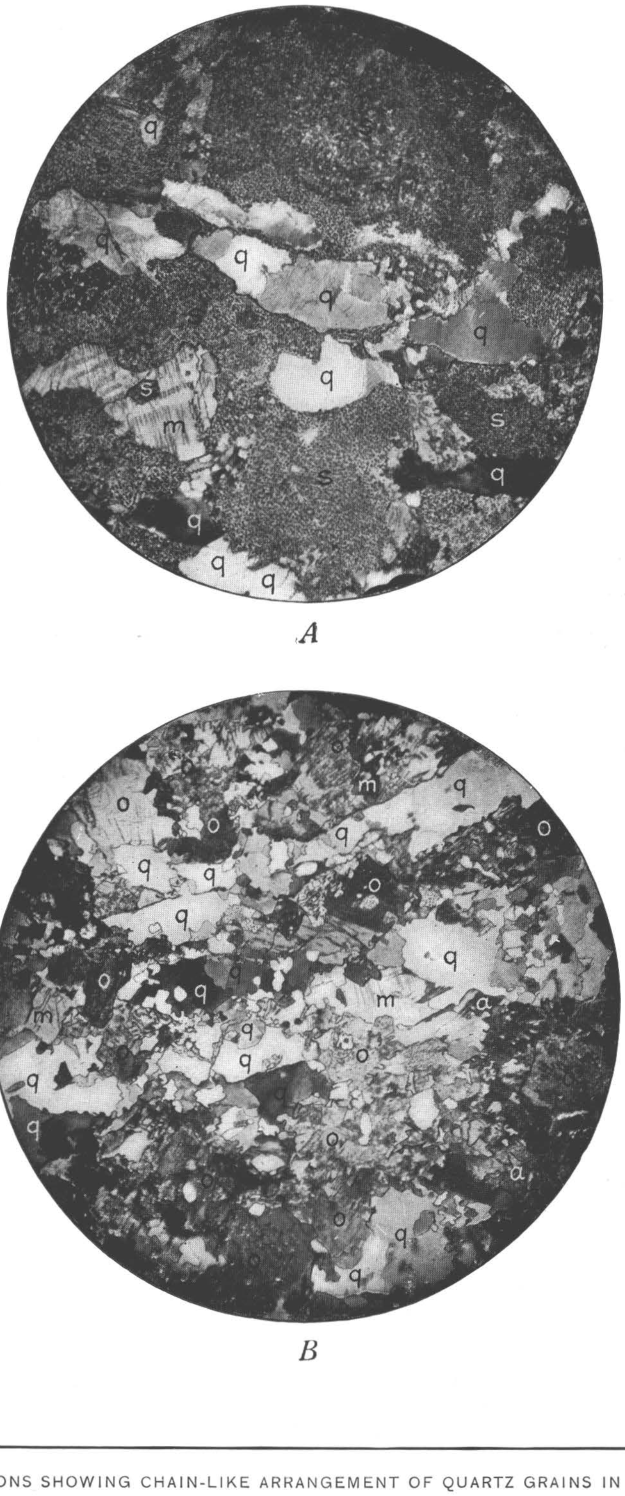
[c] Bulletin Société Géologique de France, 1846-47, 2d ser., IV, 1, p. 490.

PLATE XIX.

THIN SECTIONS SHOWING CHAIN-LIKE ARRANGEMENT OF QUARTZ GRAINS IN ALASKITE.

A, Chains of magmatic quartz grains in alaskite, the beginning of vein-like structures; *s*, feldspar (chiefly orthoclase) almost entirely altered to fine muscovite (sericite); *m*, fresh microcline; *q*, quartz. Microphotograph of thin section of alaskite (specimen 64), wall rock of auriferous quartz in Hickey tunnel workings, Drinkwater mine. Magnified 11 diameters.

B, Grouping of magmatic quartz grains in chains; the beginning of vein-like segregations of quartz; *o*, orthoclase, either clear or slightly altered to sericite; *m*, clear microcline; *q*, quartz; *a*, striated feldspar, not determined. Microphotograph of granitic alaskite (specimen 103) from Vanderbilt mine. Magnified 11 diameters.



THIN SECTIONS SHOWING CHAIN-LIKE ARRANGEMENT OF QUARTZ GRAINS IN ALASKITE.

have been noted—such as apatite, magnetite, sphene, probably ilmenite, and tourmaline.

Microscopical study of thin sections shows that the crystallization of the alaskite was slow and interrupted. Two distinct periods or generations of crystals are always represented. In different sections the nature and relative amounts of the minerals belonging to each generation varies greatly, but the following general observations apply to all cases:

1. Quartz is usually absent from the first generation, or, if present, is subordinate. In the second generation it is always predominant. In some cases the first generation may be entirely of feldspar and the second entirely of quartz, but the separation is usually not so marked, some of the feldspar crystallizing with the second generation together with the predominant quartz.
2. Microcline is almost always of the second generation. Very rarely does it enter into the first.
3. Albite and oligoclase-albite occur generally in the first and second generations.
4. Zircon and pyrite have been noted included in the minerals of the second generation, but not in the first.[a]

In some cases the rock is almost entirely made up of crystals of the first generation, with the second generation represented in a very subordinate way. Other sections show the first generation only as scattering idiomorphic crystals, with the second generation making up the greater area. In most cases, however, the division is fairly equable.

The chief lesson taught is that the quartz is slightly but distinctly younger than the feldspar. It is frequently segregated into irregular chains of grains which lie between bands of more feldspathic material. (Pl. XIX, *A* and *B*.) The later generation cements the interstices between the idiomorphic crystals of the first generation or invades these crystals along cracks. Sometimes these crystals are considerably broken, indicating some slight disturbances in the magma in the interval between the first and second crystallizations. (Pl. XX, *A*.)

Fresh crystals of calcite are sometimes inclosed in fresh feldspar of the second generation, which also incloses zircon crystals. In this case the calcite as well as the zircon is plainly a magmatic formation which crystallized before the latest feldspar.

In nearly every section muscovite is present, generally in fine fibers. In most cases this muscovite has evidently formed at the expense of some of the feldspar, and on casual observation it might be summarily disposed of as secondary sericite. Sericite is a term used for the fine variety of muscovite which is especially common as an alteration product; but the name applies only to the form and habit and not to the mineral, which is identical with the larger crystals. For this reason, as already

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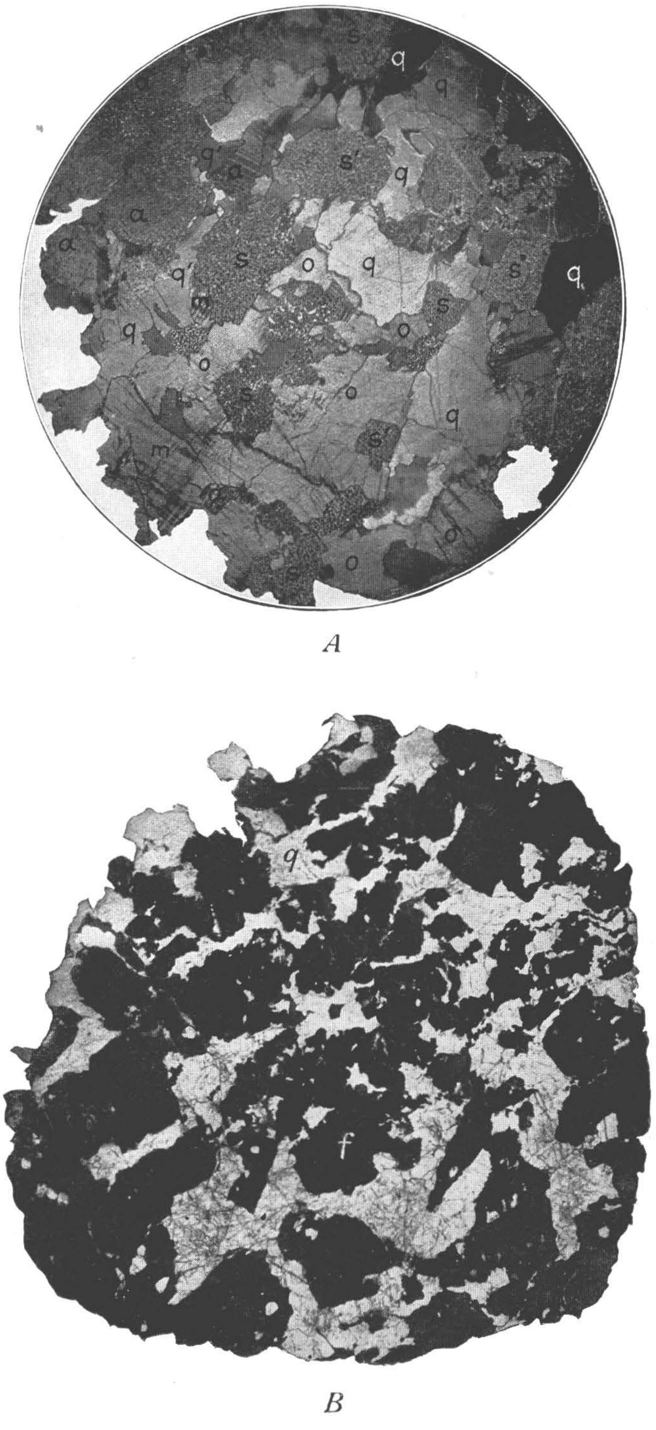
[a] Brögger, W. C. (Mineralien der Syenitpegmatitgänge, Zeitsch. für Kryst., p. 164), places pyrite and other sulphides in pegmatite dike veins among the minerals formed at the second period of consolidation, when the action of water and other mineralizers was more potent in forming minerals than during the first period of consolidation, which was that of ordinary magmatic solidification. He also (p. 161) notes that while zircon is formed during the first period, it is highly probable that it is formed by the action of mineralizers, probably fluorine; and it also occurs (p. 164) among the minerals of the second period. A. La Croix (Nouvelles Archives du Muséum, Paris, 1902, Tome 4, p. 86) describes, in an alkaline granite from Madagascar (frequently pegmatitic) allotriomorphic or idiomorphic zircon inclosed in the quartz, sometimes in the feldspar. He regards this zircon as later than all the minerals except quartz. It is distributed in the granite, and not localized in veins. He regards it as the product of emanations contemporaneous with the final consolidation of the rock.

PLATE XX.

THIN SECTIONS SHOWING TWO PERIODS OF CRYSTALLIZATION IN ALASKITE.

A, Two generations of crystals in alaskite fabric. First generation consists of feldspars largely altered to fine muscovite (partly sericite); *s,* orthoclase partly altered to fine muscovite (sericite); *a,* andesine-oligoclase partly altered (less than orthoclase) to fine muscovite. Second generation consists of clear unaltered feldspar and quartz; *o,* fresh orthoclase; *m,* fresh microcline; *q,* quartz. Note frequent idiomorphic crystals of first generation (e. g., the two altered orthoclase crystals marked *s′*). Note also the frequent irregular intrusion of crystals of the first generation by the minerals of the second generation (as shown, e. g., by the quartz tongue *q′, q′*). The alteration of the earlier feldspar to fine muscovite is believed to have taken place after the crystallization of the first generation and before that of the second. From microphotograph of thin section of alaskite (specimen 109) from Frank No. 2 prospect; magnified 11 diameters.

B, Alaskite showing the first generation, consisting of feldspar (probably mostly orthoclase), and a second generation, consisting of quartz with a little microcline. The second generation of quartz cuts into and breaks vein-like across the older feldspar. Note especially the feldspar grain at bottom of illustration, which is broken into and separated by a vein-like arm of quartz. Light portions are quartz (*q*), with a little clear microcline; dark portions feldspar (*f*). Specimen 70, from Hickey tunnel workings, Drinkwater mine (wall rock of auriferous vein). From photograph of a thin section viewed against a clear sky; the feldspar being largely altered to sericite and kaolin becomes semiopaque; enlarged 4 diameters.



THIN SECTIONS SHOWING TWO PERIODS OF CRYSTALLIZATION IN ALASKITE.

stated in a previous publication,[a] the writer prefers to use the term muscovite throughout, there being in many cases no more need or advisability for two terms than there is of using a separate term for ordinary coarse crystalline quartz and for the fine-grained variety commonly encountered in thin sections as the result of secondary processes.

The fact, however, that this muscovite has formed only at an expense of the feldspars of the first generation, while those of the second generation are clear, lends it at once an extraordinary interest. (Pl. XX, *A*; also Pl. XVIII, *B*.) The earlier formed feldspars contain fine muscovite, whose distribution along cracks, cleavages, and along their peripheries shows beyond a question that the mica is subsequent to the feldspar and formed at its expense. Occasionally the feldspar is largely or even entirely transformed into a mat of fine muscovite fibers. In size these fibers, however, vary greatly, increasing from the fine sericitic variety to coarser and coarser phases until blades of crystalline muscovite are reached which are relatively small in proportion to the size of the other minerals, but are nevertheless characteristic granitic muscovite. Such muscovite crystals, included as they usually are in the feldspar, would ordinarily be interpreted as earlier formed crystals which have been included in the subsequently consolidated feldspar, but the invariably perfect transition from these to the sericitic variety shows that all have a common origin, which is the secondary origin above stated.

From study of numerous sections the following general points in regard to the muscovitization are learned:

1. The microcline is always clear and subsequent to the muscovitization.
2. The quartz is almost always clear and subsequent to the muscovitization, but sometimes incloses fibers and blades of muscovite.
3. The orthoclase and striated feldspars (chiefly albite and oligoclase-albite) are in part muscovitized and in part clear, as is natural from their belonging to both generations.

From this it will be seen that the partial alteration of the feldspar into more or less fine-grained sericite took place when the magma was partially consolidated and before the deposition of the remainder which formed the second generation.

These different observations show that the crystallization process of the alaskite magma was slow, so that in many cases the magma became filled with contiguous idiomorphic feldspar crystals of the first generation, the interstices between which were filled with the residual fluid. The first generation of crystals was rigid enough to be partly cracked and fissured in places, and in these cracks and fissures, as well as in the interstitial spaces between the crystals, the residual fluid solidified. The study of the alaskites indicates that many of the fissures were formed by contraction consequent upon partial consolidation. Others seem to have been due to movements brought about by pressure on the still viscous magma. Thus the quartz, which makes up always the chief part of the second generation, besides forming as intergranular quartz within the unbroken alaskitic fabric, filled the small fissures, and collecting in larger masses formed itself on a small scale an independent intrusive in nearly the same sense as the alaskitic magma had done. We may logically conclude

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[a] Professional Paper U. S. Geol. Survey No. 42, p. 232.

that this quartz left upon consolidation a residue, which was still thinner and more aqueous, which had its part in the metamorphism of the country rocks, and whose mineralizing effects will be noticed later on.

NATURE OF INTRUDED ROCK.

The rock into which the siliceous magma was injected is a comparatively thick series of thin-bedded, shaly, and calcareous sediments intercalated with beds of pure limestone, now metamorphosed into marble. The thin-bedded sediments are sometimes carbonaceous, sometimes streaked with sandy material. (Pl. XXI, *B*.)

Near the siliceous intrusions the strata are often saturated with siliceous material in seams, lenses, and nodules, and are also altered throughout their whole mass chiefly by silicification. Locally the alteration has produced mica schist and occasionally the microscope shows the presence of green hornblende and epidote, as well as quartz and feldspar, in the altered rock. The intrusions of quartz-feldspar material or of quartz alone are sometimes interlaminated in the schists like the leaves of a book, making a kind of gneiss. In some cases, as near the Crescent, this alteration of the intruded strata may extend only a few feet away from the zone of intrusive lenses of quartz and alaskite, showing its dependence upon this intrusion.

The altered country rock contains gold in small quantities, as shown by assays, chiefly those taken in the Hickey tunnel (p. 50). This gold was probably introduced along with other materials during the process of metamorphism.

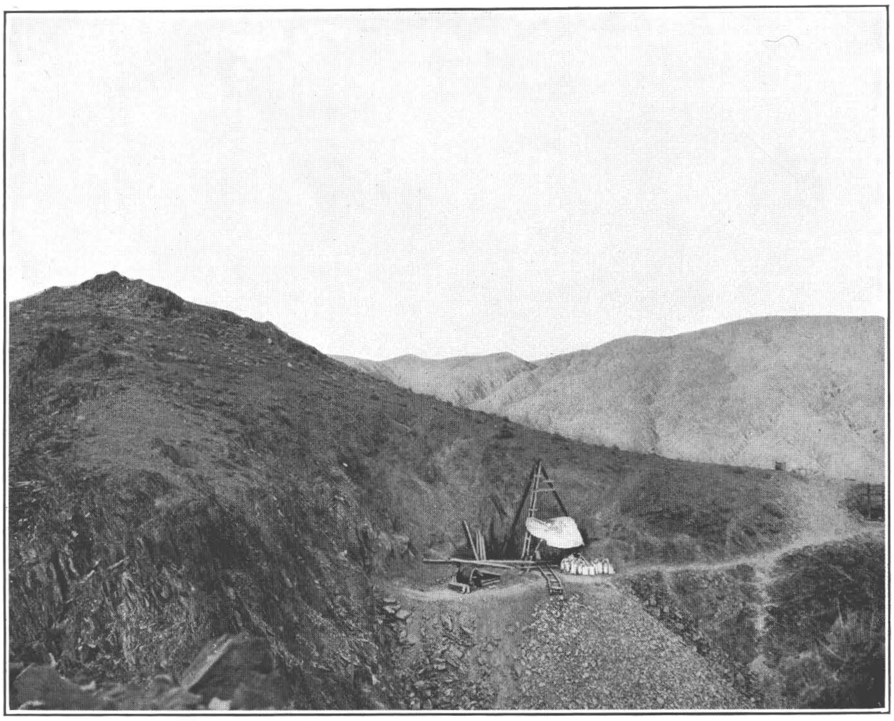
FOLDING AND FAULTING.

The limestone-slates are contorted on a minor scale. Most of this crumpling was probably due to the intrusion, for the parallelism of the bedding to the lenses shows that not only the granitic alaskite but the alaskite-quartz and even the quartz lenses have pushed aside the schist to make room for themselves. There is very little folding on anything but a microscopic scale. Faulting on a small scale was observed in outcropping rocks, but no important faults were detected.

CRUSHING.

All the rocks—limestone, slate, alaskite, quartz, and altered diorite or greenstone—are locally more or less crushed, though much of the rock is intact. The crushing varies from a mere straining to complete granulation. There has been practically no crystallization or metamorphism subsequent to the crushing. Sometimes a very little sericite has been developed along the crushed cracks. In one thin section of alaskite from the Crescent, where there had been crushing subsequent to the final consolidation, it was observed that along cracks the crushed orthoclase and microcline were being altered to albite, but not to any great extent. Universally otherwise the crushed feldspars of the alaskite remain perfectly fresh.

In the Frank No. 2 it has been noted that some of the alaskite is crushed and some uncrushed, the difference appearing to be due to the slightly different age of the alaskites. In this case the diorite or greenstone is also uncrushed. In other instances the greenstone has escaped most of the crushing, while all of the alaskite has been subjected to it. In some crushed alaskite and quartz it has been found that the



A. PAYMASTER MINE, LONE MOUNTAIN DISTRICT.

B. CORRUGATED, THIN-BEDDED LIMESTONE IN CANYON IN MINERAL RIDGE, 1 MILE NORTH OF SILVER PEAK.

pyrite has also been affected, showing that it was formed previous to the stress; in other mines uncrushed pyrite occurs in rock which has been crushed, and it is therefore subsequent to the stress.

From these observations the conclusion is drawn that the chief crushing was attendant upon the crystallization of the alaskite and quartz, was in general previous to but partly contemporaneous with the diorite intrusion, and was previous to the deposition of the subsequent ores.

FORM OF ORE DEPOSITS.

The ore deposits are lenses of various dimensions, as seen both on horizontal and vertical planes. These lenses are most abundant along certain zones in the intruded formation and overlap one on another. They disappear by wedging or by forking and splitting into two or more branches. Thus a series of quartz stringers may unite horizontally or vertically to form a massive lens.

These lenses are original and are not fragments of larger dike-like bodies which have attained their form as a consequence of shearing. The wedging out of the lenses is not attended by evidence of unusual movement. Moreover, the phenomena of splitting and uniting (fig. 39), which are observed quite as frequently as the simple wedging, forbids the assumption that the form is not primary.

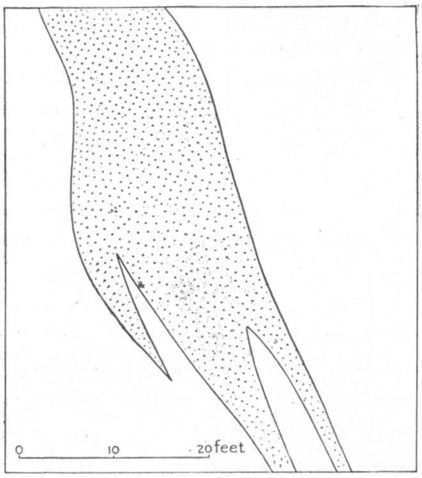


FIG. 39.—Rough horizontal section of portion of quartz lens exposed in lower stopes of the Drinkwater tunnel, showing forking of lens.

CONCENTRATION OF GOLD.

The assays given in the description of the Drinkwater mines show an unusual quantity of disseminated gold in the alaskites and to a certain extent in the schists which they have intruded and which have been metamorphosed at the time of the intrusion. Therefore it is probable that this alaskitic magma contained more gold than the ordinary magma. Moreover, the quartz lenses contain throughout much more gold than do the alaskite lenses, and the values in this quartz usually decrease with incoming feldspar, although there are cases where this rule is not observed (see p. 50). It seems, therefore, that the more siliceous the magma became the more marked became the presence of gold. Thus the magma was capable of holding the gold dissolved and of separating it, along with the silica and other alaskitic elements, from the less siliceous and earlier crystallized granites. A relatively large proportion of gold tended to remain in solution in company with the excess of free silica, and a large part of this was deposited when this excess of free silica crystallized in the form of magmatic quartz, whether in the interstices of the alaskite, in small cracks, or in the lenticular bodies into which the silica also collected.

Besides the chemical fitness of the siliceous magma to contain gold in solution, other properties of the last-crystallized quartz must have been more favorable to local concentrations than in the case of the portions of the magma which crystallized earlier. Many observations have been recorded in various parts of the world which indicate that a granitic magma tends to grow more aqueous and less viscous as it becomes more siliceous. Some reasons for believing that the alaskite was less viscous than normal granitic magmas will be indicated farther on. In accordance with this idea the quartz which was the last to consolidate should have been less viscous than the alaskite. This would have allowed a greater mobility of materials and a greater range of currents, permitting the accretion of certain materials and allowing the gold to increase in favorable localities to commercial quantities.

SUBSEQUENT MINERALIZATION.

In the chief mines of the district, those of the Drinkwater group, the formation of ore minerals subsequent to the primary consolidation of the quartz lenses has taken place on an unimportant scale. None of the ores now in sight are even partially of this character. Occasionally, however, some later precipitation has taken place. In the Hickey tunnel beneath a decomposed greenstone dike which had been intruded along the hanging wall of a quartz lens the quartz was cracked for a foot or more from the contact, and in these cracks pyrite had formed, derived in large part from the diorite. Along this zone the ore is sometimes richer than in the unaltered quartz below, sometimes poorer. The richer ore has a gangue of quartz with some calcite and chlorite and carries pyrite and galena. The calcite, like the pyrite, is probably derived from the greenstone.

Farther east on the same zone, in the Western Soldier and Homestake, all the mineralization that was observed was primary. In the Mary, however, the occurence of subsequent mineralization is clear and the primary and subsequent ores occur together. In the primary ore lenses the gold is mostly in a free state and is said to average $12 or $15 to the ton. These lenses have been cracked by subsequent movement and the cracks, especially those near the hanging wall, have been filled with pyrite and galena of the same nature as the sulphides in the primary quartz but more abundant. In this subsequent ore, or, rather, ore which has been affected by both primary and subsequent mineralization, values of $26 to $84 are reported. Throughout the mine the hanging-wall portions of the lenses are richer than the rest, a fact which suggests ascending solutions as the cause of the subsequent mineralization.

In the Last Chance, on the same zone, besides the ordinary primary ore there is an undoubtedly subsequent band of galena and altered pyrite, a fraction of an inch thick, on the contact of a greenstone dike with a quartz lens. This band shows good gold values.

In the Frank No. 2 fragments of the auriferous quartz lens included in intrusive greenstone seem to be richer than the average. This ore shows galena and pyrite in parallel cracks in the quartz. These sulphides are undoubtedly therefore subsequent. They are associated with some contemporaneous calcite which, as in the case of the Drinkwater mines, is probably derived from the greenstone. The values here are also high in gold.

From the above data the conclusion is reached that subsequent to the first or primary deposition of minerals and subsequent to the intrusion of the diorite, minerals were again deposited along cracks in the original quartz. These minerals are the same as those first deposited, and on this account they might be thought to be due to secondary concentration, the material being derived from the minerals first formed and simply concentrated by subsequent circulating waters. This perhaps has sometimes been the case, but in the chief example, that of the Mary mine, the amount of the subsequent deposition is so large as to suggest a fresh and independent supply of material. This conclusion is arrived at also by the aid afforded by the consideration of the Great Gulch mine, where the subsequent mineralization is undoubtedly an independent process. The phenomena in the Mary mine indicate the work of ascending waters, and if the conclusion which the writer believes to be most probable is accepted—that the subsequent deposition brought new material not derived from the first—then these new solutions must have had a composition like those from which the primary ore was deposited, although, judging from their effects, they were more attenuated and more like ordinary vein solutions. In this case we may adopt the explanation which has been arrived at in the case of the Great Gulch mine to account for the fact that the primary and subsequent mineralization followed the same channel, namely, that the primary quartz is the most brittle rock of the terrane and when subjected to stress would crack and offer channels for circulating solutions which the surrounding schists and even the tougher and less homogeneous alaskite would not afford.

RELATIONS OF THE GREENSTONE OR ALTERED DIORITE.

Dikes of diorite of no great size are frequent but not abundant near the mines and prospects, and often border quartz lenses or split them. As already stated, the distribution of these dikes in relation to the main granitic intrusions are such as to suggest that they may be genetically connected with this general intrusion and form one of the latest phases of it. The intrusion of the dikes preceded the subsequent mineralization. The conclusions above arrived at as to the nature of this mineralization favor the hypothesis that the mineralizing solutions were an after product of the grantitic intrusion, representing a later stage than the quartz lenses. If this is true, as will be more strongly indicated later on, the age of the diorite is fixed as subsequent to the intrusive quartz magma, which in part constitutes an ore, and antecedent to most of the work accomplished by the later and thinner granitic solutions, whose activity was probably of considerable duration.

A striking circumstance, affording a clue which can not be neglected, is that the greenstone which accompanies the quartz and alaskite lenses is always decomposed, while the earlier alaskite which it cuts is fresh, with largely unaltered feldspars. If any doubt should arise after the previous descriptions as to the primary age of the fresh feldspar, this is set at rest by the fact of its having been crushed and granulated in many cases by earth movements, which frequently have not affected the adjacent diorite nearly to such a degree. Therefore there is only one explanation of the circumstance above noted, namely, that subsequent to the diorite intrusion solutions have circulated through the rocks which were similar in chemical composition to the alaskite and so have not attacked the alkaline feldspars, but were different in composition from the diorite and so attacked and decomposed the soda-lime feldspars as well as the other dioritic constituents. Such alkaline solutions must have been very aqueous, for in many cases they have left no trace other than the decomposition of the diorite. In some cases, however, the subsequent mineralization also occurs, suggesting that the decomposition and the mineral precipitation were due to the same solutions. One is also naturally led to consider that the chemical similarity of these later solutions to the alaskite and to the solutions which deposited the primary ores is not accidental, but results from intimate relationship, and to postulate that such later solutions were residual from the last crystallization of the alaskite and quartz magmas, and that the activity of these solutions endured throughout and subsequent to the dioritic intrusions. The interesting fact above noted, of the alteration of potash feldspar to albite along a crack subsequent to the crystallization, indicates that at least some of the circulating solutions carried sodium in excess of potash.

The close association of the greenstone with the quartz and alaskite, and frequently with the subsequent ores, easily leads one to the hypothesis that this subsequent mineralization was dependent upon the diorite; but most of the diorite dikes have no later ores in their vicinity, and in the mine where the largest deposit of subsequent ore was noted there is no diorite, so that the two phenomena have evidently no very intimate relation. Both are probably manifestations of a common activity, both have probably been brought into the quartz zones because the easy fracturing of these afforded the most inviting channels, and the intrusion of the diorite in its turn has locally brought about fractures in the brittle quartz which have served as channels for the subsequent solutions.

GENERAL CONCLUSIONS.

The general conclusion is that in this district a series of thin-bedded, fissile, shaly limestones have been intruded by a highly siliceous alkaline magma. The magma was a viscous fluid, less viscous than a normal granitic magma, but still capable of the rôle of intrusion. From this magma crystallized, besides some of the ordinary accessory granitic minerals, principally feldspar and quartz, the consolidation of the feldspar in general preceding that of the quartz. The proof that the magma penetrated the sedimentary rock mass in every pore, and that many of the larger intrusive lenses are of accumulated material which was intruded along small channels now often difficult to find, together with the relatively slight amount of fracturing to which the older crystals have been subjected, indicates that the crystallization was all accomplished subsequent to the injection. It was, however, slow, so that the residual viscous quartz, before its final consolidation, was in part drawn off into large and small reservoirs and so could play the rôle of an independent intrusion. A process of magmatic differentiation by partial crystallization is here proved.

When the alaskite magma was partially crystallized, the residual portion, previous to the consolidation of the material occupying the interspaces, altered the earlier formed feldspar more or less to muscovite, undoubtedly through the action of contained fluorine. It has long been known that orthoclase may be altered to muscovite (often sericitic) and quartz, especially near ordinary mineral veins, where the action has been ascribed to mineralizing waters, probably containing fluorine[a]. The same alteration is strikingly shown near tin veins, where it has been regarded as due to the

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[a] Spurr, J. E., Prof. Paper U. S. Geol. Survey No. 42, p. 231.

vapors accompanying the mineralization, and these vapors have usually been held to be the after product of a granitic magma, and to represent in part the final stage of eruptive activity. As noted previously, also, fluorine has been found necessary for the artificial production of mica. That the formation of muscovite wherever it occurs, even in granite, has been due to the action of mineralizers such as fluorine, is therefore a well-grounded theory. This, however, the writer believes is the first case where it has been shown by microscopic study that muscovite has universally developed as the result of the alteration of already formed feldspar by the action of a residual, probably fluorine-bearing, magma, a residual magma which afterwards crystallized out as feldspar and quartz, with occasionally some contemporaneous primary muscovite.

The chemical composition of muscovite is similar to that of potash feldspar, so that the feldspar is easily decomposed by the effect of the proper reagents to muscovite, together with some quartz. The possibility of the origin of the muscovite in granite, and perhaps the quartz also, by the alteration of amorphous feldspar, was suggested as early as 1864 by Bischof[a]. He wrote:

> The mica, which occurs in its own crystal form in granite, may possibly have originated from an elementary amorphous feldspar mass. In this case the separated silicic acid may have been entirely removed in the alkaline silicates or a part may have remained as quartz. In the latter case the quartz in granite would have the same origin.

That the alaskite lenses are the fillings of cavities which were already present in the schist is out of the question. The parallelism of the schistosity, with the curving walls of the lenses, shows that the intrusion occupied spaces which it itself created. It is probable, moreover, that before the process of consolidation began the magma had entirely filled the reservoirs which consolidated as lenses, for the relatively homogeneous texture of the alaskite is as striking as it is in regular zonal dikes and is against any idea of gradual accretion during consolidation. As the form of the alaskite lenses is identical with that of the quartz, and as there are all transitions in composition between the two rocks, the same is probably true, though perhaps less strikingly, of the quartz bodies. The lenticular form of these masses (including the ore bodies) is like that of pegmatite dikes and pegmatitic quartz veins which have been observed in many other places, in schists near intrusive granite contacts. This form is believed by the writer to be the normal one for attenuated, aqueous, but still viscous granitic material, injected into schists from granitic masses. Attenuation is indicated by the fact that the lenses are typically isolated, the entrance canals often not being visible; that the material, however, was relatively viscous and had considerable body is shown by the fact that instead of losing itself in the schists it has forced them open so that they bend conformable to its boundaries. More aqueous solutions would have simply penetrated the schists, and impregnated and replaced them along openings such as schistosity planes or fractures. Moreover, the largest feldspars, even where the rock is coarsest and most pegmatitic, reach only a few inches in diameter, and are not comparable to the giant crystals found in some pegmatites. This fact is taken to indicate a viscosity and a relative lack of mobility in the fluid. The fact that the same characterizations apply as a rule to both the alaskite lenses and the

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[a] Chem. und phys. Geologie, vol. 2, p. 744.

quartz lenses indicates that the alaskitic fluid must have been much the same as that of the quartz, both being less viscous than that which has formed the true granites, which neither in this quadrangle nor in similar provinces is accustomed to form lenticular intrusions, but which occurs in bold and well-defined dikes and sheets of which all the connections are easily traceable. Yet the alaskite here is transitional to granite, showing that the variation of viscosity as well as composition was gradual, with no critical point of change, and that the mobility increases with the increasing siliceousness of the magma. The alaskite magma must have been aqueous, and the proportion of water must have sometimes been considerable. This is indicated by the numerous cracks which formed in the alaskite, which were filled by the residual quartz and which can best be explained as contraction cracks, due to loss of volume on consolidation (Pl. XIII, *A*).

The intruded limestone slates, however, were often thoroughly saturated with siliceous and often feldspathic material. This indicates material allied to that which has filled the lenses, but of greater attenuation and penetrating ability. It is regarded as material residual from the solidification of the quartz and alaskite lenses.

After the last crystallization of the intrusive alaskite and quartz, diorite dikes were injected, and probably directly afterward (for a direct connection with the granitic intrusion is probable) relatively thin aqueous solutions circulated along cracks and produced a subsequent mineralization, not approaching, however, in commercial importance in this especial district the primary mineralization. The brittle quartz of the lenses, having been cracked, offered the best channels, and here the subsequent mineralization took place, generally under the relatively impervious schist hanging walls, indicating ascending waters. In the case of the Mary mine the results do not resemble so much a rearrangement of old material as a new deposition, for the new material differs in containing a greater proportion of sulphides to free gold, indicating a greater amount of sulphur in the solutions; yet the materials deposited—pyrite, galena, gold, etc.—are identical in nature to those of the first mineralization, and a later stage of the first process is suggested. This hypothesis is only formed and strengthened in the writer's mind by the consideration of other subsequent ore deposits, to be described later, whose significance is clearer.

For various reasons it is believed that this later aqueous residue of the granitic eruptions was highly alkaline and that in some cases sodium preponderated over potassium.

The quartz and feldspars which have crystallized from the alaskite and quartz magma are crowded with fluid inclusions.

In general the inclusions in granitic quartz are held to represent imprisoned portions of the liquid residual from total crystallization. In cases where the nature of these inclusions has been chemically investigated (in other regions) it is found to be largely pure water. In other cases considerable amounts of potassium chloride, sodium chloride, sulphates of potash, soda, and lime and also free acids were present. Sorby obtained from the powder of a piece of quartz so much alkaline chlorides and sulphates that he estimated the content of such salts in fluid inclusions to be at least 15 per cent.[a] Carbonic acid is present in many of these inclusions. In other

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[a] Quart. Jour. Geol. Soc., 1858, p. 472. Cited by Zirkel, Lehrbuch der Petrographie, 2d ed., vol. 1, p. 171.

microscopic fluid inclusions cube-shaped crystals have separated out which have been recognized as sodium chloride. Zirkel[a] notes the presence of such tiny cubes in the quartz of a syenite granite porphyry from Nevada, whose exact locality, however, is not indicated.

If the investigation of fluid inclusions in quartz offers one clue to the chemical nature of the solutions which represent the final residue of granitic consolidation, valuable clues are also offered by the investigation of the nature of minerals which are deposited in the last stages of this process. An observation by Doctor Lehmann is applicable in this connection.[b] According to him in the region of Saxony which he studied, the orthoclase of the pegmatite dikes is usually intergrown with albite in the form of perthite. Albite also covers the orthoclase in thick plates. In these cases it is quite evident that so long as the orthoclase substance was being separated out the albite, as well as the quartz, remained chiefly in solution and only separated in independent crystals toward the end of the orthoclase formation. The large orthoclase crystals appear to be etched as if they had afforded material for the formation of the free albite through a partial leaching out of the microscopically small interlaminated albite lamellæ. Nevertheless, the albite can not in every case owe its existence to this leaching, and Doctor Lehmann concludes that from the mineral solution only a little albite was precipitated at the same time as the orthoclase, but when the orthoclase substance was exhausted more and more albite was precipitated.[c]

The one case in the Crescent property cited above (p. 108) of the formation of albite at the expense of potash feldspar subsequent to the crystallization of the alaskite seems to fall in line with Doctor Lehmann's observations.

The order of events was then as follows:

1. Intrusion of a thin siliceous magma into calcareous and shaly sediments.
2. Consolidation of granitic portions.
3. Consolidation of alaskitic portions.
4. Consolidation of quartzose portions. } With attendant crushing.
5. Diorite intrusion.
6. Circulation of solutions residual from consolidation of No. 4, alteration of diorite to greenstone, and deposition of subsequent ores.

Nos. 2, 3, 4, and 6 are regarded as really a single process whose different stages, as indicated, have no natural boundaries, but overlap and interlock. No. 5 is an interruption of the process in the shape of an invasion of a different magma. Yet this interruption can not safely be regarded as accidental and foreign to the natural order of events. The diorite, as already noted, is probably a phase of the granitic intrusion, and the presence of altered diorite or greenstone is striking in many gold fields of the world, especially those which have been suggested or shown to be primarily dependent upon granitic intrusions. Concerning some of them, indeed, there are published reports in which the origin of the gold is referred to the

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[a] Zirkel, Lehrbuch der Petrographie, 2d ed., vol. 1, pp. 171 and 172.

[b] Lehmann, Dr. J., Die Enstehung der Altkrystallinschen Schiefergesteine. Bonn, 1884, p. 48.

[c] This observation is cited and supported by W. C. Brögger (Die Mineralien der Syenit-pegmatitgange, Zeitsch. für Kryst., 1890, p. 154). Brögger (op. cit., pp. 167, 168) concludes that some albite forms in the pegmatitic dike-veins at a later period than the potash-feldspars, being one of the products of the second period of consolidation, when the chief factor in mineral formation is the influence of the "mineralizers" residual from the previously consolidated portion of the magma. In part this later albite has originated by replacement of earlier orthoclase, showing that the residual solutions had grown sodic.

PLATE XXII.

THIN SECTION SHOWING GENESIS OF MAGMATIC QUARTZ VEIN IN ALASKITE.

Drawing of vein-like portion of thin section 254 (alaskite from the Magpie prospect Windypah district), showing the genesis of a magmatic quartz vein. Areas of feldspar (dark) are drawn as a whole to distinguish them from the quartz areas (light). Each of these areas, however, is in detail a mass of interlocking crystals. The quartz of the veinlet is of the same age and character as the intergranular quartz between the feldspars. The feldspar is chiefly orthoclase and albite. Note the typically idiomorphic outlines of the feldspar against the quartz, both in the veinlet and the intergranular quartz. The feldspar is the earlier crystallization, and masses of idiomorphic crystals floated in the magma almost filling it. The residual magma crystallized as quartz, completing the solidification of the rock. The mass of earlier feldspar crystals was often solid enough to be split, and in the crack thus formed the later quartz took on an elongated form and became a vein. Enlarged about 38 diameters.

THIN SECTION SHOWING GENESIS OF MAGMATIC QUARTZ VEIN IN ALASKITE.

greenstone on account of the close relation of the two, while the general existence of the same gold fields has been maintained by other writers to depend upon granitic intrusions. This, for example, is the case in some of the Australian gold fields. In many such cases the greenstone and the auriferous quartz may perhaps be, as they are at Silver Peak, separate manifestations of a general great process and otherwise not intimately related. It is easy to mistake the close association as indicating the simple dependence of one upon the other. For instance, the ores at Silver Peak have been sometimes explained by visiting engineers as dependent upon the greenstone.

ANALOGOUS CASES ELSEWHERE IN THE QUADRANGLE.

THE DIVIDEND GROUP OF PROSPECTS IN THE WINDYPAH DISTRICT.

These prospects lie within a zone of alaskite some 150 yards wide, which itself lies in the center of an area of granitic rock and is intrusive into it. The alaskite is fine and even grained, containing quartz and feldspar in equal proportions, the feldspar being both orthoclase and albite. The rock contains original pyrite largely altered to limonite and hematite, with a little magnetite and original hematite. There is occasional biotite and a little sphene and zircon. In some cases the feldspar is largely altered to sericite and sometimes is entirely decomposed. As a rule the feldspar has idiomorphic to hypidiomorphic outlines, and the quartz occupies the spaces between the feldspar crystals, which it also sometimes invades along cracks.

The microscope shows that some portions of the alaskite have much more quartz than others, and by a complete withdrawal of the feldspar typical granular contemporaneous quartz results, usually in parallel streaks. (Pl. XXII.) Microscopically, the alaskite contains small bunches and veinlets of such segregated quartz. These bunches have an irregular and indefinite distribution and are sometimes mixed with coarse feldspar, indicating their contemporaneous origin.

The quartz, as well as the alaskite, incloses some pyrite, which generally contains some gold. Perfectly fresh alaskite has been claimed to be second-class ore, but the assay of one specimen showed only traces of gold and silver. Similar alaskite with the feldspar entirely decomposed to sericite is claimed to be first-class ore. In specimens of this free gold is visible. Most of the ore, however, has been sought in the quartz lenses or near them in the alaskite.

GENETIC RELATIONS OF THE GREAT GULCH ORES.

At the Great Gulch mine the general geology is like that of most of the typical gold mines of the Drinkwater type. The country rock is a thin-bedded limestone slate, considerably altered and schistose. Alaskite occurs in interbedded lenses in the schist, occasionally in cross-cutting bodies. Lenses of white vitreous quartz are also frequent. These often become feldspathic and pass into alaskite.

The ore is arsenopyrite, which occurs in streaks of all thicknesses up to 1 or 2 feet, but usually much less. These streaks are of irregular size, contracting to small seams and expanding to lenticular masses. The larger bodies are noticeably associated with alaskite and quartz lenses, especially with the quartz. In these lenses the ore occurs sometimes as cross-cutting streaks, but usually as bands parallel to the walls of the lenses and the bedding of the schists. The hanging wall of quartz lenses is an exceptionally favorable locality. In part the ore has originated by replacement of limestone schist and alaskite.

The association of the ores with the silicious injections is plainly due to the fact that these, being more rigid, have yielded better openings than the slaty country rock, when stress was applied subsequent to their intrusion. These cleaner and more definite cracks were naturally the channels for mineralizing solutions. The localization of the gold near the hanging wall of a fractured quartz lens beneath the relatively impervious schist indicates that the solutions were ascending.

The general conclusion is that fracturing occurred subsequent to the intrusion of the primary alaskite and quartz. Along the channels formed at this time the ascending waters rose, carrying sulphur, iron, arsenic, and gold, which they deposited. The period of this mineralization is uncertain from the local data, but the resemblance of the phenomena here to those of the subsequent mineralization in the Mary mine is important. The Great Gulch mine offers a more striking and unequivocal case of subsequent independent mineralization, and in default of evidence to the contrary we may couple the mineralization in the two mines together.

GENETIC RELATIONS OF THE SILVER MINES OF MINERAL RIDGE.

CHARACTERISTICS OF THE POCATELLO GROUP.

Aside from the mineralization, the general geology at the Pocatello and Vanderbilt mines is like that of the Great Gulch mine. The country rock is a schist, which represents a shaly limestone, now more or less altered, with the development of isolated crystals of microcline, orthoclase, oligoclase-albite, quartz, etc. This is very near the top of the limestone-schist formation, which is overlain by massive brown dolomite. In the schist are alaskite lenses associated with quartz lenses, both having the same characteristics as at the typical gold mines. The ore zone runs along a zone of these quartz lenses. Greenstone dikes and sheets are present, following especially the zone of quartz lenses; they are in general parallel to the quartz, but sometimes cut across. As is the case in the gold mines, the diorite is entirely altered to secondary materials. Near the greenstone the quartz is frequently cracked, broken, and mineralized. Assay shows this portion to be richer than the ordinary white quartz in both gold and silver.

The ore on the whole is altogether subsequent to the quartz, in which it occurs along cracks. The most characteristic mineral is the mixed sulphide and oxide, containing copper, antimony, silver, and gold, described on page 91. The values in the ore are said to have been principally silver, though some assays showed much more value in gold than silver, and a comparison with portions of the quartz which do not contain subsequent ore shows that both the gold and silver in this case are principally of subsequent origin.

The conclusion arrived at is that the schists were first injected by a silicious magma, which crystallized as alaskite and quartz. Basic dikes were subsequently injected, which followed along the zone of quartz and alaskite lenses, because here fracturing was more easy on account of the greater brittleness of the materials. The intrusion of the diorite produced considerable fracturing. Along these fractures circulating mineral solutions deposited gold, copper, and silver, and these were very likely the solutions which altered the diorite to greenstone. The whole history indicated is analogous to that of those mines in the Drinkwater group, which show noticeable subsequent mineralization, although the character of the ore is somewhat different in that more silver and copper in proportion to gold are present.

CHARACTERISTICS OF THE BLACK WARRIOR GROUP.

The prospects of the Black Warrior group are in the dolomitic marble which overlies the schist formation, and are not far from the schist boundaries. The ores are veins or bands of quartz or jasperoid running parallel to the bedding planes and occasionally cross cutting the formation. They are irregular in form and are evidently due mainly to replacement. Microscopical study shows that the quartz as a rule has a jasperoidal retiform texture, unlike that of the granular quartz previously described. In the quartz the black stetefeldtite-like copper-silver-antimony mineral, and some galena, are disseminated, and are plainly primary and contemporaneous with the gangue. These veins are believed to be the result of waters which have obtained access along fractures and have spread out along convenient stratification planes. Greenstone dikes of the same character as those previously described are intrusive into the dolomite, chiefly in interbedded sheets, and are often near the vein. These dikes sometimes occur on the foot or hanging wall of the ore or both. The relative age of the greenstone and ore is doubtful.

COMMON CHARACTERISTICS OF POCATELLO AND BLACK WARRIOR GROUPS.

In both the Black Warrior and Pocatello groups of ore deposits the ores are similar in nature, being characterized principally by the black stetefeldtite-like mineral. Both are accompanied by greenstone. The chief difference is that one is in the dolomite near the schist formation, while the other is in the schist near the dolomite, also that in one case the inclosing quartz is contemporaneous with the metallic minerals and in the other is antecedent to them.

The similarity of the ores suggests that both are due to the same mineralization. In the Pocatello group, where the channels of mineralizing waters were in older quartz, any silicifying potentiality which the waters may have had would be obscured while in the dolomite of the Black Warrior group its effects would be plain. In the latter case the solutions are shown to have been silicious. The decomposed state of the greenstone in both groups suggests the same conclusion that was reached in the case of the gold mines only—that the mineralizing solutions were alkaline.

This mineralization seems to differ from the subsequent mineralization, described in the case of the Great Gulch, Mary, and other gold mines and prospects, in the presence of more silver and copper, although otherwise the facts are not unfavorable for regarding all as belonging to the same period. The writer desires to put forth here as a plain hypothesis an idea which has been arrived at by considering and reasoning from the distribution and character of ore deposits throughout the quadrangle. This hypothesis is that in the granite, or in rocks silicified by the metamorphic effect of the granite, solutions of granitic origin have deposited gold predominantly, and that in the calcareous or dolomitic intruded rocks more silver and copper were precipitated from the same solutions, the difference being due to the selective precipitative influence of the wall rocks.

GENETIC RELATIONS OF THE LONE MOUNTAIN GROUP OF MINES.

The Lone Mountain group of mines, as described in this report, are all situated in Paleozoic stratified rocks. These rocks are limestones, dolomites, and shales, which have been more or less metamorphosed by the intrusion of granitic masses. The metamorphism is most intense near the contact and fades away gradually as the distance from it increases. The limestones and dolomites are changed to marble, the shales to hornstones and schists, with the development of typical metamorphic minerals.

The few specimens of intrusive granite and alaskite examined show characteristics similar to those of some of the phases studied from Mineral Ridge. Alaskite from near the prospects at Weepah is similar to a very common type near the Drinkwater mines. A specimen of the Lone Mountain granite is like the granitic phase of alaskite in the Mary mine. In this Lone Mountain type, as well as in the Mineral Ridge granite, two generations of crystals are indicated by microscopic study, and some magmatic alteration of feldspar to muscovite, between the first and second crystallizations, is evident.

The veins of the Lone Mountain group characteristically follow the stratification of the sedimentary rocks. Where they thus occur along bedding planes, these planes have evidently been the sites of differential movement, which has produced crushing and greater openness. More rarely the veins are found in crosscutting shear or fault zones.

Along the vein zones, whether parallel or transverse to the stratification, the vein material, consisting chiefly of quartz, occurs rather irregularly in separated veinlets or in lenses and pockets of considerable size. Some of the veins are apparently filled deposits, while others, especially those in limestone or dolomite, are due to replacement.

In the ores of the Paymaster-Esperanza type, the black stetefeldtite-like mineral occurs, together with galena and pyrite. Copper, silver, and gold are present. In ores of the Enterprise type, magnetite, specular iron, pyrite, chalcopyrite, and galena, with gold and silver, are present. At Weepah the quartz contains a small amount of the stetefeldtite-like mineral, with galena and free gold and a little copper. At the Alpine mine the primary ore is galena, now largely altered to carbonate. There is also a little copper stain. In general, therefore, there is a strong likeness among the ores of this district.

The chief gangue mineral of this group of veins is quartz, but there is usually some calcite. In the Enterprise group many other minerals are present, chiefly epidote and garnet.

Diorite made up of feldspar and hornblende runs along a part of the Enterprise vein zone. It is partly altered to epidote, carbonates, etc. At the Alpine mine diorite sheets and some crosscutting dikes occur in the marble and occasionally in the granite, but these do not seem to be associated with the ore and are regarded as probably of later origin.

The deposits of metalliferous jasperoidal quartz at Weepah and Alpine are, as indicated by their location near the intrusive granite contact, plainly dependent upon the same general action that produced the metamorphism of the sediments in which they occur. The metals have been introduced by siliceous solutions which emanated from the consolidating granite. The Enterprise type of deposits, with its gangue of typical contact metamorphic minerals, is still more clearly contemporaneous with the contact metamorphism of the strata. Some of the deposits of the Esperanza group are as much as 5 miles from the contact of granite on the map, and the sediments in which they occur are only slightly metamorphosed, so that fossils have been found in them, yet their mode of occurrence and the nature of their materials show a close relationship to the others described.

The general conclusion is that at the time of the intrusion of the granite siliceous solutions emanated from the hardening mass and penetrated the surrounding sediments, which were thus recrystallized and metamorphosed. Such solutions circulated most vigorously along openings which had been formed by the granitic intrusion. Most of these openings lay along bedding planes; some along crosscutting shear zones. Within half a mile or a mile of the granite there is evidence that a considerable quantity of such solutions vigorously circulated along favorable openings, but at a greater distance, as in the region of the Paymaster group, the solutions had evidently become scanty, since they deposited small and irregular quartz veins which only partially filled the channels.

These circulating granitic waters, producing metamorphism in the rocks and vein formation in the fractures, plainly brought in from the granite the quartz and the various metals of the veins.[a] Evidently the genesis of these deposits is similar to that of the Black Warrior group of Mineral Ridge.

GENETIC RELATIONS OF ORES IN THE SOUTHERN PART OF THE QUADRANGLE.

All of the described prospects in the southern part of the quadrangle are near intrusive bodies of granitic rock, with which they are plainly closely connected.

The described prospects in the Dyer district are identical in type with the Paymaster vein, in the Lone Mountain region, in respect to gangue, ore, and wall rock. They are mostly bedding-plane deposits, consisting of irregular streaks of quartz following zones of crushing. Their values are chiefly in silver, and the principal metallic mineral is the stetefeldtite-like mineral previously described. The localization of these deposits near a small area of granitic rocks and their association with a small deposit of specular iron indicate that they are the effect of granitic solutions.

In the Windypah district the type of deposit found in the Dividend prospects, already described, is due directly to siliceous magmatic segregation. Other quartz veins, of the Hector type, follow shear zones in granite. In these shear zones the amount of quartz is variable, and the supplies of solutions were evidently not copious. The quartz contains pyrite and gold, and the wall rocks are sericitized and in part

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[a] Molybdenite has also been reported from the Lone Mountain district, but without satisfactory confirmation. (Eng. and Mining Jour., Oct. 31, 1903, p. 667).

kaolinized. The resemblance of these veins in composition to the Dividend type of segregated veins leads to the belief that these are also due to siliceous residual solutions derived from the consolidation of granite, which have circulated along available channels in portions of the granite which had already consolidated.

Another type of the Windypah veins (Chloride type) occurs in calcareous and argillaceous sediments near the contact of the granite. The gangue is chiefly quartz, the metallic minerals chiefly stetefeldtite, galena, copper pyrite, etc. The values are chiefly in silver, but there is some gold. These minerals follow fracture zones, especially along alaskite dikes. They have formed largely by replacement. The country rock consists of metamorphosed sediments containing typical contact metamorphic minerals, including a little tourmaline, a mineral which was not noted in the contact metamorphic zone of the Lone Mountain district.

Altered diorite or greenstone dikes are sometimes associated with the ores, which are mostly subsequent to the dioritic intrusion, but no genetic connection between the two was observable.

The MacNamara prospect, already described, in the Palmetto district, belongs to the Chloride type. Here again the vein is a typical crushed zone and contains irregular streaks of quartz carrying galena, chalcopyrite, and pyrite, the values being mostly in silver, with considerable gold and lead. The country rock is a typical contact-metamorphosed sediment containing, as in the Windypah district, a slight amount of tourmaline. Diorite dikes are present, but again have no genetic connection with the mineralization. That part of the Paymaster zone which lies in metamorphic sediments resembles the MacNamara and still more closely the Enterprise zone of the Lone Mountain district, being characterized by typical contact-metamorphic minerals. The values here are in silver and gold. In the granite what appears to be the same zone has different properties, the deposits being of a type intermediate between the Dividend and Hector types of Windypah. The quartz veins are slightly subsequent to the alaskite, in which they sometimes occur, but have the appearance of having segregated out from the immediate vicinity. The metallic minerals are copper and iron pyrites, containing gold, and barite in one place occurs as gangue. The fact that along what seems to be the same great fracture zone the ores are of different characters in the granite and in the intruded sediments indicates a probable origin by the same solutions, and the different characters of the veins is assumed to be due to the influence of the wall rock.

GENERAL CONCLUSIONS AS TO ORIGIN OF METALLIFEROUS ORES.

The metalliferous ores of the quadrangle are intimately interrelated, and their origin has been traced to the consequences of one event, namely, the intrusion of granitic rocks into Paleozoic sediments in probably post-Jurassic time. This district is favorable for such determinations as have been made, since the granitic masses are small and the grouping of the ore deposits around them is therefore relatively more evident here than in a region like the Sierra Nevada, where the masses of granite are vastly larger.

The ore deposits may be divided into the two following chief groups:

1. Bodies of auriferous quartz, which probably separated in gelatinous form from alaskite during the process of crystallization and are of the same age and nature

as the intergranular quartz of granite and alaskite. In such quartz bodies gold is in places segregated in commercial quantities.

2. Quartz veins due to replacement or impregnation of crushed material along fracture zones by siliceous solutions more attenuated than those described above and probably residual from the crystallization of the magmatic quartz of the first type. These solutions were probably diluted in various degrees by magmatic water. Such deposits were formed chiefly along movement zones following bedding planes in the intruded Paleozoic strata, also in crosscutting movement zones in the strata, and to a less degree in the granites. They were formed contemporaneously with the recrystallization and contact metamorphism of the sediments under the influence of the granite intrusion. They are typical quartz veins in the pure carbonate rocks and in the granites, but in the argillaceous rocks the quartz is often intermixed in various degrees with metamorphic silicate minerals, such as garnet, epidote, etc. The metallic elements present are principally silver, gold, lead, arsenic, antimony, copper, and iron in various combinations. There is more gold in the granite, more silver and lead in the intruded strata. In the granite the metallic mineral is mostly pyrite, sometimes arsenical. In the sedimentary strata the characteristic metallic minerals are the altered sulphide containing silver, copper, and antimony, which we may provisionally call stetefeldtite, and galena. The differences in the character of the metallic minerals is believed to be due to the difference in the wall rocks, which have precipitated certain things from solution. Aside from the quartz, the nature of the gangue is also believed to be chiefly due to the nature of the walls.

The solutions from which all the types of ore deposits were formed are believed to have been highly siliceous and alkaline and to have contained mineralizers, such as fluorine and boron, in a limited amount.

COMPARISON OF SILVER PEAK DEPOSITS WITH OTHER ORES.

Of the various types of deposits in the Silver Peak quadrangle the most striking and interesting is that of the Drinkwater and similar mines, where the ore bodies are lenses of magmatic quartz in the schist. The other types of deposits described may be easily paralleled in other provinces of the world. They are not so distinctive as the Drinkwater type. Ores of this type doubtless exist elsewhere, but since their nature and origin have not been fully determined examples have not been described. The description of the Sultana mine in Algoma, western Ontario, given by Dr. A. P. Coleman,[a] is, however, suggestive:

> The great quartz lenses of the Sultana mine are found at the northwestern edge of an oval boss mapped by Lawson as Laurentian. The inclosing rock mapped as Keewatin is green, fine grained, and not distinctly schistose. The boss of Laurentian consists in its central part of coarse-grained gray granite with phenocrysts of orthoclase half an inch wide. Going westward toward the edge of the boss, the granite slowly becomes schistose, showing distinct parallelism of structure, and the porphyritic feldspars are rolled out into imperfect augen or lens-shaped portions. At the water's edge near the Crown Reef the coarse gray gneiss passes rapidly into the fine-grained, dark gray gneiss of a very schistose character, and then into very fine-grained black mica-schist with crumpled strips or lenses of quartz. * * * The large quartz lenses in which the mine is worked lie in the schistose edge of the boss, and contain many thin sheets or thicker bands of the dark schist.
>
> As one approaches the * * * edge of the boss * * * the signs of crushing and shearing grow intense. The quartz shows "mortar" structure, being crushed into fine particles inclosing larger fragments.

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[a] Sixth Rept. Ontario Bureau of Mines, Toronto, 1897, p. 121.

The feldspar is broken and portions shifted asunder, calcite sometimes serving as cement. * * * At the very edge the quartz is rolled out into streaks of crushed particles, the feldspar largely changed into a mixture of sericite and brown mica, and calcite and sulphides appear in considerable quantities. At the extreme edge little is to be seen in thin sections but brown biotite in minute scales. * * *

It may be imagined that the granite, while still somewhat plastic—i. e., not yet cooled to the point of consolidation—pushed up through the Huronian rocks, more or less shattering them and dragging out its own margin into the present schistose form. Before the process was complete the sheared edge of the mass was solid enough to allow the formation of great cavities between the layers of gneiss and mica-schist. Here the fluids of the now solid but still hot granite could circulate, depositing the auriferous quartz.

Taking the different types of deposits in the Silver Peak quadrangle as a whole, a number of similar examples at once present themselves in this same region.

Fifty miles northeast of the northeastern corner of the Silver Peak quadrangle is the Belmont mining district, at one time productive, but long since inactive. Here the writer has made a brief study of an interesting dike rock and its associated phenomena, which include mineral-bearing veins[a]. The dike is one of the outlying offshoots from a large body of siliceous granite. It is nearly half a mile wide and cuts Silurian slates and limestones. Near the contact the slates and limestones have been transformed into jasperoid[b] by the introduction of silica; in part they have also been altered to micaceous schists, often containing disseminated small bunches of yellow and red metallic oxides. In this rock occur quartz veins which carry rich antimonial silver ores.

The dike rock varies greatly in texture and composition. One specimen collected, classed as a siliceous muscovite-biotite granite, is remarkable for the irregular arrangement of its constituent minerals, the quartz often segregating into bunches a quarter of an inch in diameter with all the characteristics of vein quartz. A coarser-grained biotite-granite taken at some little distance from the other has the same peculiarity, and in this place the blotches of quartz, mosaics of intergrown grains, are from one-third of an inch to one-half an inch in diameter. But the rock of chief interest is one which looks like a micaceous quartzite, and indeed consists, essentially, of muscovite and quartz. Microscopic study reveals in it the presence of the feldspar albite and proves that the muscovite has largely been derived from the alteration of orthoclase. Yet the rock is fresh and hard and the change has not been effected by surface weathering.

The process must be regarded as one of endomorphism and as connected and probably contemporaneous with the exomorphism indicated by the alteration of the siliceous limestone of the wall rocks to jasperoid and mica schist. In both the intrusive and the intruded rock the result of the metamorphism has been the same, producing quartz and muscovite at the expense of the orthoclase on the one hand and of the calcite and subordinate minerals on the other. In the case of the wall rock the metamorphism, being apparently from its distribution dependent upon the intrusion, evidently took place after this intrusion, and was brought about by the solutions which accompanied the igneous rock or were residual from its solidification. Within the dike the similar alteration was probably contemporaneous with that in the country rock.[a]

White quartz veins often several feet in width occur in the immediate vicinity of this intrusive mass. For these the conclusion is reached that—

These quartz veins are probably contemporaneous with those already described as occurring in irregular form within the dike rock itself, as evidently representing the final product of the residual solution of the gen-

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[a] Am. Jour. Sci., vol. 10, Nov., 1900, p. 355.

[b] Spurr, J. E., Geology of Aspen district: Mon. U. S. Geol. Survey, vol. 31, 1898, p. 219.

> eral magma. In these quartz veins[a] the metallic minerals (chiefly stetefeldtite, an argentiferous ore of antimony, with some lead, copper, and iron) are scattered in bunches or disseminated particles, rarely in banded form. * * *
>
> The metallic minerals being from their habit plainly contemporaneous with the quartz veins which inclose them, it is evident that the deposition of these minerals, the formation of the quartz veins, the metamorphism of the country rock to jasperoid and muscovite schist, and the endomorphism of the muscovite granite to quartz-muscovite rock were contemporaneous occurrences, all brought about by the same agencies, which were the solutions representing the end product of the differentiation of the granitic intrusive rock.

In the Toyabe Range are numerous ore deposits, of which the chief ones lie near Austin, about 65 miles north of Belmont. The writer quotes his own summary of the district,[b] based chiefly upon the reports of the Fortieth Parallel Survey:

> Formerly the ores of the Toyabe Range were of great economic importance, but with the decline of the mining industries of Nevada they have been almost forgotten. The principal mining region was in the neighborhood of Austin, but mines were found from here southward all along the range. Mr. Emmons has described many of the deposits, which in nearly every case consist of veins of white quartz carrying metallic sulphides in irregularly disseminated bunches and streaks. In the vicinity of Austin, the oldest mining district in the State, the veins are mostly in granite, and rich ores do not appear to occur in other rocks. In other parts of the range, however, the veins occur in the stratified rocks. Besides quartz as a gangue mineral manganese spar and calc spar were noted, while the metallic sulphides comprise proustite, pyragyrite, stephanite, polybasite, tetrahedrite, argentiferous galena, zinc blende, copper pyrites, and iron pyrites. In some of the veins the chief silver-bearing mineral is a mixed sulphide of antimony, as is the case in the neighborhood of Belmont. The veins are often faulted.
>
> As in the case with the ores at Belmont, there is probably an intimate connection between the metalliferous quartz veins and the intrusive rocks.

About 15 miles east of the eastern edge of the Silver Peak quadrangle is the southern Klondike district, which was noted by the writer in a previous publication.[c] At this camp the main country rock is Paleozoic limestone, which is intruded by a long dike-like mass of siliceous granitic rock of a composition similar to alaskite. The constituent minerals of the rock are chiefly quartz, orthoclase, and muscovite, and by various combinations of this rock types originate in different parts of the intrusive mass which may consist, essentially, of quartz and feldspar and so are alaskites; or of quartz, orthoclase, and muscovite, constituting muscovite granite; or, finally, of quartz and muscovite only, forming an igneous rock type which has not been previously fully recognized. The rock of the dike as a whole, however, is evidently closely related to that described by the writer from Belmont. Study of thin sections has shown the same derivation for the muscovite as that described from Silver Peak and Belmont. Occasionally in the igneous mass there are small segregated portions of pure quartz, in which patches of pyrite and more rarely of galena occur. The limestone near the contact has been altered to a hornstone, in which the microscope reveals fine epidote, zoisite, and other characteristic products of contact metamorphism. At the very contact of the igneous rock with the limestone there is in places a deposit of hard hematite, which has been partly derived from oxidation of original pyrite, of which residual portions still remain. Not many yards from the contact in the altered limestone is a quartz vein which follows parallel to the contact closely for a mile or more and carries scattered values of silver and gold.

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[a] According to S. F. Emmons, Mineral industry: U. S. Geol. Explor. 40th Par., vol. 3, p. 398.

[b] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. U. S. Geol. Survey, No. 208, 1903, p. 97.

[c] Bull. U. S. Geol. Survey No. 213, p. 86.

The minerals contained are chiefly galena and pyrite, with small bunches of the rich, black copper-silver sulphide or stetefeldtite, which has been described as characteristic of those veins in the Silver Peak quadrangle that lie near the contact of the intrusive granite, but not in the granite itself.

All these mineral districts are closely similar. In all the ores have evidently originated as the result of the intrusion of granitic bodies into Paleozoic sediments, and in all cases where a close study has been made it has been found that the ore deposition was associated with contact metamorphism. The granitic and alaskitic rocks which make up these intrusive bodies are similar in those districts which the writer has examined—namely, Silver Peak, southern Klondike, and Belmont—and from Mr. Emmons's description[a] also in the Toyabe Range.

In the three districts which the writer has examined there are also similar pecularities of the intrusive rock, notably the segregation of small contemporaneous quartz masses within the rock and the alteration of feldspar to muscovite by magmatic processes.

West of the Silver Peak quadrangle the Sierra Nevada is made up largely of granitic rocks, consisting mainly of granodiorite and granite. These rocks were intruded into the Paleozoic and Mesozoic strata in post-Jurassic time, probably contemporaneously with the similar intrusions in Nevada. Associated with these intrusions, partly in the granite, but more especially in the intruded sediments, now mostly metamorphosed into schists, are auriferous quartz veins, also post-Jurassic in age, whose formation immediately succeeded the granitic eruption. In this region Whitney[b] noted that while the granite itself is not metalliferous its appearance seems to be closely associated with the metamorphism of the adjacent sedimentary rocks, while this latter condition is, as a general rule, the concomitant of the occurrence of minerals or metalliferous veins. Prof. J. F. Kemp[c] remarks:

> The enormous introduction of silica is one of the most extraordinary features of the geology of the Sierras and indicates a remarkable activity of circulating waters. The igneous intrusions doubtless promoted, if they did not cause, the circulations.

Mr. Waldemar Lindgren[d] writes concerning the veins of a portion of this district (Nevada City and Grass Valley):

> It is not believed that the bulk of metals of the veins is derived from the rocks immediately adjoining the vein. Their origin must still be left an open question; but the probability is strong that they were dissolved from the more deep-seated parts of the granodiorite, which appears to form the foundation of the Sierra Nevada, and brought to the surface by the thermal waters, the whole process being the closing chapter, the last manifestation of the abyssal granitic intrusions.

Mr. Lindgren adds that the thermal waters were doubtless surface waters from the higher portions of the range which penetrated to a considerable depth before again reaching the surface. More recently, however, Mr. Lindgren has adopted the hypothesis that the solutions which deposited the veins are of magmatic origin. He writes[e]:

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[a] U. S. Geol. Explor. 40th Par., vol. 3, p. 324.

[b] The Auriferous Gravels of the Sierra Nevada, p. 353.

[c] Ore Deposits of the United States and Canada, 3d ed., p. 370.

[d] Gold-quartz veins of Nevada City and Grass Valley: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 175-176.

[e] Characteristics of gold-quartz veins in Victoria: Engineering and Mining Journal, March 9, 1905.

> With some confidence I would formulate the hypothesis that the gold and the quartz in this type of veins have been deposited chiefly by "cruptive after-effects;" in other words, chiefly by hot ascending waters originally contained in the granitic magma and released from it by decreasing pressure, due to its eruption into the upper parts of the lithosphere. It is quite possible that atmospheric waters may have played a certain part by aiding the precipitation and by effecting certain forms of concentration in the deposits.

These gold-quartz veins of California are characterized by the common occurrence of albite as a gangue mineral. F. A. Genth described albite in pyritiferous gold-quartz veins in California,[a] and it has been noted as a common occurrence by subsequent observers.[b] In the Mother lode district Doctor Ransome[c] has described veins consisting almost entirely of albite with some quartz, and veinlets of albite alone; these in places contain bunches of free gold. In connection with the presence of albite in these veins the observations of Lehmann may perhaps be enlightening (p. 115). These observations indicate that the last attenuated granitic residue contains a great deal of soda, so that albite is deposited from it, along with quartz and other materials.

The general conclusion is that the Silver Peak deposits are part of those contained in a larger province, represented more abundantly in the Sierra Nevada of California, with only outlying smaller areas in adjacent portions of Nevada. In these smaller areas, however, their isolated situation probably makes it possible to study the nature and origin of the deposits of the whole province better than in the larger occurrence. All the ore deposits of this province seem to owe their existence to the intrusion of the post-Jurassic granite, which now by erosion forms a large part of the main mass of the Sierra Nevada and occurs in less quantities eastward into Nevada. The ores seem to be due to siliceous solutions, which were residual from the later stages of crystallization of the granitic rocks. These solutions frequently deposited the minerals they contain (silica, gold, etc.) along fractures or shear zones or other channels, thus forming the typical gold-quartz veins of the region. In Nevada these solutions formed in places where the wall rock consisted of the calcareous strata intruded by the granite a type of noble silver-gold veins (that is, veins containing a comparatively small amount of the baser metals) characteristic of the period.

In studying the ore deposits of Tonopah, which lies only about 10 miles in a straight line east of the Lone Mountain district in the Silver Peak quadrangle, the conclusions were reached that the veins owed their origin to the action of magmatic waters and vapors, whose advent followed the eruption of certain Tertiary volcanic rocks. These waters and vapors were shown to be probably such as appear at the surface in volcanic regions, in the shape of fumaroles, solfataras, and hot springs. The chief set of veins was deposited immediately after an andesitic eruption, and a less important set after a rhyolitic eruption. In the Tonopah report[d] analogies were pointed out between Tonopah and other districts in Nevada, and this comparison was extended to Idaho on the north and into Mexico on the south. Throughout this region ore is found in Neocene volcanics, and especially dependent upon the Miocene andesites and to a less extent upon the Miocene-Pliocene rhyolites. In all

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[a] Am. Jour. Sci., vol. 33, p. 249.

[b] Ransome, F. L., Mother lode folio: Geologic Atlas U. S., folio 63, U. S. Geol. Survey, p. 8.

[c] Op. cit., p. 9.

[d] Prof. Paper U. S. Geol. Survey No. 42.

these cases the ores were believed to have the origin described above for Tonopah. More than one period of mineralization, following different volcanic eruptions, has thus been determined, but all these deposits are genetically connected with Neocene volcanics, and so have been grouped together. These deposits are characterized by certain common features in regard to gangue, ores, and alteration of the wall rock. On account of these characters these veins form a type of noble silver-gold veins, distinct from that of the silver-gold veins which have been described as connected with the granitic intrusions.

The writer has characterized the region in which these silver-gold veins occur in the Neocene volcanics as a metallographic province. The interresemblance of the different ore deposits connected with the granitic intrusion in western Nevada is such as to justify rating this region as a metallographic province also. This province appears to be typically developed in California, for which reason we may call it the California province, while the province characterized by the ores in Neocene lavas is best represented east of the Sierra Nevada, in the State of Nevada, and may therefore be called the Nevada province. In western Nevada the Nevada province overlaps upon the California province, and along this overlap the ore deposits belonging to one group are superimposed upon those of the other. The Nevada province is coextensive with the appearance of Neocene andesites and rhyolites at the surface; the California province with the appearance at the surface of the post-Jurassic granitic rocks. Where, as in western Nevada, these granitic rocks and the strata which they include, together with the attendant veins, are exposed by erosion in patches lying in the midst of Tertiary volcanics, the veins belonging to the two periods may occur very close together. In the Silver Peak region Tertiary lavas overlie the granite and the post-Jurassic veins, but in this quadrangle no Tertiary vein formation has been discovered.

CHAPTER IV.

DEVELOPMENT OF THE THEORY OF METALLIFEROUS VEINS OF MAGMATIC QUARTZ.

The most important contribution to the theory of ore deposition made in the previous pages is the establishment of the fact that some auriferous quartz bodies may be of magmatic origin and may, indeed, be regarded as a phase of granitic magmas. This conclusion supports the theory proposed by the writer in 1898 to explain the auriferous quartz veins of the Yukon district in Alaska.[a] At the time that this theory was formulated the writer had little knowledge of certain geological literature bearing upon the theory. The whole theory, including the transition of quartz veins to pegmatites and these to granitic rocks, was at that time original with him, but by continued study he finds that more and more of it had been anticipated, until practically the only portion left which he can consider as original is the conclusion that granitic quartz veins, which are really the ultra-siliceous form of the magma, may contain metals, especially gold, in sufficient quantity to constitute ores, and the corollary, later announced, that gold-quartz veins are especially connected with intrusive bodies of granitic rock.[b]

In the following few pages an attempt is made to sketch the progress of thought by which the writer's theory has been in part anticipated, and there is added thereto some accumulated information bearing upon the problem.

CRYSTALLIZATION OF GRANITE.

Early in the nineteenth century it was pointed out that the relative order of crystallization of the different minerals in granite was not that of their relative fusibility and that therefore the rock could not be due entirely to cooling from fusion.

In 1822, Breislak[c] pointed out the difficulty above mentioned.

> If the granites are crystallized by cooling, their constituents ought to separate and to crystallize at different epochs corresponding to their different degrees of fusibility. * * *
>
> It seems that sometimes the most fusible substance has crystallized before the less fusible one and is included in it.

This objection having fallen into complete oblivion, M. Fuchs[d] recalled the attention of scientists to these phenomena. He vigorously pointed out the impossibility that the mixture of minerals found in granite should have crystallized from a condi-

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[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 312.

[b] Trans. Am. Inst. Min. Eng., vol. 33, p. 321.

[c] Traité sur la structure du globe, Paris, 1822, tome 1, p. 356. Cited by Scheerer, Bull. Soc. Geol. France, 1846-47, 2d ser., IV, 1, p. 477.

[d] Sur les theories de la terre, etc., Munich, 1844. Cited by Scheerer, op. cit., p. 477.

tion of simple fusion. He remarked, moreover, that though crystals analogous to those of natural minerals have been formed in furnaces there had never resulted in this way a mixture like that of granite.

In 1833, Professor Scheerer visited Norway, before the objections of M. Fuchs had appeared and before he was acquainted with the views of Breislak. He observed that in pegmatitic granites it could be noted with certainty that the feldspars had crystallized before the quartz, showing that the quartz was still liquid, or at least pasty, while the feldspar was in process of crystallization. He concluded—

> that the most correct idea that can yet be formed concerning the origin of these rocks is that which attributes to the two elements fire and water an equal creative power. * * * One must admit that it is impossible to regard this rock as having been in a state of purely igneous fluidity.

Professor Scheerer pointed out that several of the minerals in granite contain water. He therefore reasoned that the magma must have had at least as much water as the solidified rock now contains. If it had had very much more, forming a humid base, such a magma would occupy a much greater space than the granite formed by its consolidation. The observed phenomena, however, show that dikes of granite occupy about the same space when cool as when in the magmatic form, showing that the proportion of water in the magma can not have been very large. He concluded—

> The quantity of water contained primitively in granite ought constantly to be between 1 and 50 per cent, and it is very probable that the amount is closer to the minimum than to the maximum. Here is an approximate idea of the quantity of water in the granitic base. If one fixes it at 5, 10, or 20 per cent, it is almost the same thing.

The substance of Scheerer's views has been corroborated by the most careful microscopical and chemical work since his time, without any very great advance in the general conception. Microscopical study has shown positively that in granitic rocks the order of crystallization is not that of relative fusibility, but for the commoner elements is rather that of relative basicity. As a rule the order of crystallization in granitic rocks has been found to be (1) dark minerals (amphibole and biotite), (2) feldspar, (3) quartz. On account of this relative order of crystallization it has been pointed out that if at any stage of the consolidation the minerals already formed are concentrated, rocks of all degrees of basicity may originate. Rosenbusch remarks[a]:

> Since the more basic compounds are in general the older, it is self-evident that the concentrations of earlier-formed minerals and mineral combinations must have the mineralogical composition of basic rocks—that is to say, in a granitic rock, syenitic, dioritic, and gabbroid facies must form. If one considers this process as progressing further and further, it is seen that, together with the basic crystallized material, a continually more acid residual magma will develop, which itself finally crystallizes, and we have then a sort of splitting up of the homogeneous eruptive magma into geologically closely related masses of basic and acidic rocks.

MAGMATIC ORIGIN OF CERTAIN PEGMATITES AND CERTAIN QUARTZ VEINS.

The more siliceous varieties of granitic rocks, representing usually later phases of consolidation than the normal granites, have not always been thoroughly understood. Especially the coarse-grained facies known as pegmatites have been con-

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[a] H. Rosenbusch, Mikroskopische Physiographie der Massigen Gesteine, 3d ed., Stuttgart, 1896, p. 34.

sidered by many students as vein formations subsequent to the granitic injections and due to quite different processes. This idea was due to the fact that these pegmatites are often found to be transitional into veins made up mostly of quartz, and because in other ways they showed many points of resemblance to veins for which an origin by deposition from circulating waters was nowhere denied. This conception as to the essential difference between pegmatites and granites depended primarily upon the false conception which still lingers in the minds of geologists, although long ago shown to be incorrect, that granite is a simple igneous rock, solidified from a molten condition, and that other conception, which also is still firmly intrenched in the minds of many geologists, that all veins are due to deposition from waters which everywhere traverse the rocks and which have not necessarily any close genetic connection with igneous magmas. It is now, however, acknowledged by many that there is no critical line between granites and certain quartz veins nor between the processes by which they were formed. Between the granites and the quartz bodies, pegmatites often form an intermediate step. The terms "igneous" and "aqueous" for the processes by which the two ends of this transition series were formed is misleading, nor do the three terms which have been proposed, "igneous," "aqueo-igneous," and "aqueous" express the truth, for, according to the writer's conception, there is no sharp line at any point. At one end of the series the true granites are not wholly igneous, and at the other end the quartz veins are not wholly aqueous. The processes which formed them all are nearer together than these terms signify.

In 1823, Charpentier[a] came to the conclusion that the granitic pegmatite dikes are fissure dikes "which were formed simultaneously with, or at least very soon after, the consolidation of the inclosing granite."

In 1838, Keilhau[b] took the view that certain Norwegian pegmatite dikes are not fissure fillings but are dike-like segregations from the syenitic rocks in which they lie. This view was afterwards expressed also by Hausmann.[c]

The views of Scheerer,[d] published in 1846-47, and above referred to, concerning the crystallization of granite had some connection also with the theory of pegmatites. He wrote:

> There are frequently found, in granite and primitive gneiss, cavities whose walls are covered with crystals of different varieties. * * * We observe the same phenomena in a certain class of veins that are found in granitic and other rocks. It can be recognized in an almost material manner that their filling has been accomplished by the deposits of solutions or of juices which have escaped from the inclosing rock. That is why they are called segregation veins (filons de sécrétion).
>
> In sum, the attentive observer of granitic rocks can not avoid the idea that these contain, so to speak, a juice, which, running into the cavities and fissures, covers their walls with crystals. This juice penetrates more or less into the stratified rocks that the granite comes in contact with in its plastic state, and penetrating them, and thereby favoring their metamorphism, it takes a greater or less part in the formation of contact products. The fluid impregnating the warm mass of the granite could hardly be anything than water at a very high temperature, but nevertheless maintained in a liquid state and capable of escaping in tiny drops under an enormous pressure. It would contain in solution part of the solid substances and especially silica.

Although views like those cited above first obtained in regard to the origin of pegmatitic rocks, another theory was subsequently developed which for some time was

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[a] Essai sur le constitution géognostique des Pyrénées, p. 158. Cited by Brögger, Zeitschr. für Kryst., vol. 16, p. 215.

[b] Gæa Norvegica, I, 58. Cited by Brögger, op. cit., p. 220.

[c] Cited by Brögger, op. cit., p. 221.

[d] Op. cit., p. 493.

predominant both in America and Europe. This was the theory of lateral secretion, by which the origin, both of pegmatitic rocks and metalliferous veins, was explained. The application of this conception to the explanation of pegmatites was probably first made in 1863 by T. Sterry Hunt,[a] in connection with his studies on Canadian pegmatites, and developed in succeeding essays.

Later, in 1875, H. Credner [b] came to the same conclusion in regard to the origin of the pegmatitic rocks of Saxony. He concluded that the material of these granitic dikes had not been intruded from below and had not even been formed by hot mineral springs, but were due to seepage water which had partially decomposed and leached the country rock to furnish the pegmatitic minerals.

In 1869, G. Kreischer [c] adopted for certain pegmatitic rocks an explanation similar to that of Hausmann above cited, namely, that they were of contemporaneous origin in the inclosing igneous rock.

In 1881, G. Woitschach [d] came to the same conclusion concerning certain German pegmatites that was reached by Kreischer and Hausmann. Similar views have been taken by other authors, such as Kalkowski [e] and Teall.[f]

In 1884, Dr. J. Lehmann[g] published his studies concerning the pegmatites of Saxony. He took a decided stand for the igneous and magmatic origin of these rocks, vigorously opposing the explanations of Credner. The phenomena which seem to have led Credner to his belief consisted of certain evident relations between different wall rocks and the pegmatites which they inclose. Doctor Lehmann acknowledged this relation but pointed out that it was of minor importance and that all the pegmatites must be referred to the granitic magma.[h] Doctor Lehmann went further, in announcing that the quartz veins or dikes (Gänge) associated with the pegmatites are also a phase of the granite magma. He writes:[i]

> If one goes from eruptive granites and the lesser dikes to the pegmatites, and farther on to the dike formations which are poor or lacking in feldspar, one easily comes to consider certain quartz veins as eruptive injections. * * * To be sure, if one confines himself to words and considers the eruptive masses only in connection with high temperature and fusion, then it is clear that these quartz veins or dikes can not have originated in this way. The granite magma is, however, essentially different from those magmas which reach the earth's surface. * * *

Doctor Lehmann added many individual descriptions and arguments to fortify his conclusions, describing many phenomena which find their parallel in the Silver Peak region of Nevada. Speaking in general of the granitic dikes of his province, Doctor Lehmann writes:[j]

> In connection with the increased size of the constituents, now one, now another, of them predominates. Here the quartz becomes subordinate, there the orthoclase. Dikes which are meters thick and consist of predominant clear or milky quartz, in which are embedded only occasional feldspar, tourmaline, or mica crystals,

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[a] Cited by Brögger, Zeitschr. für Kryst., 1890, vol. 16, p. 216.

[b] Zeitschr. deutsch. geol. Gesell., Berlin, 1875, vol. 27, p. 34. Cited by Brögger, loc. cit

[c] Neues Jahrbuch für Min., 1869, p. 209. Cited by Brögger, op. cit., p. 221.

[d] Cited by Brögger, op. cit., 221.

[e] Zeitsch. deutsch. geol. Gesell., 1881, vol. 33, p. 653. Cited by Brögger, loc. cit

[f] British Petrography, p. 291.

[g] Die Enstehung der Altkrystallinschen Schiefergesteine, Bonn, 1884.

[h] The influence of different wall rocks in producing more or less characteristic types of minerals and mineral associations in pegmatites which form phases of granitic intrusions has also been studied by Mr. S. H. Ball in the region of Georgetown, Colo. (Report not yet published.)

[i] Op. cit., p. 25.

[j] Op. cit., p. 47.

seem to be very widely separated from true granite, and yet they belong to the granite formation of our mountains. These feldspar-bearing quartz veins, as well as those quartz veins in which, together with quartz, only tourmaline or only mica or albite are present, must have originated in the same way as the granite dikes proper or at least in a manner related to this and only modified. The opening up of the dikes to form mineral druses is also not against the idea of an origin by injection.

He adds:[a]

> We shall never grasp the meaning of the formation of granite in the region of the old crystalline schists if we do not trace up all the forms in which the granite magma can appear. To be sure, not every occurrence of granite is favorable for this study. * * *
>
> Every conception of a granite magma must in the first place take note of the silicic acid which has separated out as quartz, and on this account in the past the presence of quartz has created the greatest difficulties and aroused the greatest attacks.
>
> Elevated temperatures and heavy pressure were doubtless operative at the origin of the granite, and also a rôle must be ascribed to the intermixed water and other condensed volatile materials, which must be regarded as belonging to the granite magma in the beginning and can not have been brought to it from above. * * * We see in the neighborhood of great granite dikes and masses, certain impregnations and dike fillings as the result of their splitting up. These mineral deposits, since they did not reach the surface, must have had a fluid magma-like or aqueous vehicle. * * * These fluid secretions of the granite, which are equivalent to the gaseous and vaporous secretions of the lavas, can well be likened to hot jellies which solidify in cooling with a very variable water content. The ability of silicic acid to form jellies with little or with much water makes this conception attractive. The combination with boric and carbonic acid, fluorine, and other volatile materials is certainly also to be considered. Such a jelly-like magma must have been capable of crystallization through cooling, and according to the degree of the burden of the mineral materials which it carried must have filled the space more or less completely with its crystallization products. If it contained great amounts of components which remained fluid (and that must have been mostly water, besides gaseous products), then the character of the solution must have become more and more altered through successive precipitation, and a part of the mineral material may have attained greater distances from the original point than the part which early separated out as feldspar. Between such a jelly-like magma and a saturated aqueous solution we can think of a long series of transitional steps. In this way it seems to me that the connection of pegmatitic dikes with granular granites, as well as the very remarkable transition in the crystallization of the pegmatitic dikes, which often contains druses, and finally the close connection of these with dike fillings, which consist only of quartz, tourmaline, and muscovite or of quartz alone, becomes explicable. * * *
>
> Those dikes in our mountains which consist mostly of quartz and inclose feldspars as large as one's head. * * * can only have been formed simultaneously in a fluid mass. The mass which fills them contradicts with sufficient distinctness the idea of a precipitation from attenuated solutions and from ordinary seepage water. We have further, also, the testimony of Gümbel. Delesse also declared that, under great pressure and through mixture of water, quartz softens in the interior of the earth—that is, it may go over into a viscous gelatinous silica—in which process a temperature which is not extraordinarily high may have assisted. Observations which can not be otherwise explained are reported from numerous sources. Therefore since viscous silicic acid can unite itself with any given amount of water, it is not wonderful that when it goes over into the crystalline condition the quartz fills up the space entirely, if only a little water was intermingled; and that in the same mass, when it is burdened with a greater amount of water, the material on separating out forms druses, assumes the form of naked incrustations, and finally does not differ from the material separated out from ordinary aqueous solutions and mingles with these.

These detailed observations of Lehmann have been repeated frequently, and often made independently without knowledge of previous investigations, so that a constantly accumulating mass of evidence has been formed, though not much has been added to the results of Lehmann's investigations.

In 1887 A. W. Howitt[b] published important studies concerning pegmatitic rocks in Victoria, Australia. This is a region of auriferous quartz veins, which occur

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[a] Op. cit., p. 52.

[b] Notes in the area of intrusive rocks at Dargo: Trans. Roy. Soc. Victoria, vol. 23, p. 127 et seq.

characteristically near the contact of masses of intrusive granitic and dioritic rocks which have broken through and metamorphosed Paleozoic sediments. Mr. Howitt draws a distinction between these auriferous quartz veins and other veins of quartz to which he assigns a pegmatitic origin. He does not, however, give any criteria for distinguishing the two classes of veins save that one is auriferous while the other had not been proved to be so. These two classes of veins occur both at Dargo and Omeo. The auriferous quartz veins contain pyrite, arsenopyrite, galena, and gold. The quartz veins which he classes as pegmatitic consist either of quartz alone (milky or translucent) or of quartz containing tourmaline, feldspar, or muscovite, "or two or all of them together in varying proportions, so that veins may be extremely quartzose with but little proportion of other minerals or may be so charged with them as to become a variety of pegmatite."

From study of these veins Mr. Howitt found that the tourmaline crystals are frequently isolated in the midst of the quartz, which is molded perfectly around them and even fills cracks which had formed in consequence of their breaking. The isolation of the tourmaline indicates that the quartz was not deposited from solution, but was a denser plastic mass, which yet was capable of some movement under pressure. Mr. Howitt concluded that the quartz had been forced into the fissures in a colloidal condition.

> It seems to me, therefore, more than probable that such quartz veins as these represent some of the residual silica of the plutonic magma after the compound minerals had crystallized out, and that this residuum was squeezed out while in a colloid state into every adjoining fissure and plane of separation. No high temperature would, on this view, be necessary to produce these dike-like quartz veins, for the exudation of the still colloidal silica was brought about by the reduction of temperature, which caused the plutonic magma to solidify.[a]

In 1888 Mr. Howitt[b] came to the same conclusion for another group of rocks in this region. He writes:

> The granites, therefore, taken as a whole, including all the above varieties, represent an intrusion of plutonic rocks of several consecutive ages of the same period of plutonic invasion, and the series is increasingly acid, the later dikes being mainly of orthoclase (microperthite) and muscovite or of orthoclase and quartz. Finally, the veins and even strong dikes of crystalline quartz or of quartz and tourmaline (schorl), which are associated with these granites, represent the last portions of still fluid (uncrystallized) magma.

In 1890 W. C. Brögger[c] published some studies on Norwegian pegmatites. Brögger argues that the pegmatites of his district are essentially intrusive and magmatic, but differs from Lehmann as to the origin of the granitic quartz veins, which he (Brögger) regards as exudations from the solidifying magma. He acknowledges the transition between the quartz veins and the pegmatites, but regards the two as forming different classes. The pegmatite he regards as the last stage of consolidation of the granitic magma. The transition between this and true granites he says is perfect, the series being granitites, granophyres, aplites, and pegmatites. The quartz veins into which the pegmatites are transitional, and which follow the peg-

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[a] Mr. Howitt, in spite of the evidence which he has set forth in regard to the plutonic origin of many of the quartz veins in the auriferous districts, and in spite of the fact that he has shown the auriferous quartz veins to be connected with the intrusive granite contact, turns his face from these phenomena when he attempts to explain the origin of the gold in the auriferous quartz. He goes back to the old theory that the veins aredue to circulating waters which have derived their silica and their gold from the Silurian strata through which they have percolated, and that the gold was originally contained in the Silurian ocean and was precipitated in the sediments of that period.

[b] Notes on certain metamorphic and plutonic rocks at Omeo: Trans. Roy. Soc. Victoria, vol. 24, pt. 2, p. 100 et seq.

[c] Die Mineralien der Syenitpegmatitgänge: Zeitschr. für Kryst., vol. 16.

matites in point of time, do not, nevertheless, belong to this series, but are fissure fillings which are not entirely or not at all due to precipitation from true magmatic solutions.[a] He divides the formation of the pegmatites into four stages.[b] The first period, the phase of magmatic consolidation, yields certain minerals, among which the principal ones are apatite, titanite, zircon, magnetite, lithia-mica, fluorite, and feldspars, deposited in about the above order. The second period of minerals comprise those formed chiefly by the influence of mineralizers, or deposited from circulating fluids. These are minerals rich in fluorine, boron, and sulphur, such as fluorite, tourmaline, molybdenite, zinc blende, pyrite, galena, and copper pyrite. Zircon and albite also occur among the minerals of the second period. The third stage is that of zeolite formation, and the fourth that of fluocarbonates and carbonates.

In 1894 A. C. Lane[c] called attention to the fact that "there is a continuous series from pegmatites to segregation veins and true fissure veins filled by ascent. * * * Pegmatites are one form of residual magmas, the segregation veins a further step."

In 1895 G. H. Williams[d] discussed the origin of Maryland pegmatites. He concluded that many of these pegmatites were intrusive and an integral part of granitic intrusions. Another class of pegmatites, however, which he admits is not distinctly separate from the intrusive pegmatites in point of composition or appearance, he believed to have a different origin, on account of their being transitional into typical quartz veins. Such pegmatites he considered to have been formed by lateral secretion from the inclosing rock, for no one, he believed, could doubt that the vein quartz into which such pegmatites are transitional have this origin.

In 1896 C. R. Van Hise recorded the transition in the Black Hills from granite to pegmatite and from pegmatite to quartz veins. He believed[e] that pegmatites in different cases have been due to three processes:

> In some cases igneous injection, in some cases aqueo-igneous action, and in other cases pure water cementation, and in still others combinations of two or all of these processes.

The transition from granites to quartz veins which he has noted he appears to consider as marking these stages between true igneous injection and aqueous cementation. The water concerned in these processes he did not refer to the magma especially, but to the underground water in general, in the belief that under sufficient pressure and temperature magma and water are miscible in all proportions.

In 1897 W. O. Crosby and M. L. Fuller[f] contributed the most important essay on pegmatites which has appeared in American literature. They described cases in New Hampshire where there was a perfect gradation in composition between typical pegmatite and quartz veins. The quartz veins have locally cut the pegmatite and are therefore younger, but are nevertheless probably substantially contemporaneous with the quartz which is an integral part of the pegmatite. They dissent

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[a] Op. cit., pp. 226-232.

[b] Op. cit., pp. 160-174.

[c] Geologic activity of the earth's originally absorbed gases: Bull. Geol. Soc. America, vol. 5, pp. 259-280

[d] Fifteenth Ann. Rept. U. S. Geol. Survey, p. 675 et seq.

[e] Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 686.

American Geologist, vol. 19, No. 3.

from Williams where he maintains that the pegmatite which is transitional into quartz veins has a different origin from the rest, and maintain that this transition is an obvious and frequent relationship, and that the quartz veins are the end product of the same great process of differentiation which has produced the pegmatites. They propose a theory that pegmatites may be formed in two ways: First, by normal magmatic differentiation in a large body of magma. In this case the pegmatite, where it is still in its original place of differentiation, may pass gradually into normal granite, or the pegmatite magma may migrate, crystallizing in fissures in the parent granite or the surrounding rock. As another possible mode of formation, they believe that when apophyses of normal granitic magmas invade heated aqueous rocks and become hydrated their magma becomes a pegmatitic one.

In 1898 J. E. Spurr [a] observed the transition from quartz-feldspar rocks (to which he later gave the name alaskite) to quartz veins.[b] These quartz veins contain pyrite, argentiferous galena, and free gold.

In 1898 F. D. Adams [c] described some interesting nodules and veins in granite from Ontario. In this granite are spherical or oval quartz nodules containing tourmaline. In some places these nodules are arranged in rows, and along some portions of a given row the nodules may join, forming what appears to be a true vein. The chief constituents of the nodules are quartz, muscovite, and sillimanite. Sometimes plagioclase and orthoclase are present, and again tourmaline, iron ore, and pyrite. Professor Adams regards this as a case of primary magmatic differentiation and compares the veins to the quartz veins, frequently associated with tourmaline, which are transitional from pegmatites, and occur in connection with many granite magmas.

In 1899 Otto Nordenskjöld [d] observed, in the Klondike region, transitions such as Mr. Spurr had described from the near-by Fortymile district of the Yukon province. These transitions were from granites to pegmatites and perhaps into pure quartz veins. Nordenskjöld, however, did not observe gold nor pyrite in these rocks.

In 1901 J. F. Kemp [e] wrote that on the north shore of Long Island Sound "pegmatites are abundantly developed in connection with granites, and all grades are shown up to practically pure quartz."

In 1903 J. E. Spurr [f] noted the transition at Silver Peak, Nevada, from granitic rock into quartz veins. Mr. H. W. Turner had made the same observation independently. Mr. Spurr also noted the transition from quartz veins into granite at various other places, including the vicinity of Oro Grande on the Mojave River in southern California, in northwestern Nevada in the Walker River Range, and near Randsburg, Cal.

G. A. Waller and E. G. Hogg described in 1903 [g] some interesting quartz-tourmaline dikes in Tasmania. In the region described a granite is intrusive into

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[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 312.

[b] Am. Geologist, April, 1900, p. 229.

[c] Nodular granite from Pine Lake, Ontario: Bull. Geol. Soc. America, vol. 9, pp. 163-172.

[d] Die Geologischen Verhältnisse der Goldlagerstatten des Klondikegebietes: Zeitschr. für prakt. Geol., March, 1899, pp. 71-83.

[e] The rôle of the igneous rocks in the formation of veins: Trans. Am. Inst. Min. Eng., vol. 31, p. 182. Genesis of Ore Deposits, p. 693.

[f] Trans. Am. Inst. Min. Eng., vol. 33, p. 313.

[g] The tourmaline-bearing rocks of the Heemskirk district: Report of the Secretary for Mines of Tasmania, 1903.

metamorphosed Silurian sediments. The granite contains tourmaline throughout, usually associated with the quartz. Nodules of quartz containing tourmaline and a little feldspar occur in the granite, either isolated or collected in masses, and seem to correspond with the phenomena described by Doctor Adams, above cited. In connection with the granites, tourmaline aplites occur, which appear to represent a differentiation product of the granite. The aplites contain quartz-tourmaline nodules in greater abundance than the granite. Rocks consisting entirely of quartz and tourmaline are frequent, and are divided by the authors into dikes and veins. The quartz-tourmaline veins consist of quartz and tourmaline with, as lesser constituents, cassiterite and pyrite, as well as some bismuthinite, molybdenite, pyrite, chalcopyrite, galena, zinc blende, and fluorite. The veins are partly due to the filling of fissures and partly have originated by replacement of the wall rock. The dikes consist of a uniform granular mixture of quartz and tourmaline, with sometimes a little feldspar. The tourmaline is older than the quartz. These dikes often contain included angular fragments of the country rock. In some cases quartz has segregated, so that the dike is of white quartz, almost free from tourmaline. It seems evident that the tourmaline is an original constituent of the granite magma, since it is present in all the rocks. The local increase in amount of tourmaline is accounted for by a process of differentiation in the magma, and the quartz-tourmaline nodules are accounted for by a similar process. This quartz-tourmaline magma, collecting together, has formed the quartz-tourmaline dikes. The quartz-tourmaline veins are accounted for by a further magmatic separation, which has separated a highly aqueous from a less aqueous magma. From the former, which would frequently be a saturated solution, highly heated and containing boron, fluorine, and hydrogen sulphide, the quartz-tourmaline veins and the metamorphism of the wall rock are supposed to have resulted. The magma, which formed the quartz-tourmaline dikes, however, seems to have been in a viscous condition.

In 1903 Cross, Iddings, Pirsson, and Washington[a] recognized the transition from granites to quartz veins and recognized the fact that such quartz veins belong in the category of igneous rocks. The name of dargase is here given (p. 265) to a certain type of rocks transitional between granite and intrusive quartz veins. These rocks are referred to as described by Howitt from Dargo, Victoria, Australia. In the articles by Mr. Howitt, above cited, however, there is not found any analysis of the rock in question.

A. C. Lawson[b] in 1904 described aplite dikes cutting a hornblende gabbro. These dikes grade into facies so siliceous as to be practically quartz veins, and on the other hand into veins of feldspar.

C. R. Van Hise[c] in 1904 repeated his conclusions, above cited, as to the origin of pegmatites. In regard to the water concerned in the process of pegmatitization he states that a considerable part, in some cases most of it, is derived from the magma itself, while in perhaps the greater majority of cases the water has been derived from the surrounding rocks. Van Hise (pp. 1048–1049) here takes the view that auriferous quartz veins can not be in any case a final phase of granitic intrusions

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[a] Quantitative classification of igneous rocks, Chicago, 1903.

[b] The orbicular gabbro at Dehesa, San Diego County, Cal.: Bull. Dept. of Geol., Univ. California, vol. 3, No. 17, p. 388.

[c] Mon. U. S. Geol. Survey, vol. 47, p. 720, et seq.

and doubts whether metals other than those of iron and aluminum have been formed by magmatic segregation, on account of the enormous amount of segregation required.

In 1905 J. E. Spurr and G. H. Garrey[a] described for the area near Georgetown, Colo., the frequent transition of pegmatites to quartz veins, both being phases of granitic intrusions.[b]

In 1905 E. C. Andrews[c] described pegmatites and quartz veins, grading into one another, as consolidating phases of granitic intrusions in New South Wales, Australia.

In general the writers' opinions as to the origin of pegmatites and pegmatitic quartz veins are very close to those held by Scheerer, Lehmann, Howitt, and Crosby and Fuller.

CONCENTRATION OF METALS OTHER THAN GOLD IN DIKES OF GRANITIC PEGMATITE AND OF QUARTZ.

One of the most obvious characteristics of pegmatites, and one which has always been noticed in every study is the concentration in them of the rare as well as the commoner elements. Elements such as wolfram, lithium, tantalum, tin, etc., are frequent and are often concentrated to a great extent. These rare elements include some of the more common metallic ores. Brögger[d] in his study of the pegmatites in Norway found magnetite, molybdenite, zinc blende, pyrite, galena, and copper pyrite as primary minerals in pegmatites.

IRON IN PEGMATITE.

S. L. Penfield and E. H. Forbes[e] described in pegmatite, at Rockport, Mass., a lenticular shell of magnetite about 1 inch thick surrounding fayalite.

A. C. Spencer[f] in 1904, after studying the magnetite deposits of Sussex County, N. J., concluded that the magnetites are connected in origin with intrusive dioritic pegmatites. All the deposits are referred to a single genetic type, probably including the zinc-bearing deposits at Franklin Furnace. The pegmatite is most often composed of oligoclase with some hornblende and occasionally mica. Quartz and microcline are sometimes present. Accessory minerals are garnet, apatite, sphene, spinel, allanite, and magnetite. Magnetite occurs in grains in all the igneous rocks. Masses of magnetite and hornblende occur associated with pegmatites in such a way as to lead to the conclusion that both have originated by segregations connected with the invasion of the pegmatite.

J. E. Spurr and G. H. Garrey[a] described in 1905 magnetite-bearing pegmatites from the Georgetown, Colo., region:

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[a] Bull. U. S. Geol. Survey No. 260, p. 104.

[b] In 1903 Mr. Whitman Cross observed in the Pikes Peak region, Colorado, many cases of quartz veins transitional into pegmatites, which in turn were transitional into the intrusive granites.

[c] Records Geol. Survey New South Wales, 1905, vol. 8, pt. 1, pp. 108-152.

[d] Zeitsch. für Kryst., vol. 16, pp. 163-164.

[e] Am Jour. Sci., 4th ser., vol. 1, 1896, p. 129.

[f] Mining Magazine, vol. 10, No. 5, Dec., 1904.

The pegmatites contain varying proportions of one or more of the following minerals: Quartz, feldspar, biotite, and muscovite. Magnetite and pyrite are common accessory minerals. Occasionally the pegmatite consists almost entirely of white or red feldspar, while at other times it assumes the phase of veins composed essentially of pure quartz cutting older rocks. The pegmatites are usually rather acid, but magnetite is frequently found in them in large quantities. ' The granites and other igneous rocks often contain magnetite as an accessory constituent, but the magnetite is vastly more abundant in the pegmatite than in the other rocks. Places were observed were the segregated magnetite in the pegmatite or in the quartz veins of pegmatitic origin was nearly equal in volume to the rest of the rock mass, and in consequence almost formed an iron ore. Pyrite is also a prominent original constituent of the pegmatites at times.

COPPER IN PEGMATITE.

J. F. Kemp[a] in 1901 described pegmatites in gabbro near Princeton, Yale district, British Columbia.. The pegmatite is connected with bornite, which forms an ore there. The bornite sometimes occurs in separate streaks and sometimes in pegmatite, in which it seems to be an original mineral.

A. C. Spencer[b] in 1904 described copper-bearing pegmatites from the Encampment district, Wyoming. In one case microscopic examination indicates that the copper is later in origin than the rest of the pegmatite, and so may, perhaps, represent a subsequent process. In other copper-bearing pegmatites the copper ore, which is chalcopyrite, largely altered to chalcocite near the surface, has formed at the same time as the quartz of the pegmatite, while both are somewhat later than the feldspar.

Jules Catherinet[c] in 1905 confirmed Kemp's views in regard to the copper ore in the Yale district of British Columbia. The pegmatite, he says, does not differ markedly from other occurrences of this rock, except that it contains bornite. The chief feldspar is orthoclase with some oligoclase. Tourmaline, fluorite, and calcite are occasionally found. Careful study warrants the conclusion that the bornite is an original mineral to the same extent as the mica and the feldspar. This pegmatite also contains gold and platinum, the former in a native state, the latter in the form of arsenide and sperrylite. The two minerals occur in flakes in the bornite and in the chalcopyrite and also in the orthoclase, where they form minute particles which give the impression that the two minerals are in the rock as original components. It is regarded as possible that the chalcopyrite may be an alteration product of the bornite.

TIN, TUNGSTEN, MOLYBDENUM, ANTIMONY, BISMUTH, AND LITHIUM IN PEGMATITE.

Tin ore is of frequent occurrence in pegmatite. In the Black Hills of South Dakota, according to Mr. S. F. Emmons,[d] the tin deposits occur in an area of coarse-grained granite. The Etta mine deposit, the only one that has produced any considerable quantity of tin, is a lenticular body of pegmatitic granite, which consists of quartz, albite, lepidolite, and spodumene individuals of great size up to 8 or 9 feet in dimensions. Cassiterite occurs in connection with lithia mica and is accompanied by columbite and tantalite.

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[a] Trans. Am. Inst. Min. Eng., vol. 31, p. 182.

[b] Prof. Paper U. S. Geol. Survey No. 25, pp. 41 and 95.

[c] Eng. and Min. Jour., vol. 79, No. 3, p. 125.

[d] Cited by A. J. Collier, in Tin deposits of the York region of Alaska: Bull. U. S. Geol. Survey No. 229, 1904.

In the Moolyella tin field of Western Australia[a] the whole area is of granite, which is traversed by quartz veins and pegmatites. The pegmatite is made up principally of quartz, albite, and a little mica, together with a few garnets and cassiterite. The tin occurs in greatest quantity in alluvial deposits, where the mineral is derived from the erosion of the pegmatite and also as a result of the decomposition of the pegmatite in situ. Residual or surface tin may be found wherever the pegmatite veins are numerous.

In the Greenbushes field, western Australia, the rocks are largely crystalline, granitic, and gneissic, cut by dikes of diorite, tourmaline granite, and pegmatite. Some of the pegmatite dikes contain a little less than 2 per cent of tin. Veins up to 2½ feet wide, carrying tin and much tourmaline, occur in the granite. Zircon, garnet, monazite, and considerable amounts of niobates and tantalates occur with the tin.[b]

In northern New England, which is in the northeastern part of New South Wales, Australia, the mineral-bearing veins, according to Mr. E. C. Andrews,[c] have a close genetic relation to siliceous granites intruded at the end of the Paleozoic era and the beginning of the Mesozoic, and are almost always arranged peripherally with respect to the bodies of granite. An important group of these veins consists of pegmatite grading into vein quartz, and such veins are considered as phases of the granitic intrusion, representing the later stages of consolidation. These veins contain tin, tungsten, molybdenite, antimony, and bismuth, and are of great economic importance. Gangue minerals include quartz, feldspar, tourmaline, fluorite, beryl, black mica, chlorite, sericite, monazite, emerald, and topaz. Copper pyrite and arsenical pyrite also occur.

M. L. De Launay[d] furnishes some interesting notes upon pegmatites carrying original lithia mica, cassiterite, and antimony in the Central Plateau region in France. He writes:

> The deposit at Montebras, formerly exploited for tin, constitutes to-day the only industrial source in the world of amblygonite, a mineral utilized by the production of lithia, of which it contains 6 to 8 per cent. * * * So far as one can judge, it seems that the amblygonite is associated with quartz and cassiterite in their regular veins, which cut a porphyritic granulite. * * * This same granulite, which is encountered discontinuously in a rather extensive zone (from 800 to 1,500 meters) which is slightly staniferous throughout, incloses elsewhere other veins of the same kind, in which epidote predominates and sometimes cassiterite.

Professor De Launay, continuing, describes briefly a number of tin-bearing veins in this same district and closes with the following statement:[e]

> In a general way it seems that the cassiterite-bearing veins, as well as those containing amblygonite, are only a peculiar phase of the pegmatites, in which these useful minerals play the same rôle as the quartz, feldspar, and muscovite. It is to be remarked, moreover, that in the ordinary pegmatites at Montebras, even when tin is not visible, it nearly always exists finely disseminated in quartz in sufficient quantity to render the quartz unfit for use in the manufacture of glass.

In the same general region Professor De Launay describes an antimony mine in pegmatites:[f]

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[a] Maitland, A. Gibb, Geological features and mineral resources of the Pilbara gold field: Bull. Geol. Survey of Western Australia No. 15, 1904, p. 102.

[b] Cited by F. L. Hess, Occurrence and distribution of tin: Bull. U. S. Geol. Survey No. 260, p. 172.

[c] Records Geol. Survey New South Wales, 1905, vol. 8, pt. 1, pp. 108-152.

[d] Excursion a quelques gites minéraux et métalliferes du Plateau Central: Extrait du Compte-Rendu du VIIIe Congres géologique International 1901, Paris, 1901, p. 10 et seq.

[e] Op cit., p. 15.

[f] Op. cit., p. 16.

> The little antimony deposit at Montignat is only interesting as an example of the very numerous stibnite deposits that are scattered in the Central Plateau. * * *
>
> There is in this place, in the midst of the very granitic gneiss, which has a granular, slightly banded structure, and is often difficult to distinguish from a granite proper, a dike of a special variety of granulite. * * * The maximum thickness of this dike is 8 meters. In it stibnite is found localized in the form of a stockwork of stibnite-bearing quartz. * * * The dike itself is very regular, but the antimony-bearing veinlets in its mass are, on the contrary, very irregular, as is the case with most antimony deposits. Their thickness is most often from one-half to 2 cm. In them the stibnite is associated intimately with quartz and mispickel, and sometimes the stibnite and sometimes the quartz predominates.
>
> The antimony-bearing granulite at Montignat is of a special type that I have frequently had occasion to observe in the neighborhood of the antimony veins in the northern part of the Central Plateau. * * * In reality it is a granular pegmatite (composed of quartz and generally altered feldspar without muscovite) in which pyrite frequently occurs, if not at Montignat at least in other deposits.

The Carolina tin belt[a] has a length of about 35 miles in North and South Carolina. In this belt sedimentary rocks of undetermined age, including shales, limestones, and sandstones, have been intensely metamorphosed and contorted. These sediments have been invaded at several times by igneous intrusions. Comparatively large masses of basic dioritic or gabbrolitic rock were intruded. Biotite granite is also among the igneous rocks, and numerous dikes of pegmatite cut both the metamorphosed basic intrusion and the sediments. The pegmatite is of chief interest in connection with the tin deposits, for in intimate association with some of it the ore is found. The tin belt is limited to the occurrence of pegmatite.

The pegmatite masses are irregular in shape. Forking or branching is rather common, and frequently a dike pinches out completely. There are two varieties of the rock. One is composed of quartz and microcline and carries no tin; the tin-bearing variety contains abundant muscovite. These rocks are undoubtedly of igneous origin and have exerted some contact metamorphic influence upon the intruded wall rock. The tin in these dikes is in the form of cassiterite, and from all obtainable evidence it seems probable that the cassiterite is an original constituent, like the quartz and feldspar.

Granitic dikes older than the pegmatite and closely associated with it carry tourmaline, and quartz veins, also rich in tourmaline, occur near the pegmatite dikes.

G. O. Smith[b] has described molybdenum ore of economic value occurring in pegmatite in Maine. Molybdenite occurs both in pegmatite dikes and in the granite cut by these dikes. The mineral is found in bunches or crystals 1 or 2 inches in diameter and is intimately mixed with the quartz and feldspar of the pegmatite. Molybdenite occurs at several other localities in Maine, as well as in other New England States. The pegmatite dikes are apparently contemporaneous with the granite intrusion and represent the latest crystallization of the granitic magma. In the pegmatitic magma molybdenum disulphide appears to have been a prominent constituent and to have crystallized early in the consolidation of the dikes.

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[a] L. C. Graton, Bull. U. S. Geol. Survey No. 260, p. 188.

[b] Bull. U. S. Geol. Survey No. 260, 1905, pp. 197-198.

PRESENCE OF GOLD IN MAGMATIC QUARTZ VEINS WHICH ARE DEPENDENT UPON GRANITIC INTRUSIONS.

The writer believes that of all the metals segregated or concentrated into certain places during the crystallization of the ultra-silicious phases of granitic intrusions gold has the most economic importance. The presence of gold in granites, pegmatites, and aplites has frequently been noted;[a] but the chief place in which the gold has been found to be segregated is not so much in these rocks as in the closely-related quartz veins, which show by their relations and general characteristics a magmatic origin. These veins have been deposited by aqueous magmas which were in various stages of dilution by waters and varied from the aqueous yet probably viscous silicious magma which has deposited quartz lenses corresponding in age to the intergranular quartz of granites and alaskites to the thinner residual solutions or magmas containing more water and less dissolved material, but none the less being truly magmatic in respect to the water, associated gases, and dissolved substances.

EUROPE.

On the island of Bömmel, in Norway, the chief country rock is "gabbro," in which large dikes of "quartz porphyry," passing into granite, and of altered diorite, occur. South of this district is a large tract of slate in which are nonauriferous quartz veins. The "quartz porphyry" dikes and those of diorite contain strong gold quartz veins, whose general contemporaneity with the period of igneous intrusion is shown by their being older than some dikes and younger than others.[b]

According to De Launay the gold at this place is associated with the granite.[c]

Professor Vogt[d] describes certain veins in Telemarken, Norway, which contain chalcopyrite, bornite, and chalcocite, also a little native silver and gold, with a gangue of fluorite, tourmaline, apatite, muscovite, and calcite. These veins are considered to be genetically connected with the granite in which they appear. This is a normal biotite-granite with orthoclase, microcline, and oligoclase, and no muscovite. Near the veins the granite is altered to muscovite, quartz, and calcite, with a little chalcocite, fluorite, and chalcopyrite or bornite.

In the neighborhood of Beresovsk, in the Ural Mountains, are granites which contain disseminated free gold that has been held to be original.[e] Near these granites are quartz-feldspar-muscovite rocks, which have been called beresite. The peculiar structure and composition of this rock is analogous to that of similar rocks in the Nevada mineral districts, as is specially pointed out by the writer for the district of Belmont.[f] The Russian beresite is regarded by the miners as the surest index to gold, and native gold occurs within the rock itself. This gold has been held to be an original constituent.

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[a] More rarely free gold has been noted in basic rocks. See W. H. Weed, Eng. and Min. Journal, March 31, 1904; M. L. De Launay, Contribution à l'étude des gîtes métallifères, Paris, 1897, pp. 109-110; J. E. Spurr, Trans. Am. Inst. Min. Eng., vol. 33, p. 321.

[b] Phillips and Louis, Ore-Deposits, 2d ed., p. 519.

[c] Contribution à l'étude des gîtes métallifères, Paris, 1897, p. 111.

[d] Zeitschrift für prakt. Geologie, 1897, p. 144; cited by W. Lindgren, Trans. Am. Inst. Min. Eng., vol. 30, p. 643.

[e] Beck, Richard, Lehre von Erzlagerstätten, p. 324.

[f] Spurr, J. E., Am. Jour. Sci., vol. 10, Nov. 1900, p. 356.

H. L. Barvir[a] in 1903 discussed the origin of the gold in certain parts of Bohemia. South of Prague lies the city of Eule, in whose neighborhood gold has been obtained since prehistoric times. East of the city are granites intrusive into schists. In the schists there are also abundant dikes, which are chiefly schistose greenstones and schistose porphyries. The granite contact has the same direction as the gold-quartz veins and many of the igneous dikes. The minerals in the gold-quartz veins of the district are quartz, calcite, dolomite, chlorite, some orthoclase, pyrite, arsenopyrite, and native gold, with occasional chalcopyrite and molybdenite. In other fissure fillings are iron-alumina garnet, epidote, albite, laumonite, stilbite, natrolite, and analcite.

> From the extended studies of the author and his pupils concerning the connection and the geological significance of the different rocks of the gold district, it is evident that the *gold in southwestern Bohemia is connected principally with the granite massif of Little Bohemia, with its magmatic differentiation products and its minor phases.* In part it was a primary constituent of the granite; in part it has been deposited from the hot springs during the intrusions, and finally it has been leached out from the already consolidated rocks by means of these same hot springs. Gold-bearing veins filling fissures due to atmospheric agencies are very subordinate.

AFRICA.

In the Transvaal, South Africa, the gold is sometimes associated with granite and diorite. Phillips and Louis[b] observe that in the De Kapp district the rocks, "both stratified and granitic, are traversed by dikes of diorite and pegmatite. * * * In the neighborhood of the granite these rocks occasionally carry small ferruginous intercalated deposits which are generally auriferous. * * *"

De Launay[c] mentions two other districts in the Transvaal where the ores are genetically connected with silicious igneous rocks and are related to a group of tin veins.

M. A. Lacroix,[d] writing of the gold deposits in Madagascar, concludes:

> Several observations made in other regions, notably the demonstration of the existence of free gold along the cleavage planes of the granulitized mica schists near Nantes and in the tin veins of Limousin,[e] lead me to the conclusion that the gold has been formed in Madagascar by the emanations of the granitic magma, which has so profoundly impregnated the crystalline schists of the island.

De Launay[f] observes that certain auriferous earths in Madagascar are probably the result of the decomposition of diorites under conditions similar to those in Guiana.

AUSTRALIA.

The gold deposits of eastern Australia are among the most important in the world. In the province of Victoria, in the districts of Dargo and Omeo, Howitt[g] has shown (1887-88) that many of the quartz veins are of direct magmatic origin, corresponding to the quartz crystallized in the last stage of the consolidation of granite.

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[a] Betrachtungen über den Ursprung des Goldes bei Eule und an einigen anderen Stellen in Böhmen. Archiv für naturw. Durchforschung von Böhmen, XII, No. 1, Prag, 1901, 98 p. Abstract in Neues Jahrbuch für Mineralogie, 1903, vol. 1, p. 440.

[b] Ore Deposits, pp. 734-735.

[c] Contribution à l'étude des gîtes métallifères, Paris, 1897, pp. 111-112.

[d] Cited by J. E. Spurr in Native gold original in metamorphic gneisses: Eng. and Min. Jour., Feb. 4, 1904.

[e] These localities are in France. (J. E. S.)

[f] Contribution à l'étude des gîtes métallifères, Paris, 1897, p. 110.

[g] See p. 134.

He also pointed out the close relation of many of the auriferous quartz veins to the contact of granitic rocks intrusive into Paleozoic sediments. He did not, however, suggest that these auriferous quartz veins had a magmatic origin.

In 1872 Mr. Richard Daintree[a] drew attention to the fact that the auriferous deposits in the province of Queensland, eastern Australia, are entirely confined to those districts which are penetrated by certain eruptive rocks, principally pyritiferous diorite. The pyrite in these diorites was shown to be occasionally distinctly auriferous and to have produced gold in paying quantities by its decomposition. Subsequently Mr. Daintree learned from geologists in New South Wales and Victoria details to show that the auriferous deposits of these provinces have the same genetic relations. Some of the most important auriferous veins were regarded by Mr. Daintree as the "result of hydrothermal agencies which preceded and accompanied the protrusion and which in some cases continued long after the igneous rock had cooled down."

From the book of Phillips and Louis[b] the following is quoted:

> Daintree, Hacket, Wilkinson, and others have shown that a large portion of the gold in Victoria and Queensland is due to the agency of intrusive dikes of felstone, elvan, and diorite, so that reefs of quartz in Silurian rocks are not, as was at one time supposed, the exclusive source of Australian gold.
>
> At Timbarra gold is found in granite. These gold fields consist of a granitic table-land, traversed by dikes of eurite[c] and pegmatite; also occasionally showing veins of auriferous quartz, *which may possibly be segregation deposits.*[d] The weathered granite is sluiced, and very fine gold, to the extent at times of 5 pennyweights to the ton is obtained. *Gold has been found to occur here in unaltered granite and in eurite,*[d] as well as in the decomposed granite.

In 1905 Mr. Waldemar Lindgren[e] described the gold quartz veins of Victoria. In the western gold fields of Victoria slates and sandstones are intruded by large masses of granitic rock. Aplitic dikes cut the slates at the contacts, which are marked by narrow aureoles of contact metamorphism. The granite rarely contains quartz veins.

> The vein filling is almost always a massive, milk-white and sometimes glassy quartz, containing gold and a small percentage of sulphides, chiefly pyrite and arsenopyrite, but also a little galena, zinc blende, molybenite, and stibnite; fluorite and tellurides seem to be absent. Barite is rare. * * *
>
> The intrusion of the granitic rocks followed the plication of the slates and preceded the Devonian sedimentation. Consequently the granitic intrusion and the formation of the quartz veins were closely associated events. Field evidence shows that the quartz veins are later than the granite and the attendant aplitic dikes.

Mr. Lindgren offers the hypothesis that—

> the gold and the quartz in this type of veins have been deposited chiefly by "eruptive after-effects;" in other words, chiefly by hot ascending waters originally contained in the granitic magma and released from it by decreasing pressure, due to its irruption into the upper parts of the lithosphere. It is quite possible that atmospheric waters may have played a certain part by aiding the precipitation and by effecting certain forms of concentration in the deposits.

Albite occurs in the Victoria gold quartz veins, as at Bendigo.[f]

In New England, in the northeastern part of the province of New South Wales, according to E. C. Andrews,[g] there have been two periods of granitic intrusion, one of Carboniferous age and one post-Paleozoic (and pre-Mesozoic). There appears to

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[a] Phillips and Louis, Ore Deposits, pp. 641–642.

[b] Ore Deposits, p. 659.

[c] "Alaskite." (J. E. S.)

[d] The italics are mine. (J. E. S.)

[e] Eng. and Min. Jour., March 9, 1905.

[f] Lindgren, W., Economic Geology, vol. 1, No. 2, p. 163.

[g] Records Geol. Survey N. S. Wales, 1905, vol. 7, pt. 1, pp. 108–152.

be no genetic connection between the first period of igneous activity and ore deposits; but with the rocks of the later period, especially the siliceous phases, ores are closely connected, occurring near the periphery of the granite bodies. These ores are divided into three classes: (1) Segregations from cooling acid magmas, containing as valuable components chiefly cassiterite, wolfram, and bismuth; (2) magmatic segregations, slightly later and originally more aqueous than those first named, containing as valuable components cassiterite, bismuth, molybdenite, and probably silver-lead and zinc ores; (3) ores formed by aqueous secretions from dikes which were more basic than those mentioned above and which were injected after the consolidation of the more acid magma. The valuable components of the ores of this class are gold, silver, copper, lead, antimony, scheelite, and zinc.

In western Australia, in the district of Coolgardie, according to M. Gascuel, as cited by De Launay,[a] the gold-quartz veins are present almost exclusively in greenstones (diorites and diabases), which are decomposed into red clay at the surface.

A specimen from the Mount Monger mine, in northeast Coolgardie, described by Mr. A. Selwyn-Brown,[b] weighs 100 ounces and consists of 85 per cent gold, the balance being ferruginous quartz and tourmaline. The tourmaline crystals are thickly studded in the solid gold and sparingly in the quartz. The country rock is largely granitic, and quartz veins, mostly auriferous, are numerous. These veins always carry pyrite, and occasionally tellurium has been detected. Both tourmaline and gold occur in the massive granite.

ASIA.

In China the reported gold-quartz veins occur almost entirely in granite, as at Ninghai, the Chao-Yuen district, and Yeshui, in Mongolia.[c]

The writer is verbally informed by Mr. Bailey Willis that according to his information from Mr. G. B. Wilson, engineer in charge, the mines of Kushantsi, near Jehö, in Mongolia, are in granite and diorite.

In Siberia the connection of gold with granite and granulite has been observed in more than one place, especially by M. Levat in the Trans-Baikal region, southeast of Irkutsk. According to M. Levat the gold is contained in aplite, which is connected with granite masses. In another locality, on the Zeya River, a northern tributary of the Amoor, M. Levat believed the gold to have a direct genetic relation to intrusive granites.[d]

SOUTH AMERICA.

BRAZIL.

The gold deposits of Brazil, especially in the province of Minas Geraes, are of considerable interest. In this district, at Candonga, according to W. J. Henwood,[e]

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[a] Contribution à l'étude des gîtes métallifères, Paris, 1897, p. 109.

[b] Eng. and Min. Jour., Dec. 9, 1905, p. 1062.

[c] Phillips and Louis, Ore Deposits, p. 618.

[d] Levat, E. D., L'or en Sibérie Orientale, Paris, 1897; cited by M. L. De Launay, Contribution á l'étude des gîtes métallifères, Paris, 1897, p. 111, and by C. W. Purington, Eng. and Min. Jour., 1905, p. 71.

[e] Henwood, W. J., Observations on metalliferous deposits, Trans. Roy. Soc. Cornwall, vol. 8, pt. 1, 1871, pp. 175-176, 311, 320.

the granite contains particles of free gold sparingly mixed with quartz, feldspar, and iron ore, just as tin ore is sprinkled in the granite of Cornwall.[a]

Concerning the ore deposits of the region, Henwood writes:

> Although the metalliferous deposits are more quartzose and contain a larger proportion of iron ore than the rock, they partake of its granitic character. Through this ferruginous granite gold is always thinly scattered[b] alloyed, however, with from 5 to 8 per cent of palladium,[c] and of a yellow as pale as that assumed occasionally by native silver.[d] It forms sometimes a model, sometimes a mold for other minerals, and thus embeds in some places the same ingredients which embed it in others.[e] Gold in rough crystals[f] often studs the sides of drusy cavities; and in minute spheroids, seldom more than from 0.012 to 0.022 of an inch in diameter, it is sometimes scantily disseminated through other parts of the formations.
>
> Their more quartzose portions inclose nests of earthy brown iron ore and small octahedral crystals of pure bright yellow gold.[g] * * *
>
> The auriferous repositories are bounded by joints of one series; but barren matter within joints of different range sometimes interrupt them;[h] in both, however, as in the adjoining rocks, the prevalent ingredients are granitic.[i] * * *
>
> The only auriferous granite in Minas Geraes consists of a yellowish feldspar, white quartz, and oxydulated iron ore,[j] irregularly mixed, however, with crystalline granules of gold, which alloyed with from 0.05 to 0.08 its weight of palladium[k] and sometimes inclosing, but more frequently embedded in the other ingredients, thus forms an integral part of the rock.[l]

In 1887, De Launay[m] noted that the group of auriferous mispickel veins, such as those at Passagem and at Faria, in Brazil, probably belong to the family of tin veins and are connected with siliceous igneous rocks. He noted that at Passagem the veins contain tourmaline, bismuth, and pyrrhotite.

E. Hussak, in 1898,[n] described the gold-bearing quartz veins of Passagem, in the State of Minas Geraes, in Brazil. The Passagem gold mine lies 7 kilometers east of Ouro Preto, the capital of the State of Minas Geraes, and, together with Morro Velho, s one of the most important Brazilian gold mines. The vein consists chiefly of white quartz, tourmaline, and arsenopyrite, with subordinate amounts of pyrite and pyrrhotite. It really forms a series of leaves which are alternately narrowed and enlarged and are alternately rich and poor in gold, so that the thickness of the vein varies between 2 and 15 meters. The largest lenses are filled with schistose quartzite and metallic quartz poor in gold. The portions which consist of pure, finely crystalized arsenopyrite and black tourmaline are the richest. With the accession of quartz

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[a] "Three miles southeast of Two-bridges" on Dartmoor, "where some tin mines are worked, that metal is found disseminated in the granite as one of its integral parts." Berger, Geological Transactions, vol. 1, p. 120.

[b] Captain Herbert, Asiatic Researches, vol. 1, 1829, p. 236. Ante, pp. 3, 46, Notes.

[c] Johnson, Percival Norton, F. R. S., F. G. S., etc., MSS. Also W. J. Cock, On palladium, London, Edinburgh, and Dublin Phil. Mag., 3d Ser., vol. 23. 1843, p. 16.

[d] Levy, Description d'une collection de minéraux formée par M. Henri Heuland, vol. 2, pp. 320–328.

[e] Carne, Cornwall Geol. Trans., vol. 4, p. 100.

[f] Mohs, Mineralogy (translated by Haidinger), vol. 2, p. 437. Levy, Description d'une collection de minéraux, vol. 2, p. 313.

[g] Lott, Edward W., Commissioner of Candonga, 1844, MSS.

[h] Helmreichen, H. V. von, 1844, MSS.

[i] Cornwall Geol. Trans., vol. 5, Tables XIII, XVI, XLIII, L, XC.

[j] Ante, p. 175.

[k] Ante, p. 176.

[l] Berger, Geol. Trans., vol. 1, p. 120. De Luc, Geological Travels, vol. 3, p. 342, Herbert, Asiatic Researches, vol. 1,, p. 236. Sedgwick, Phil. Mag. and Annals, vol. 9, 1831, p. 283. Henwood, Cornwall Geol. Trans., vol. 5, pp. 15, 53, 73, 119, 235. Murchison, Geology of Russia in Europe, vol. 1, p. 483. Ante, pp. 46, 175.

[m] Contribution à l'étude des gites métallifères, Paris, 1897, p. 111.

[n] The gold-bearing quartz veins of Passagem in Minas Geraes, Brazil. Zeitschrift für praktische Geologie, Oct., 1898, p. 345.

the ore grows poorer. On rich hand specimens gold can be seen with the naked eye in granules or crystals grown upon arsenopyrite or tourmaline.

The following minerals were found: Gold, arsenopyrite, pyrite, pyrrhotite (copper pyrite), galena and stibnite (according to Ferrand), quartz, oligoclase-albite, muscovite, green chrome-bearing muscovite (fuchsite), zircon, monazite, xenotime, magnetite, rutile, biotite, tourmaline, andalusite, staurolite, hercynite, garnet, disthene, cummingtonite, calcite, dolomite (according to Ferrand), siderite and ilmenite. Doctor Hussak divides these into the following groups:

1. Vein minerals: Quartz, arsenopyrite, pyrite, copper pyrite, pyrrhotite, galena, stibnite, gold (with bismuth), calcite, dolomite, siderite, and ilmenite, of which the last named, including the gold, are apparently secondary infiltrations and later formations.
2. Granite minerals: Quartz, muscovite, biotite, oligoclase-albite, zircon, monazite, xenotime, perhaps also amphibole, magnetite, and rutile.
3. Contact minerals: Tourmaline, andalusite, staurolite, disthene, garnet, hercynite, cummingtonite, and also, certainly in part, biotite.

In the quartz vein tourmaline plays the chief rôle as the accompaniment of the minerals. In the portions of the vein which have a granitic structure, the tourmaline and quartz aggregates have a great similarity to the luxullianite of Cornwall. The tourmaline and quartz portions of the Passagem vein pass by gradual transition to pure arsenopyrite.

Doctor Hussak concludes (p. 356) that the quartz vein is of intrusive nature, an ultra-acid granitic apophysis. In favor of this interpretation is the near occurrence of a granite massif, about 1 kilometer away in air line, and the certainly proved occurrence of occasional minerals which are thoroughly characteristic of granitic rocks, such as zircon, monazite, and xenotime, in angular crystals. The occurrence of a feldspar near albite in a quartz vein seems also to favor a granitic origin. Albite is known to be a very frequent component of pegmatitic granite veins. This eruptive quartz vein broke through the quartz schists, shattered them, and in part absorbed them, and formed against the hanging wall and against the foot wall a definite contact zone characterized by the minerals already mentioned. The native gold is doubtless a secondary infiltration precipitated from solutions, as well as the calcite. The pyrite, pyrrhotite, and arsenopyrite are considered to have the same origin as the quartz. Similar quartz veins, only a few meters thick, break through the mica schist at many points in Minas Geraes and Goyaz. These carry gold and are relatively rich in splendidly formed monazite crystals.

In 1899 O. A. Derby[a] discussed the origin of a layer of argillaceous material in fine-grained quartzite in the region of Diamantina, Minas Geraes, Brazil. The argillaceous material, which consists of quartz and kaolin, and can hardly be else than a rock of original granitic or pegmatitic type, to judge from the character of its contact must have been eruptive. Macroscopic accessory elements are rutile and specular iron. By washing, a heavy residue, consisting of anatase, magnetite, tourmaline, and xenotime is obtained. The last-named mineral is the most significant, as it is only

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[a] On the association of argillaceous rocks with quartz veins in the region of Diamantina, Brazil: Am. Jour. Sci., 4th ser., vol. 7, 1899, pp. 343-356.

known in situ in Brazil as an extremely constant and characteristic accessory of the ultra-acid (muscovite) granites and pegmatites.

> The observations above recorded indicate the presence in the older series of the region of dikes of a rock characterized by titanium minerals and monazite as primary accessories that have been sheared and metamorphosed together with the rocks into which they were injected, and that the schistose and presumably weak layers thus produced have more frequently than others been the seat of subsequent injections of pegmatitic material that passes to pure quartz. * * *

In 1904, Mr. Derby [a] confirmed the statement made by him many years before [b] that in the districts of Campanha and São Gonçalo, gold occurs in gneiss. This gneiss has the characteristics of a sheared granite, and the gold is in crystalline form. The residue from crushed samples of this rock is chiefly of zircon, with some magnetite and ilmenite. The amount of gold in the specimens examined was 5 to 10 grams per metric ton. This mode of occurrence, independent of sulphides, and more or less independent of quartz veins, seems to predominate throughout the district.

Under the heading "Gold in granitic apophyses," Mr. Derby described certain veins:

> These having the appearance of ordinary quartz veins are characterized by included patches of kaolinized feldspar or of mica, carrying one or more of the characteristic granitic accessories—zircon, monazite, and xenotime—and are evidently extreme phases of granitic (pegmatitic) dikes and stringers. Throughout the Diamantina district it is rare to see an outcrop of these veins which does not show signs of having been worked or at least prospected for gold. The only one examined that is certainly gold-bearing was close to the great diamond working of São João da Chapada, in which a fine example of the quartz-kaolin type is presented. This cuts a somewhat sheared diabase and consists of vein quartz of the ordinary aspect, with partings and patches of green muscovite, which give an abundant residue of rutile and monazite. A lode which has been quite extensively worked at Bandeirinha, about 20 miles to the southward, is believed to be of this character, since the concentrated sand gives an abundance of beautifully fresh monazite of the peculiar prismatic type described in the above-mentioned paper.
>
> The great mine of Morro Velho, in the Sabará district of Minas Geraes, is of this character, as are also the adjacent mine of Raposos and that of Cuyabá (at least as regards its main lode), about 10 miles distant. The sulphides are pyrite, pyrrhotite, arsenopyrite, and chalcopyrite—zinc blende and galena occurring only as great rarities. The gangue is a finely granular mixture of carbonates of iron, magnesia, and lime (siderite, dolomite, and calcite, apparently in this order of abundance), with quartz and apparently also a feldspar, albite, which in the mass of the ore is distinguishable with difficulty from the quartz, but appears in great perfection and beauty in the vugs. Typical vein-quartz occurs only in subordinate amounts and local developments. * * *
>
> A singular feature now appearing in one part of the Cuyabá lode is a considerable mass of a coarse-grained greenish rock of granite texture, composed essentially of plagioclase feldspar thickly sprinkled with arsenopyrite and showing irregular fracture zones filled with green chlorite. This mass, which carries a little zinc blende, occurs in the width of the better ore, with which it appears to have a genetic connection. This also recalls a feature of the Passagem lode.
>
> Feldspar, in the form of beautiful crystals of albite, is common in the vug linings at Morro Velho and is evidently a constituent of the gangue as well, though owing to the fineness of the grain and the absence of observable twinning it is distinguishable with difficulty from the quartz.

L. Ferraz,[c] describing the Palma gold deposits in the State of Minas Geraes, Brazil, writes that the field is characterized by the crystalline character of the rocks, gneiss predominating with granites and syenite.

> The granites, some typical, some with amphibolite, pyroxene, and garnet, form a series tending toward a true syenite. Veins of granulitic black tourmalines in prisms of various sizes, separate or agglomerated, and veins of pegmatite, common or of graphic structure, cut into the primitive masses.

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[a] Notes on Brazilian gold ores: Trans. Am. Inst. Min. Eng., vol. 33, pp. 282-287.

[b] Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 443.

[c] The Palma gold deposit of Minas Geraes, Brazil: Min. and Sci. Press, March 19, 1904, p. 199.

Two distinct types of rock occur—the miascitic, rich in black mica and ilmenite; and the zirconian, containing a certain proportion of zircon and monazite.

Among the residuary minerals found in the pan concentrates are the following: Sphene or titanite, rutile, garnets, black tourmalines, graphite, zircon, oligist (hematite), magnetite, disthenite, staurolite, and monazite.

Gold is found in a state of great purity, as flakes, grains, and small nuggets, in alluvial gravels which cover the river beds and the area subject to floods, as well as the country surrounding the headwaters of the streams previously detailed. The pan concentrates consist mainly of quartz grains, titaniferous minerals—such as ilmenite, titanite, and rutile—almandine and pyrope garnets and melanite, black tourmaline and monazite. Oligist (hematite) and magnetite occur in diminished proportion. Wherever the gravel be panned, more or less gold is found.

CHILE.

In Chile, De Launay [a] notes the existence of gold in granite, together with cassiterite, copper pyrite, compounds of bismuth, tellurium, selenium, etc. The statement is made [b] that the gold in many granites on the coast range in Chile is of primary origin.

GUIANA.

In British Guiana Phillips and Louis [c] state that gold-quartz veins occur mostly in metamorphic schists and gneiss, and nearly all the streams and rivers that traverse regions occupied by the above rocks or by granite are gold-bearing.

At the Omai placer mine, on the Essequibo River, in British Guiana, according to E. E. Lungwitz,[d] a dike of aplite contains quartz and feldspar, the latter largely plagioclase. Gold occurs in it in fine dust and coarse nuggets, and is accompanied by quartz. The aplite has been tested to a depth of 800 feet. It contains $1 to $15 per ton in gold. It also contains pyrite, sericite, epidote, zoisite, and carbonates.

Mr. J. B. Harrison,[e] government geologist, regards the gold as not an original constituent of the aplite, but as having been brought into it by percolating waters, and that it was in part derived from the degradation of an overlying diabase dike.

Messrs. Harrison and Perkins[f] state their belief that the siliceous rocks of the district, whether gneiss, granite, or porphyry, do not appear to have been the original sources of practically any of the gold of the auriferous gravels, which have probably all been derived from the basic rocks, either the diorite or the diabase, "or from parts of the acidic rocks impregnated with the metal by percolating water during their intrusions. The parts of the diabase rocks which are the richer in iron ores and especially in pyrites are also the richer in content of gold."

E. E. Lungwitz[g] is also of the opinion that the origin of the gold in British Guiana stands in the closest connection with the diabase. He writes:

> There is no gold district in Guiana without diabase, and the richest portions of the Guiana gravels are characterized by the fact that the fissures in their neighborhood which have been filled by diabase have been again occupied later on by aplite or diabase intrusions. The result of this was a thorough shattering of the hanging and foot walls of these dikes, the filling of the adjacent fissures by quartz, and enrichment of the

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[a] Contribution à l'étude des gites métallifères, Paris, 1897, p. 111.

[b] Beck, Richard, Lehre von Erzlagerstätten, Berlin, 1901, p. 19, on the authority of H. Schultze.

[c] Ore Deposits, 2d ed., p. 188.

[d] Zeitschr. für prakt. geologie, July, 1900, p. 217. See also W. H. Weed, Eng. and Min. Jour., March 17, 1904, p. 440.

[e] Cited by W. H. Weed, Eng. and Min. Jour., March 17, 1904, p. 440.

[f] Report on the geology of the Essequibo, Potaro, Konawaruk, and Demerara rivers, Georgetown, Demerara, 1900, p. 69.

[g] Zeitschrift für praktische geologie, July, 1900, p. 217.

> salbands by gold ores. The size of the veins is variable, but according to my experience hardly ever as much as 3 feet. On the other hand, the number of small quartz veins is so great that in many places the aplite goes over into so-called beresite—for example, at Omai and Potaro. The age of these secondary fissures is very different, as appears from their intersection and their characteristic vein filling. In most cases the gold is associated with cupriferous iron pyrites, more rarely arsenopyrite, and in some small veins (Omai) with scheelite. I wish to call attention especially to the last-named case, since it is one of the few occurrences where gold appears associated with wolfram minerals.

While recognizing the accuracy of the descriptions of the British Guiana gold ores given by the above-named geologists, and the fact that the gold is associated with basic dikes, certain features seem to the writer to indicate that the conception of the origin of the gold has not been made broad enough to include the bearing of all the associated facts. The presence of eruptive granites and of aplite dikes, frequently auriferous, and especially the association of gold with tungsten and mispickel, are significant features, which must be considered. Tungsten is an element frequent in tin deposits,[a] is one of the most characteristic elements in pegmatite, and, like tin and molybdenum, seldom occurs in notable amounts except in pegmatites and granitic rocks.[b] Arsenopyrite is also frequently found in pegmatites and veins of the tin group, and, as above noted (p. 146), De Launay[c] has stated his belief that the auriferous mispickels belong to the family of tin veins. It thus appears possible that in British Guiana the deposition of the gold ores represents one of the closing phases of the great granitic intrusions, and that the basic dike rocks, with which the gold ores are associated, as well as the siliceous dike rocks in connection with which they are also frequently found, are representatives of the general process of granitic injection, earlier than the veins, while still subsequent to the main intrusion. A similar group of phenomena, attendant upon a great granitic injection, beginning with the main intrusion of granite and followed by the diorite and diabase (usually altered to greenstone) dikes, the ultrasiliceous (aplite, pegmatite, eurite, or alaskite) dikes, and the auriferous quartz veins which usually represent the last stage of all, can be recognized or suspected from the previous descriptions in many important auriferous districts, such as those of Australia, Madagascar, etc. A similar group of phenomena has been studied by the writer in the Silver Peak district.

After the above was written and in proof the writer has seen a later report by Mr. J. B. Harrison on the petrography of the Cuyuni and Mazaruni districts, British Guiana, and of the rocks at Omai, Essequibo River.[d] The rocks of the districts are described in detail. They consist of siliceous gneisses which are granites and granitic rocks altered by shearing, and which are intruded by numerous pegmatite veins, which in places are highly feldspathic; in other places consist almost entirely of quartz. Garnet, beryl, and apatite occur in these pegmatites. Assays of the gneisses show the presence of gold in all, at the rate of a few grains per ton. These granitic gneisses are traversed by basic gneisses and schists, which represent sheared basic intrusives in the granitic rocks. Assays of these rocks show the presence of gold in all, in quantity about the same as in the older granitic rocks. "The gold accom-

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[a] For example, the tin deposits of Mount Bischoff in Tasmania, described by W. von Fircks, Zeitsch. deutsch Geol. Ges. Bd. 51, p. 433, 1899; cited by W. Lindgren, Trans. Am. Inst. Min. Eng., vol. 30, p. 623. See also J. H. L. Vogt, Zeitsch. für prakt. Geol., July, 1898, p. 238.

[b] Kemp, J. F., Ore deposits of the United States and Canada, 3d ed., p. 37.

[c] Contribution à l'étude des gîtes métallifères, Paris, 1897, p. 111.

[d] Report on the petrography of the Cuyuni and Mazaruni districts, etc., Georgetown, Demerara, 1905.

panies in part the heavy metals of these metamorphosed rocks; but some of it is present in the numerous tongues and veinlets of quartz which traverse them, filling cracks and spaces between or crossing their folia."[a] Other igneous rocks of the district, in part schistose, in part massive, may be classed in general as porphyries of varying composition. The schistose facies were found by assay to contain small quantities of gold. Granitic rocks are also described, more or less gneissose. They include aplite and granite, which pass locally into quartz-diorite and diorite. Syenite and gabbro also occur. All these rocks yielded gold on assay. Diabase also occurs.

Following are part of Mr. Harrison's general observations as to the source of the gold:[b]

> The comparatively few dikes of diabase which are noticeable in the district apparently indicate that in it the diabase, which may be regarded as the main source of gold in the central district of the colony, plays only a subordinate part as a source of supply. The results of the assays given in this report indicate that gold is present in more or less minute amounts in all of the country rocks of the district, and that the proportions found in the basic rocks are, on the whole, only a little higher than those in the acidic ones.

Concerning the derivation of the gold at the Omai mine, referred to above, Mr. Harrison remarks:

> While the country at Omai is in accordance with that of the district generally, it differs from it in one very important respect—the epidiorites and chlorite schists, which are the country rocks, have been intruded by a mass of aplitic granite which appears to be the main source of the gold at Omai.

Although Mr. Harrison still believes that the basic rocks of these districts were originally the source of the gold, these later observations of his are more in harmony with the writer's suggestions above than are his earlier ones; as also is his observation that the gold in the basic rocks occurs in part in numerous veins and veinlets of quartz, which traverse the rocks.[b]

De Launay[c] notes that in French Guiana the gold appears often to be associated with diorites, which have decomposed in place to form auriferous earth. He also notes that in the contested territory between French Guiana and Brazil, according to M. Bernard, the gold is found associated with manganiferous quartz in diorites, with veins of granulite. These igneous rocks occur in gneisses and amphibolite schist.

NORTH AMERICA.

BRITISH AMERICA.

In the gold-bearing region of Nova Scotia, quartz veins are contained in metamorphosed sedimentary rocks, which are cut by many great intrusions of granite.[d]

Dr. A. P. Coleman[e] has furnished notes on the gold mines of western Ontario. After a summer's work in the gold region he remarks:

> Two points have struck me forcibly during the summer—one, the frequency with which true fissure veins bearing free gold have been found in or near masses of eruptive granite which have burst through the Huronian schists; the other, that at two points immense bodies of schists, impregnated with sulphides—i. e., fahlbands—have proved auriferous, and in one instance a hill of porphyry of great extent shows the same feature.

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[a] Op. cit., p. 23.

[b] Op. cit., p. 51.

[c] Contribution à l'étude des gîtes métallifères, Paris, 1897, pp. 109-110.

[d] Kemp, J. F., Ore deposits of the United States, 4th ed., p. 397.

[e] Fifth Report Ontario Bureau of Mines, 1895, p. 86.

On the Pelly River, in British Columbia (a part of the Yukon gold belt), Dr. G. M. Dawson[a] found evidence to show that the development of quartz veins had occurred contemporaneously with the upheaval of the granites, and probably by some action superinduced by the granite masses themselves while they were still in a formative condition.

In a number of different cases free gold has been described as an original constituent of igneous rocks in British Columbia. In 1894 Ferrier[b] identified original native gold in a perfectly fresh porphyritic syenite from the Kamloops district. R. W. Brock[c] has described a number of similar cases. He has described a gold-bearing porphyry dike from the North Fork of the Salmon River, West Kootenai, British Columbia. As no sulphides were detected and the rock is quite fresh, the gold is probably native and an original constituent.[d] Of twelve specimens of unaltered porphyry dikes from different West Kootenai points collected as rock specimens, but submitted for assay, six proved auriferous. An absolutely fresh alkali syenite-porphyry dike in the Valkyr Mountains east of lower Arrow Lake contains coarse free gold, visible to the naked eye.[e] The rock, which was collected as a petrographical specimen, contains several particles of native gold almost as large as pin heads. Mr. Brock remarks that the large bodies of copper-gold ore exploited in this region occur alongside or near these dikes, with which they appear to be genetically connected.

ALASKA.

The relation of gold ores to intrusive granitic rocks has been noted also in different parts of Alaska. The writer in 1898[f] described the occurrence of masses of hornblende granite intrusive into schists and gneisses in the Yukon gold district. There is a gradual transition series from this typical granite to a biotite granite, and from this by diminution of the biotite into quartz-alkali-feldspar rocks or alaskites. In the alaskite series the change continues by relative increase in amount of quartz and decrease in feldspar. Finally, by disappearance of the feldspar, the rock becomes entirely of quartz. These more siliceous granitic phases are entirely in the form of dikes. Quartz veins or dikes in the Yukon district, which probably have this origin, contain pyrite, argentiferous galena, and free gold. From them a portion of the Yukon placer gold is probably derived. Associated with the siliceous dikes are basic dikes, which also pass by transitional phases into the normal granites. The basic and siliceous dikes are regarded as complementary, both belonging to the later stages of the granitic intrusive phenomena.

On the Tanana and White rivers, Alaska, Mr. A. H. Brooks[g] noted at a number of places transitions between quartz veins and coarse pegmatites similar to the transition noted by the writer in the Yukon district. The veins are abundant in the schists of this region, and are composed largely of barren white vitreous quartz, but not infrequently contain other minerals. Calcite is a common constituent. Copper, iron pyrite, and galena were also observed in the veins. None of the veins found

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[a] Ann. Rept. Geol. and Nat. Hist. Survey Canada, vol. 3, pt. 1, p. 35B.

[b] Rept. Geol. Survey Canada, 1894, p. 395B.

[c] Eng. and Min. Jour., March 31, 1904.

[d] Jour. Canadian Min. Inst., 1889, p. 84; Geol. Survey Canada, Summary Rept., 1901, p. 64.

[e] Summary Rept. Geol. Survey Canada, 1901, p. 64.

[f] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 312.

[g] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 484-486 incl.

showed free gold to the naked eye, but assays of several specimens showed the presence of small quantities of both gold and silver. The highest assay showed .05 ounce gold and .95 ounce silver to the ton.

The eastern part of the Ketchikan district,[a] in southern Alaska, is occupied by a portion of a great intrusive granite mass. The granite is cut by intrusions of various rocks, the most common being coarse white pegmatites, which occur in small dikes and veins. Diabases and basalts are also not uncommon.

> The granite itself has no economic importance, unless possibly some of it may some time be used for building purposes. The distribution of the granitic rocks, however, has a close relation to ore deposits, for the mineralization of the adjacent sediments seems to occur more often within the zone affected by the intrusions. An examination of the map of southeastern Alaska and adjacent portions of British Columbia, which shows the location of the mining districts, indicates that a certain class of deposits are found only in the two zones of metamorphosed sediments which flank the granite belt.

In the Cook Inlet region, Alaska, gold is found in aplite dikes, according to Mr. W. C. Mendenhall.[b] A sample of one of these aplite dikes given to Mr. Mendenhall assayed $7.50 per ton, mostly in gold.

In the Nome region, Messrs. Schrader and Brooks[c] report quartz and calcite veins containing sulphides cutting metamorphic marble and schists. A large area of granite was also reported. Tin also occurs in this region.[d] In the region surrounding the York Mountains limestones and slates, more or less metamorphosed, are cut by large granite masses surrounded by branches which take the form of porphyritic dikes. The distribution of the granitic intrusives is of the greatest economic importance, since many of the known tin lodes occur in the granitic dikes. The granite consists of quartz, microcline, and biotite, with accessory albite, muscovite, zircon, apatite, tourmaline, pyrite, and fluorite, and probably cassiterite. The main tin vein, situated half a mile from the granite, is a white porphyritic dike, more or less altered to greisen. It contains disseminated cassiterite with fluorite, calcite, lithia mica, and quartz. Tourmaline, topaz, pyrite, garnet, and galena are also present in the vein, and wolframite was found in the float. The siliceous ore sometimes shows spangles of free gold. The limestone which forms the wall rock of the dike is altered to epidote, garnet, etc.

UNITED STATES.

In the Appalachian gold-quartz region are numerous intrusions of granitic rocks, and pegmatite is abundant.[e] Mr. C. W. Purington,[f] however, has called attention to the fact that in the southern Appalachians, where gold-bearing quartz veins occur, although dikes are almost a constant phenomenon, they are in most cases of a basic character, siliceous dikes being exceptional. He refers especially to the Haile gold mine, in South Carolina, in which the principal mine workings are below dikes of diabase in the hydromica schists.[g]

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[a] Brooks, A. H., Prof. Paper U. S. Geol. Survey No. 1, pp. 46–47.

[b] Twentieth Ann. Rept., U. S. Geol. Survey, pt. 7, p. 321.

[c] Trans. Am. Inst. Min. Eng., vol. 30, p. 238.

[d] Collier, Arthur J., Bull. U. S. Geol. Survey No. 229, 1904.

[e] Phillips and Louis, Ore Deposits, 2d ed., pp. 786–787.

[f] Ore deposits: Eng. and Min. Jour., 1905, p. 85.

[g] Described also by G. F. Becker, Gold fields of the southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 306. Also H. B. C. Nitze and H. A. J. Wilkins, The present condition of gold mining in the southern Appalachian States: Trans. Am. Inst. Min. Eng., vol. 25, p. 767.

E. C. Eckel,[a] in describing the gold and pyrite deposits of the Dahlonega district in Georgia, writes:

> The writer believes that it can now be accepted as proved that in the large majority of mines in the Dahlonega district the more profitable and continuous veins occur along the contact between the mica schists and an igneous rock, the igneous rock being either a granite or a sheared diorite. * * *
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> The genetic relationships existing between the ore deposits and the igneous rock in the two cases presented (granite and diorite) are of a very different character. The diorite, as noted earlier in this paper, was injected into the schists at a much earlier period than that during which the ore deposits were formed. * * * The fact that many prominent gold-bearing veins occur along the contact between the diorite and the mica schists is not due, therefore, to any direct action of the diorite considered as an igneous rock but to the facts (*a*) that fissures are most likely to be formed along the contact between two formations differing in hardness and rigidity, and (*b*) that such fissures, minute at first, may have been enlarged by the solution of the relatively unstable diorite.
>
> With regard to those deposits which occur along the contact between granite and mica schist the case is somewhat different. Here the intrusion of the granite may possibly have some direct genetic connection with the formation of the ore deposits.

These contradictory observations as to the relative influence of basic and siliceous dikes on the formation of gold veins in the Appalachians call up at once the similar situation noted above for Guiana and others of the world's gold fields, and we may suspect in this case also that the greenstone dikes as well as the siliceous dikes are both phases of great granitic intrusions, while it is most probably true that the auriferous veins, if, as seems to be indicated, they are of magmatic origin, are much more closely related to the siliceous dikes than to the basic ones.

Observations upon the magmatic origin and the connection with the intrusive granites of auriferous quartz veins in Nevada and California have been made in the preceding pages. North of Nevada, in Idaho, Mr. W. Lindgren[b] divides the gold deposits into two distinct classes:

(1) A pre-Miocene series, probably of Cretaceous age and most likely formed in about the same time as the California and Oregon gold-quartz veins. These deposits occur chiefly in the great granite area of the State, which is known to be post-Carboniferous and pre-Miocene, and which appears to have been intruded at approximately the same time as the great granite batholiths of California.

(2) A post-Miocene series occurring in basalt and rhyolite. These veins are of the usual propylitic type, and are characterized by containing both silver and gold.

In Madison County, Mont., gold-quartz veins occur in granite, in Beaverhead County at the contact between limestone and granite, in Lewis and Clark County in granites and slate.[c] In the Bitterroot Range and Clearwater Mountains of Montana, according to Mr. W. Lindgren,[d] nearly all the veins occur in granite or gneiss, chiefly near the eastern and western margins of the great central granitic area, which itself seems to be generally barren of valuable deposits. The granites are intrusive into slates, limestones, greenstones, and gneiss. The veins are auriferous fissure veins, and two chief belts have been distinguished, one containing chiefly gold and the other containing copper, lead, and silver as well as gold.

The following notes in regard to gold ores near Helena have been kindly fur-

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[a] Bull. U. S. Geol. Survey No. 213, p. 57 et seq.

[b] Trans. Am. Inst. Min. Eng., vol. 30, p. 824.

[c] Kemp, Ore Deposits of the United States, 4th ed., p. 320.

[d] Bull. U. S. Geol. Survey No. 213, 1903, pp. 66, 70.

nished to the writer, together with specimens of the rocks and ores, by Mr. W. H. Weed.

About 4 miles south of Helena there is a contact between a great intrusive mass of granite or quartz monzonite on the south and intruded sedimentary rocks on the north. The date of this intrusion is post-Cretaceous. The rock is a biotite-granite or quartz-monzonite, containing tourmaline near the borders, not in the main mass. Practically all the gold in the Helena region is derived from a belt in the granite near the contact and to a less extent in the intruded rocks. A zone following the contact and having a width of 3 miles covers practically all the gold-producing area. The general nature of the ores has not been especially studied. Mr. Weed, however, has collected specimens and notes from the Winscott mines, 4 miles south of Helena. At this point there lies in the granite an elongated pegmatitic mass which contains gold and is mined as ore. There is also gold in the neighboring granite or diorite.

Specimens of this pegmatitic rock shown to the writer by Mr. Weed are composed macroscopically principally of feldspar, tourmaline, pyrite, and quartz. There is a general radiating structure, the tourmaline and feldspar being arranged frequently in sheaves of elongated crystals, while the quartz and pyrite are granular and are included in the elongated crystals or are arranged between the sheaves. This structure grades to the granular type. A thin section of this rock shows under the microscope an apparent allotriomorphic granular structure irregularly intergrown. The abundant feldspar is in part orthoclase, in part a striated feldspar, not determined but very likely albite. The feldspars are partly fresh, partly altered to a brownish, low-refracting aggregate, perhaps kaolin. Occasionally the feldspar occurs in idiomorphic crystals in quartz. Tourmaline is abundant in highly pleochroic idiomorphic crystals. It has been observed included in feldspar. As a rule quartz and tourmaline are closely intergrown and contemporaneous. The tourmaline makes up about one-third of the slide and is segregated in one portion of it. Pyrite is abundant, closely associated with the tourmaline, with which it is intergrown and contemporaneous. Pyrite occurs idiomorphic in quartz and vice versa. Biotite is a subordinate but common mineral, included in the quartz and feldspar and probably older than these. Sphene is a common accessory. Occasional magnetite was observed, perfectly octahedral striated crystals being included in quartz. A little chlorite is present.

In the hand specimens the different minerals are often grouped or segregated in pegmatitic fashion, so that bunches of almost pure tourmaline originate, others of pyrite, others of feldspar, etc. The tourmaline and pyrite are generally grouped together.

In many places this pegmatitic type becomes more granular and regular on the edges, and seems to show transition phases, by decrease of tourmaline and pyrite and increase of biotite, to the wall rock.

In many of the specimens of the pegmatitic phase gold occurs in beautiful, sharp crystals, easily visible or even conspicuous to the naked eye. In the body of the rock these gold crystals are sometimes intergrown with the pegmatitic or granitic quartz, and they thus occur in one case in a phase intermediate between the granite and the pegmatite. These crystals are often perfectly clean and free from iron stain. More often the gold crystals occur close to or lining the walls of tiny druses which are frequent in the rock, in which cases they are intimately associated with tourmaline, quartz, and feldspar (probably albite) crystals. In one case two small idiomorphic tourmaline crystals seem entirely inclosed in a sharp crystal of gold. In some cases tiny crystals of probable feldspar (albite?) are subsequent to the gold.

The gold crystals often occur close by unoxidized pyrite, showing that the free gold is not one of the secondary products dependent upon oxidation.

All the minerals of this rock, which appears to the writer to be a true pegmatitic phase of a granitic rock, are primary and practically contemporaneous. The periods of crystallization overlap, yet there is a rough order of sequence which for the principal minerals may be expressed as follows:

1. Biotite.
2. Feldspar.
3. Feldspar, magnetite pyrite, tourmaline, quartz, and gold.

In the Black Hills of South Dakota, according to Professor Kemp,[a] pegmatites in the vicinity of Harney Peak have proved to be gold bearing. These ores are regarded by Professor Kemp as similar in character to those described by Hussak from Ouro Preto in Brazil and to some in the Transvaal.

Prof. C. W. Hall[b] has furnished notes on eastern and central Minnesota, where, in connection with intrusions of hornblende-biotite granite, there are "granitic veins." These are "locally pegmatitic, with coarse and well-developed feldspar individuals embedded in a matrix of hornblende and biotite, while elsewhere they are finely textured, possess a reddish color, and are highly siliceous in composition." Associated with these are veins of quartz. In the St. Louis River district the veins when wide become pegmatitic. The veins sometimes carry segregated sulphides and siderite. One on Kettle River has been explored for gold.

On the north shore of Long Island, Prof. J. F. Kemp[c] observes that pegmatites are abundantly developed in connection with granites, and all grades are shown up to perfectly pure quartz. One of the largest quartz veins, which Professor Kemp thinks belongs to the pegmatitic series, carries in portions ferruginous minerals and traces of gold.

MEXICO.

In Mexico, in the Altar district, Sonora, according to José G. Aguilera,[d] the numerous veins of Sierra Pinta del Bajío are in pegmatite, which cuts crystalline schists.

> The veins carry quartz, pyrite, chalcopyrite, a very small amount of galena and blende, and contain free gold along the crests. The veins suddenly pinch out along both the course and dip and present a well characterized lenticular formation resembling a string of beads.

Prof. G. P. Merrill has described free gold in granite from Sonora in Mexico. This gold occurs in crystalline particles included in feldspar and quartz and is designated by Professor Merrill as "a product of cooling and crystallization from the original magma."[e]

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[a] Ore Deposits of the United States, 3d ed., pp. 310-314.

[b] Keewatin of eastern and central Minnesota: Bull. Geol. Soc. America, vol. 12, pp. 367-8-9, 1901.

[c] Ore Deposits of the United States, 4th ed., p. 383; Trans. Am. Inst. Min. Eng., vol. 31, p. 182; Genesis of Ore Deposits p. 693.

[d] Trans. Am. Inst. Min. Eng., vol. 32, p. 518.

[e] Am. Jour. Sci., Apr., 1896, p. 309.

CHAPTER V.

DEPOSITS OF NONMETALLIFEROUS MINERALS.

ALUM AND SULPHUR.

LOCALITY.

About 10 miles north of Silver Peak there lies a deposit of alum and sulphur. This has been many times located and prospected as a sulphur mine, but not until recently has the relatively large amount of alum in it been recognized. No important work has yet been done on the deposit.

MODE OF OCCURRENCE.

At the locality mentioned there is an elongated dike-like or neck-like mass of rhyolite, having all the appearance of being intrusive into gently folded white and red sedimentary rhyolitic tuffs of Tertiary age. In parts the rhyolite is easily recognizable as such; in other portions it is decomposed to a white powdery variety. This is especially true of two portions examined, about 600 feet apart; one some 200 feet in diameter, the other about 30 feet. The former, at the south end of the area, contains the chief alum and sulphur deposits. The latter contains sulphur, but no alum.

In the larger area the decomposed rhyolite shows sulphur throughout, coating all cracks and crevices, but generally not over a fraction of an inch thick. With the sulphur is closely associated pure alum, which has a different habit, forming veins, some of them several inches thick, that split and ramify irregularly throughout the broken masses of altered rhyolite. Analysis in the chemical laboratory of the United States Geological Survey shows it to be an ordinary potassium alum (kalinite). There are also occasional gypsum seams, of the same habit as the alum, but much less abundant. Bright-red stains are associated with the sulphur and alum, which were thought in the field to be possibly cinnabar. The small quantity represented by these spots is not suitable for chemical examination. In 1903, however, Dr. George I. Adams investigated the Rabbit Hole sulphur mine, in northern Nevada, near Humboldt House station, on the Southern Pacific Railway, where the geology appears to be not greatly different from that of the place being described, and has found there similar bright-red stains. Analysis of these shows them to be really cinnabar (sulphide of mercury), and there can be little question that the stains of the deposit near Silver Peak are of the same material.

The smaller area above noted, north of the principal deposit, shows sulphur in crevices, in moderately large perfect crystals nearly or quite isolated.

When exposed to the air, the alum rapidly dehydrates and crumbles to a white powder, so that it is not conspicuous in the outcrop, and the real amount of it present is visible only when it has been freshly taken out.

MANNER OF FORMATION.

These areas are evidently pipes or chimneys through which sulphurous volcanic gases have ascended. Since the rhyolite bodies are probably intrusive, the gases seem to have followed the intrusion. This action is familiar around recently active volcanoes, and it is called solfataric action, from the fact that sulphur (Italian solfo) is deposited by it. For this reason the volcanoes of Italy, Mexico, and other places yield a large amount of the world's sulphur. The formation of alum by the escaping steam and gases of these solfataras is also known to occur in many localities. While the sulphur is a direct sublimate from the sulphurous gases, as its occurrence just described in the Silver Peak deposits indicates, the alum, which is a hydrous sulphate of aluminum and potassium, is formed by a combination of the steam and the sulphuric acid emitted from the solfataras with the potash and aluminum contained in the rhyolite. This combination is rendered possible by a preliminary decomposition of the rhyolite by the escaping gases. The presence of cinnabar is also interesting, since this mineral is one of those which has been found as a sublimate on the walls of crevices in volcanoes, as for example, at Vesuvius, where it has been deposited by jets of escaping gases. The deposit of cinnabar at Steamboat Springs, some distance north of here and just north of Carson, is also significant.

COMMERCIAL ASPECTS.

Though the alum in these prospects is present in far larger quantity than the sulphur, it is somewhat more localized. It forms an irregular network of veinlets, and yet from the manner of formation the chimney undoubtedly continues downward. The decomposed rhyolite is so friable that the material could easily be worked on a large scale. The rhyolite itself in the alum locality has been found by analysis to contain a large percentage of alum. The whole deposit, therefore, would have to be worked together, and the sulphur could also be collected as a by-product.

BORATES AND SALT.

DESCRIPTION OF DEPOSITS.

Within the area of the Silver Peak quadrangle there are several playas or alkali flats, which occupy the areas of greatest depression in the desert valleys between the mountains. These playas consist of level areas of mud, which are hard and dry, or wet, according to the season of the year and the frequency of the rains. After any considerable rainfall sheets of water collect in these depressions and form shallow and evanescent lakes. The mud of these playas is frequently intermixed with and crusted with deposits of soluble salts, consisting in this region chiefly of common salt and borates of lime and soda. These playa deposits have been described by Mr. H. W. Turner, from whose work the following quotation is taken:

> The playa deposits comprise four areas in Fish Lake Valley, one in Clayton Valley, and one in Big Smoky Valley, locally known as the San Antonio marsh. All of the playas in Fish Lake Valley within the quadrangle

contain borax salts and are being worked for borax. The Big Smoky playa shows a thin white coating, which consists largely of chloride of sodium, over many square miles. Over other portions of the valley are deposits of other salts, such as sulphate of soda, which are ordinarily termed alkali.

On the economic map there are shown areas containing workable deposits of borax salts and of table salt or chloride of sodium. The borax salts are confined to Fish Lake Valley and the table salt deposits to Clayton Valley. Chloride of sodium is, however, abundant in all the playas, but nowhere sufficiently concentrated and pure to be of economic value outside of Clayton Valley.

There are also other salts, sulphates, and chlorides which form white incrustations on the Fish Lake and San Antonio playas. A series of playa deposits was collected by J. D. Reed and sent to Washington for analysis.

The chloride of sodium deposit north of the Pacific borax works in Fish Lake Valley contains sodium sulphate and other impurities (see analysis 4) and is not valuable unless the impurities can be removed. The chloride of sodium and borax lands are outlined only approximately. Further investigations will doubtless extend these areas.

Analyses of playa deposits.

[Mr. George Steiger, analyst.]

	1.	2.	3.	4.	5.
Insoluble[a]	3.46	5.72	35.42	4.86	84.49
H_2O	12.24	22.66	20.90	6.00	....
CaO	....	25.56	8.05	....	Present.
Na_2O	43.69	3.25	6.24	46.08	Do.
SO	9.15	33.14	.10	5.76	Do.
Cl	15.52	.82	1.97	37.44	....
NO_3	None.	None.	None.	Trace.	Trace.
B_2O_3	2.07	6.84	16.66	2.30	....
CO_2	17.49	....	.96	6.07	....
Al_2O_3, MgO, etc.[b]	....	2.20	10.13	....	....
	103.62	100.19	100.43	108.51	
Less O	3.49	.19	.43	8.45	
	100.13	100.00	100.00	100.06	

[a] In 2 and 3 dilute HCl was the solvent. In 1, 4, and 5 water was used.

[b] By difference.

No. 1, collected about 100 feet from the crossing B. M. in Fish Lake Valley, is composed of sodium carbonate, sodium sulphate, some borax, and probably a little sodium bicarbonate.

No. 2, from 150 feet northeast of the Pacific borax works, is principally sulphate and borate of lime, with a smaller amount of sodium sulphate and borate.

No. 3 is a sample of the little white nodules locally known as cotton balls. This is principally borate of lime and borax, with a little sodium chloride and carbonate.

No. 4 is from the large marsh north of the Pacific Borax Company mill, and forms a white incrustation with irregular surface over the entire marsh. It is principally sodium chloride or table salt, with smaller amounts of sodium sulphate, sodium carbonate, and borax.

No. 5 is from the San Antonio marsh in Big Smoky Valley. There appear to be no borax or other salt deposits on the San Antonio marsh of any value. The surface soil is whitened by salts, but the analysis of this soil shows that they are present only in trifling amounts.

At the time of the writer's visit the borax industry within the area of this quadrangle was dormant, and no systematic work was being done on the salt deposits. From the salt deposits in the neighborhood of Silver Peak supplies are drawn for the village of Silver Peak, and occasionally a few sacks are taken away to neighboring country stores and sold. This salt is prepared by digging a hole a foot or two feet deep in the marsh until water is reached and then letting this water evaporate. It is claimed that the salt thus produced is .99 pure.

RELATIONS TO OTHER AREAS.

The borax-bearing playa in Fish Lake Valley is the southernmost of a series of several playas or borax marshes which have produced a large quantity of borax and have played a most important part in the development of the American borax industry. These marshes are, besides the Fish Lake marsh, the Columbus marsh, which lies a short distance due north of the Fish Lake marsh and in the same general valley; the Rhodes marsh, which lies still farther north of the Fish Lake marsh and a short distance south of Sodaville, and the Teal marsh, which lies a short distance west of the Rhodes marsh.

Although the presence of borax in water from Mono Lake was discovered as early as 1860 by Doctor Veatch, and this fact was regarded by him as evidence of the presence of borax deposits in Nevada, the recognition of economically important deposits did not take place until some years later. In 1864 Columbus marsh was located as a salt bed. Some borate of lime was found and was afterwards recognized as such, but no importance was attached to the discovery. The Teal marsh, which has been one of the most productive of the borax fields of the Pacific coast, was discovered in 1873 by one of the Smith brothers, who now control the borax industry, and from this beginning the great production of American borax was started. Extensive operations have also been carried on in the Rhodes, Columbus, and Fish Lake marshes.

GENESIS OF THE DEPOSITS.

The incrustations of various salts covering the playas are among the most recent geological deposits. In part they have undoubtedly been crystallized from the waters which sometimes cover the playas and which in most places, even in the dry seasons, can be found by digging a few feet down into the mud. In the case of some playas in this region, also, there is evidence that during earlier periods of comparative humidity, the water supply was sufficient to form perennial lakes similar to the inclosed lakes still found in various portions of this arid province. In such cases the deposit of salts has been largely derived from the evaporation of the saline lake waters. In any case, whether the water which has covered the playas has been sufficient to form a permanent body or only temporary sheets, it has been derived, in part at least, from the drainage of the surrounding mountains. None of these dry lakes, as the playas are sometimes called, have any outlet, so that evaporation is a process of the utmost importance, and nearly all the salts in the waters become concentrated. From these considerations the explanation naturally arises that the salts in the playa deposits of the alkaline lakes represent the concentration of the very small quantity of salts contained in ordinary drainage water, and that the supply was derived from the leaching of the disintegrated rocks of the areas which drain into these depressions. This explanation has been somewhat widely held for the borax deposits of the desert Nevada region. About 1890,[a] however, beds of borate of lime or colemanite were discovered forming part of the early Tertiary sediments of this region, which had been in part upfolded and faulted so as to form part of the hills and mountains.[b] In the valley playas near these Tertiary borate

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[a] According to G. P. Merrill Nonmetallic Minerals, 1904, p. 316.

[b] Storms, W. H., Eleventh Ann. Rept. State Geologist of California, 1892, p. 345; Campbell, M. R., Bull. U. S. Geol. Survey No. 200, p. 17; Spurr, J. E., Bull. U. S. Geol. Survey No. 208, p. 190.

deposits, borates occur also, and in these cases it became evident that a large part of the supply was secondary and derived from the leaching of the Tertiary borates in the hills rather than from the faint traces of boron which may exist in the other rocks.

Earlier in this report (p. 21) the writer has shown that these older colemanite beds are characteristic of the broad belt of earlier Tertiary sediments which runs northwest and southeast in the region lying immediately east of the Sierra Nevada and which reaches at least as far north as northern Nevada and as far south as the Mojave desert. The internal evidence of these beds shows that much of the material was laid down in inclosed lake basins and that the colemanite beds are probably the result of the evaporation of Tertiary alkaline lakes during periods of aridity. The belt of these continental Tertiary deposits is practically that of the playa borax region, so that the writer has regarded it probable that much of the material in the playa deposits is leached from Tertiary beds in the surrounding mountains, even when these beds do not show any considerable aggregation of colemanite and other minerals due to evaporation.[a]

Though the above explanation is logical, it does not seem to cover the whole question. Within the Silver Peak quadrangle, as already described, the Clayton playa, near the village of Silver Peak, contains abundant salt deposits, but so far as known no borates, while the Fish Lake playa contains abundant borates as well as salt. The drainage area of each of these playas includes large districts of the upturned early Tertiary sediments, so that the playa deposits would be naturally expected to show the same characteristics. There is, however, another phenomenon which explains this difference and by so doing becomes an important factor in the explanation of the playa deposits in general. At Silver Peak a hot saline spring, the waters from which have not been analyzed, flows out very near the edge of the mountains and at the edge of the playa, and on the opposite or east side of Clayton Valley another hot spring emerges. Moreover, hot waters underlie the upper crust of the whole playa or marsh, especially at certain seasons of the year, according to the testimony of the inhabitants. It is plain that the incrustations of salt are largely derived from these hot spring waters. In Fish Lake Valley also there are highly saline springs, although these are not hot; and a number of mounds show the presence of springs formerly active, but now extinct. The explanation of the difference in the character of deposits in the playas which receive the drainage from similar rocks seems to lie in the presence of these springs, which, (the hot springs, at least), must be of deep-seated origin and must furnish waters differing from one another as to the salts which they hold in solution.

This was also the explanation offered by Prof. Joseph Le Conte[b] for the localization of the different salts at the Rhodes salt marsh.

> The marsh is nearly circular in form, and, as near as I can judge, about 2½ to 3 miles in diameter and contains about 5 or 6 square miles. The central part (perhaps 1 square mile or more) is covered with pure salt—chloride of sodium. Around this to the margin the nature of the deposit differs in different parts. In some parts borax in the form of crust; in some, borax in the form of tincal; in some, ulexite (a soda-lime borate);

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[a] According to Mr. Hïeronymus, keeper of the Cold Wells watering station on the edge of the Columbus marsh, borax or cotton ball occurs in the Tertiary Monte Cristo Mountains, just north of the Silver Peak quadrangle. The mountains are part of the drainage area of Columbus marsh.

[b] Third Ann. Rept. State Mineralogist, California, 1883, p. 51.

> in some, sulphate of soda, and in some carbonate of soda. Common salt is found nearly everywhere, more or less mingled with the other salts, but in a pure condition only in the central portion of the marsh. * * *
>
> If the marsh is a simple dried-up lake, the waters of which contained all these salts, then it would be impossible to account for the localization of the various kinds. The former lake, therefore, must have been supplied also largely by springs coming up in the lake bottom, and these springs brought up various kinds of salts, some one kind and some another. After the lake dried up, these springs still continuing to act would then commence to localize their products. This they are still doing. Thus I account for the localization of most of the kinds of salts. In addition to this, I think the common salt, as the most abundant ingredient of the lake water, was probably left everywhere as a crust, but subsequently was leached out and accumulated in a very pure form in the lowest or central part.

The above-mentioned explanations carry back the history of the accumulation of borax and other salts to a certain point, but do not satisfy the investigator as to the real cause why borates should be concentrated in this belt. Boron is one of the rarer elements, making up, according to J. H. L. Vogt,[a] between 0.01 and 0.001 of 1 per cent of the earth's crust. In the relative order of abundance it belongs in the same group with nickel, strontium, lithium, bromine, and beryllium. The concentration of this rare element into deposits so rich and abundant that the material becomes commercially cheap and available for domestic purposes certainly implies some active process that has separated the element from the vastly more abundant elements which accompany it in rocks and which likewise pass into ordinary aqueous solutions.

An explanation of this may be offered after considering the associations under which quantities of boron appear in various places. Compounds containing boron in commercial quantities occur in two principal ways: (1) In deposits from evaporated dry lakes, as in the case of the Nevada belt, and (2) in deposits from volcanic fumaroles. In the first instance we have of course still to seek the ultimate origin, while in the second it seems possible that we have an explanation of this origin.

Pure boric acid, or sassolite, occurs chiefly in volcanic fumaroles, to a very slight extent in certain spring waters, and in traces even in sea water.[b] It has been obtained in commercial quantities from fumaroles in two Mediterranean localities—one in Tuscany in Italy and one in the Lipari Islands. At the first-named locality hot vapors issue from the ground at many places. These consist chiefly of steam with carbonic acid. In 1818 a method was found to condense the steam and to crystallize the salts contained in solution. By this process a commercial product was obtained which contains 76.5 per cent of crystallized boric acid and 23.5 per cent of other materials—namely, sulphates of ammonium, magnesium, calcium, sodium, potassium, iron oxide, alumina, and manganese oxide; also ammonium chloride, sulphuric acid combined with boric acid, silica, and traces of organic material.[c]

Exhalations of steam containing boric acid have also long been known to proceed from the crater of Stromboli, on the island of Vulcano, in the Lipari group. At Vulcano the boric acid is precipitated together with sulphur from exhalations of steam containing sulphureted hydrogen, which emerge boiling hot from fissures. The sulphur deposited is so abundant as to become a commercial product, and

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[a] Zeitschr. für prakt. Geol., 1898, p. 325.

[b] Bischof, Chemische and physicalische Geologie, vol. 2, p. 277.

[c] Bischof, op. cit., p. 268.

alum is also a product of the fumarolic activity, as well as ammonium chloride. In 1864, according to Bischof,[a] the works engaged in utilizing these fumarolic exhalations produced, besides boric acid and sal ammoniac, 1,700 pounds of refined sulphur and 600 pounds of pure alum.

During an eruption of Vesuvius in 1851 boric acid was found in fissures.[b]

The discovery of borax on the Pacific coast of the United States was made in 1856 by Dr. John A. Veatch.[c] In the vicinity of Clear Lake, California, Doctor Veatch found hot sulphur springs containing borax and boracic acid in solution, together with chlorides and sulphates. These springs also contained carbonic acid. Doctor Veatch observes: "The whole neighborhood bears marks of comparatively recent volcanic action. Indeed, the action has not ceased yet entirely. Hot sulphurous fumes issue from several places." The waters of this district also contain iodine.

The eruptive mud from the mud volcanoes of the Colorado desert, San Diego County, contains boracic acid.[d]

The connection of large concentrations of boron in the form of boric acid and various borates with fumarolic activity following volcanic eruptions is thus clearly demonstrated for some of the most important localities in the world. If this observed origin be applied to the explanation of the borate deposits which have been formed by evaporation of the waters of arid regions the reason for the distribution of these deposits is clearly understood. The Tertiary sediments which contain colemanite beds in Nevada and California were formed during a long period of active volcanism, which is hardly yet extinct.[e] The exhalation of boron compounds attendant upon the cooling of eruptive volcanic rocks would provide a large supply of this material, which would all pass into the waters of the region. The portions which were carried out in steam from escaping fumaroles would be brought back to the surface in the form of rain, while a large portion in the later stages of cooling would come to the surface in solution in the hot springs which succeed the fumarolic phase of expiring volcanic activity. The aridity of the climate is a very essential factor in producing from these solutions, by natural evaporation, workable deposits containing borates. In a region which has free drainage to the sea or to large lakes the borates and associated salts are carried off. Thus the various inclosed lakes of Nevada and California, such as Owens, Mono, and Pyramid lakes, contain boracic acid, as well as other salts, and the same is true to a less extent of the sea water, where the salts are more diluted.

Some geologists have believed that deposits of borates were the result of the leaching of rocks carrying minerals containing boron, such as tourmaline, axinite, etc. Of the boron-bearing minerals which are rock constituents tourmaline is the most abundant and is frequent as a constituent of granitic rocks and in the metamorphic schists, especially in the neighborhood of granites. Tourmaline has been occasionally found altered to mica, chlorite, and talc, and in the process of alteration its boric acid has been separated out and may have formed borates.[f] On the

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[a] Op. cit., p. 272.

[b] Third Ann. Rept. California Mining Bureau, 1883, p. 61.

[c] Ibid., pp. 14-20.

[d] Ibid., p. 59.

[e] Spurr, J. E., Prof. Paper U. S. Geol. Survey No. 42, p. 82.

[f] Bischof, op. cit., pp. 277-278.

whole, however, tourmaline is very resistant to decomposition, remains unaltered when the surrounding minerals are decomposed, and so passes in a fresh condition from igneous metamorphic rocks into clastic rocks.[a] The study of the granitic and metamorphic rocks of the Silver Peak quadrangle and other portions of the region shows the presence of tourmaline rarely and in very small amounts, not nearly so great as in many regions which contain no borax deposits. This explanation is therefore out of the question for the district under consideration. Moreover, it is now generally recognized, as it was not at the time that the above explanation was offered, that the tourmaline in these rocks is itself the result of exhalations from cooling igneous rocks, similar in many respects to those of volcanic fumaroles, but, on account of being at great depths and under great pressure, capable of crystallizing in silicates, such as tourmaline, which are not possible under surface conditions.

According to the conception of the writer, therefore, the concentrations of boric acid in volcanic fumaroles and in the deposits of evaporated lakes or playas in arid volcanic regions owe their existence to a process of natural concentration, the first stage of which was similar to that which has produced the concentrations of boron in the form of tourmaline and other silicate minerals in and near bodies of siliceous intrusive rocks, while the second stage was dependent upon concentration by evaporation from surface waters.

A discussion of the probable origin of the Nevada hot springs, which are here regarded as the sources of the various playa salts in the region of Silver Peak, has been given by the writer in a previous report.[b] In this investigation it has been concluded that, although many of the springs are undoubtedly of mixed origin, and in many cases a part of the water may be atmospheric, a large portion is probably magmatic, and has its origin in exhalations from volcanic rocks cooling in depth. To solutions contained in such hot springs (of Tertiary age) the Tertiary metalliferous ore deposits, such as those at Tonopah, have been ascribed. For the Tonopah district the presence in these solutions of sulphur, carbonic acid, chlorine, and fluorine has been inferred. Vein fillings like those at Tonopah, constituting the metalliferous ores of the Nevada Tertiary province, represent the most easily deposited materials held in these solutions, such as silver, gold, silica, etc. These materials were deposited in the fissures at some distance from the surface, while the more easily soluble and more volatile materials were deposited higher up or at the surface. Such deposits are considered to be represented by the deposits of sulphur, alum, borax, and salt in the Silver Peak quadrangle. The presence of probable cinnabar in the alum-sulphur deposit at Silver Peak, above noted, seems to furnish a connection between these nonmetalliferous deposits and those which contain abundant metals, and the resemblance of this occurrence to that at Steamboat Springs is a step further in the idea, for at Steamboat Springs not only is the cinnabar more abundant, but gold has been and is being deposited from the waters. In a portion of the borax belt some distance south of the Silver Peak district, in Searles Marsh, northeast of Randsburg, in California, playa deposits have been found to contain small quantities of silver chloride and chlorobromide (cerargyrite and embolite), together with the more ordinary nonmetallic minerals, comprising calcium, stron-

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[a] Rosenbusch-Iddings, Microscopical Petrography of the Rock-Making Minerals, 1889, pp. 184-185.

[b] Prof. Paper U. S. Geol. Survey No. 42, p. 256.

OPENING ON COAL SEAM, WILLIAM GROZENGER, DISCOVERER OF THE FIELD, STANDING BY.

tium, and sodium phosphates; calcium, magnesium, and sodium carbonates; calcium and sodium borates, potassium nitrate, and sulphur. The association in these playa deposits and other saline beds of the halogen elements, chlorine, bromine, iodine, together with other elements likewise possessing volatile properties, such as boron and sulphur, can hardly be without very great significance, and the identity of these associations with those found in volcanic fumaroles is a strong argument for a common origin.

COAL.

At the north end of the Silver Peak range, near the northern end of the quadrangle, and just south of the road between Silver Peak and Candelaria, coal beds occur in Tertiary sandstones, shales, and volcanic tuffs, which contain fresh-water shells and Tertiary plants (see p. 20).

GEOLOGIC CONDITIONS.

On the south, only a short distance from the road, these sediments abut abruptly against a massive cliff or scarp of rhyolite, itself also probably of Tertiary age. Between the rhyolite on the south and the sediments on the north there is probably a heavy fault, running in an east-west direction. The coal-bearing beds dip northeast at comparatively slight angles, but the dip increases as the fault is neared, and in the immediate vicinity of the fault the beds acquire a reversed dip and constitute a local anticline running parallel to the line of displacement. The beds on the south limb of this fold sometimes have considerable dip. This phenomenon seems to be due to the dragging down of the strata along the fault. It is believed that the downthrow has occurred on the south side, and that the present greater height of the rhyolite on the south is due to its superior hardness, the soft sandstones and shales having been worn away relatively more rapidly. In support of this belief the downdragging of the beds near the fault just described may be appealed to, together with the fact that several minor faults near the main fault were found to have a downthrow to the south. Also it seems probable that the rhyolites on the south side may represent a higher horizon in the Tertiary than the beds on the north (Pl. XXIV).

DESCRIPTION OF THE COAL.

The coal in this district is said to have been discovered by William Grozenger, of Candelaria, in 1893, and the outcrops of the seams are now continuously located (Pl. XXIII). The chief seams are four in number. Some of them outcrop for a distance of 3,000 to 4,000 feet, in a northwest-southeast direction. Mr. Grozenger, who is very familiar with the district, has classified the seams, counting from the top, as the first, second, third, and fourth. The perpendicular distance between the first and the second seam is estimated by him to be 150 feet; between the second and third, 70 feet, and between the third and fourth, 130 feet. The uppermost seam, No. 1, seems to be relatively poor and small, and, as exposed in outcrop, of little value. No. 2 seam is in coal shale and is several feet thick. Openings on this seam show the coal to be thin bedded and to occur in connection with beds of rhyolitic tuff. In places, also, sheets of glassy rhyolite, evidently subsequent in age to the coal beds, have intruded and cut off the coal (fig. 40). There is a good deal of slate parting or bone present. No. 3 is also in coal shale and is of better quality and thicker than No. 2. No. 4 lies close to the fault, is in sandstone, and shows 6 to 8 feet of coal of much better quality than the upper seams. Some of this coal has a brilliant luster, while the coal of the other seams is of a dull color. It has been opened up in only one place, where it is overturned and dips against the fault. Here the lower 2½ feet is cleaner coal than the rest. It was used as a forge coal by Mr. Grozenger and affords a coke. Analysis by Mr. George Steiger, of the United States Geological Survey, of a general sample taken from a picked block 8 inches thick, gave the following results:

Analysis of coal from Esmeralda County, Nev.

Moisture	0.94
Volatile matter	37.35
Fixed carbon	42.63
Ash	19.08
Total	100.00

Coke good.

This analysis was made after the sample had been lying exposed to the air about six months. The amount of moisture given is therefore probably less than when the coal was taken from the mine. The important fact that the coal does not slack rapidly on exposure was, however, determined by this experiment. The analysis shows a light, bituminous coal, somewhat poorer than the Colorado bituminous coal, and, except for the larger amount of ash, comparable with some of the high-class Pennsylvania coals. It is a fairly good steaming coal and an excellent gas coal.

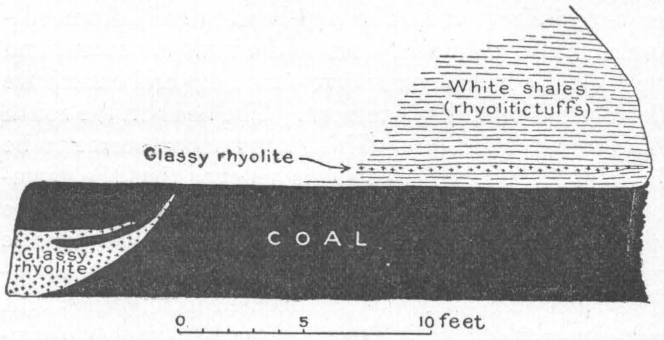

FIG. 40.—Section exposed by short tunnel of coal vein No. 2, showing intrusion of rhyolite.

An analysis of coal from the Elder-Morgan prospect, taken from unpublished manuscript of Mr. H. W. Turner, of the Geological Survey, is as follows:[a]

Analysis of coal from Elder-Morgan mine, Esmeralda County, Nev.

Moisture	3.53
Volatile combustible material	31.71
Fixed carbon	35.95
Ash	28.81
Total	100.00
Sulphur	1.05

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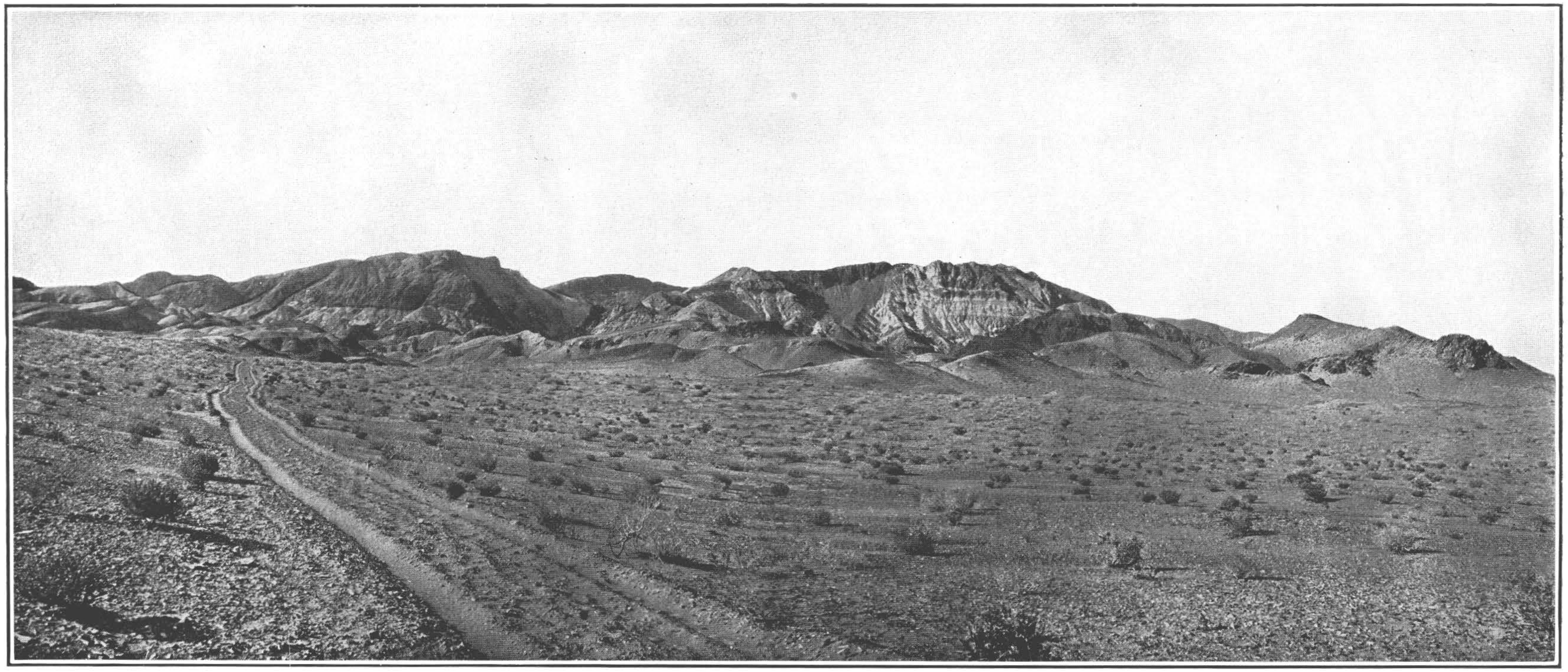
[a] Dr. W. F. Hillebrand, of the U. S. Geological Survey, who made this analysis, notes that the coke is coherent, but not much swelled.



COAL FIELDS AT NORTH END OF SILVER PEAK RANGE.

170-

This analysis, according to the writer's best information, seems to be of coal from seam No. 2.

On seam 3 of the Elder-Morgan locations an incline has been put down 160 feet, with a dip of 30°. The following description and analysis is from an article by Mr. W. J. Stoneham:[a]

> At the outcrop this vein is very dirty, containing little or no coal, but within 75 feet good coal is found on the roof and continues to the bottom of the incline, improving in width and quality. For the lowest 85 feet the coal averages 3 feet thick and is clean, compact, and glossy. An analysis of coal from this seam near the surface made by Thomas Price, of San Francisco, showed—

Moisture	1.81
Volatile matter	34.52
Fixed carbon	44.58
Ash	19.09
Total	100.00
Sulphur	3.62

> The coal forms a hard coke. At surface, the seam showed over 28 per cent ash, so that at greater depth it may contain less than 19 per cent.

In these coal seams gypsum is found and some alum, and in the old workings iron sulphate (melanterite) and coatings of sulphur. This sulphur and the various sulphates are plainly secondary and are the result of the oxidation of the pyrites, which is present in the coal. It is interesting to consider the genesis of this sulphur, gypsum, and alum in connection with the presence of the same minerals in the alum-sulphur prospect described on page 157. In both occurrences the formation of the sulphates, and probably of the sulphur, may be ascribed to the effect of sulphuric acid, working upon the bases in the rock to form the sulphates. At the coal mines the sulphuric acid, however, is derived from the oxidation of pyrites or iron sulphide, and the sulphur content in this mineral is undoubtedly of organic origin, as is the case with the sulphur almost universally found in coal. In the case of the alum-sulphur prospect, however, the sulphuric acid and the sulphur are of direct volcanic origin and are inorganic, being emanations from cooling igneous rocks.

Similar Tertiary strata exist in the Monte Cristo Mountains to the north, in the same general line with the Silver Peak Range. These mountains have not been explored by geologists, but prospectors have located coal seams in them and brought away specimens, some of which are dull and evidently full of ash, while some are brilliant looking, light, bituminous coals allied to lignite and are claimed to be good coking coals. It is reported that the seams in these mountains are considerably broken by faulting. Within the field at the north end of the Silver Peak Range, just described, there has also been probably a moderate amount of faulting, which would complicate any possible future work. It is possible that the failure to trace the known coal seams along their strike any farther than has been done is due to the action of northeast faults.

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[a] Eng. and Min. Jour., June 23, 1904, p. 1009.

PROBABLE VALUE.

In conclusion it may be reiterated that these coals in general are undoubtedly light and of poor quality. Nevertheless, a poor fuel may be better than none in a region like this, where there is very little wood supply, no water power, and where transportation is very expensive. If a sufficient supply of the brilliant, light, bituminous coals could be developed, they would probably be directly available for fuel. A more economical utilization would be the conversion of the coal into producer gas, a fuel whose energy could be transformed into electric power, and sent to the points where it is desired.

The incoming of large mining enterprises into the region should give impetus to a careful and well-considered study of the utilization of this important natural source of energy.

INDEX.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 55.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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