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GEOLOGY OF THE "QUESTA" MOLYBDENITE DEPOSIT, TAOS COUNTY, NEW MEXICO[1]

and some observations on the regional structure of the Sangre de Cristo Range along the Red River, New Mexico.

by

JOHN W. VANDERWILT[2]

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ILLUSTRATIONS

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[1]Published with permission of Molybdenum Corporation of America.

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ABSTRACT

The "Questa" molybdenite deposit is located between 8,000 and 9,000 feet above sea level on the rugged western flank of the Sangre de Cristo Range in Taos County, New Mexico. The mine is in Sulphur Gulch, a north branch of the Red River, which flows westerly and is a tributary of the Rio Grande. The mill and main office are on the Red River a short distance above the mouth of Sulphur Gulch and three-quarters of a mile from the mine. From 1921 to 1937, inclusive, the mine has produced 10,600,000 pounds of molybdenite in terms of contained MoS_2 in concentrates shipped.

The country rock is albite granite, with phases of alaskite which are porphyritic in places, intruded into a series of pre-Cambrian schist, gneiss, gneissic granite, and Carboniferous sedimentary rocks. Volcanic tuffs, flows, and breccias older than the albite granite but younger than the other rocks occur nearby. The volcanic rocks contain no molybdenite.

The albite granite is a stock exposed to a relatively shallow depth over an area of less than 2 square miles in Sulphur Gulch. The form of the stock as exposed is that of a sharp anticline, plunging south. The mineralized area is on the west limb of the "anticline" where the general trend of the contact between albite granite and its intruded rocks is northerly with dips to the west. In the vicinity of the molybdenite deposit the contact trends nearly east-west with average south dips of about 30°, under which the molybdenite is concentrated in fractures in the albite granite. The ore veins are confined to a relatively narrow zone immediately under the contact. The overlying schist and sedimentary rocks contain no open fractures and acted as a dam to the rising solutions, confining them to the fractured zone to form veins in the albite granite below.

The mineralized area is marked at the surface by numerous highly iron-stained fractures, some of which show conspicuously bright yellow molybdite. Surface exposures of molybdenite are poor when compared with the ore en-

countered in the course of mining. The veins are associated with a series of fractured zones that converge toward the contact; the area of intersection marks the more favorable places for ore. Away from the contact the veins pinch out. The mineral solutions caused appreciable alteration of the wall rock but replacement of rock is relatively unimportant. The ore is wholly vein filling and consists of molybdenite with varying amounts of quartz, fine-grained orthoclase, biotite, chlorite, pyrite, fluorite, rhodochrosite, and calcite. Chalcopyrite and sphalerite are present in minor amounts. The chlorite is of special interest because its occurrence is analogous to sericite in some molybdenite deposits; here, in addition to occurring in veins with molybdenite, it is commonly alone in small veins and also replaces much of the biotite in the albite granite. Chloritization of the schist and sedimentary rocks is also pronounced. The association of molybdenite with biotite, calcite, and chlorite is indicative that molybdenite was deposited through a relatively wide range of temperature.

Ore has been found through a vertical range of 500 feet to the lowest level developed. The character of mineralization and the controlling structures do not change throughout this 500-foot interval and mineralization is therefore to be expected to continue to lower levels.

Introduction

The "Questa"[3] molybdenite deposit, owned by the Molybdenum Corporation of America, is the only occurrence of molybdenite in typical hydrothermal veins known to have produced an important quantity of molybdenum

[3]The deposit has long been referred to as "Questa." The New Mexico State Bureau of Mines and Mineral Resources in its Bulletin No. 7 (1933) includes the deposit in the Red River district. Red River district proper, however, is characterized by scattered and weak gold mineralization without any recognized genetic relationship to the deposit of molybdenite. In addition, Sulphur Gulch is fully 6 miles from the Red River district with the intervening area virtually barren of any kind of mineralization. The molybdenite deposit is an area to itself and its incorporation in an adjoining district is not logical nor justifiable on any grounds except possibly for convenience of discussion. It might be desirable to identify and locate the molybdenite deposit by the name "Sulphur Gulch" but the name of the gulch is not shown on any map. (See U. S. Geol. Survey Taos topographic map, 30-minute quadrangle, scale 1/96000, for location of the mine and topography of the surrounding country.) For these reasons and because the deposit long has been identified in the geologic and mining literature as "Questa," this name is given preference.

sulphide ore. Molybdenite is common in pegmatite veins and in certain quartz veins generally regarded as relatively closely associated with magmatic processes and probably formed at rather high temperature. In such occurrences the wall rock of the veins shows little or no hydrothermal alteration and much of the molybdenite is characteristically in coarse flakes that make showy specimens, but rarely make ore in any quantity. Molybdenite is also found as an accessory mineral associated with copper deposits in the western United States and Mexico. Some of these occurrences promise to market large quantities of molybdenite concentrates. At the "Questa" deposits, wall rock alteration is pronounced along the molybdenite veins, and molybdenite is the only valuable sulphide. The molybdenite content varies from 4 to 20 per cent to the ton. Over 6,000,000 pounds of molybdenite (in terms of contained MoS_2) have been produced from 1923 through 1933 and the mineralized area has not been fully developed, making it eminently unique as an occurrence of molybdenite.

Production of "Questa" molybdenum mine, New Mexico, by Molybdenum Corporation of America

Year	MoS_2	Mo (MoS_2 x 0.6)
1923[1] (1 mo.)	25,393	15,236
1924	225,910	135,546
1925	522,806	313,684
1926	557,329	334,397
1927	489,189	293,513
1928	768,178	460,907
1929	823,332	493,999
1930	1,065,466	639,280
1931	800,901	480,541
1932	869,235	521,541
1933	962,562	577,537
1934	953,838	572,303
1935	557,145	334,287
1936	676,063	405,638
1937	832,054	499,232
	10,129,401	6,077,641

[1]Production prior to 1923 said to be 450,000 pounds MoS_2. (270,000 pounds Mo).

This deposit, by the end of 1937, developed by 97,257 feet of drifts, crosscuts and raises, not only gives new information of scientific interest concerning the occurrence of molybdenite but also may give criteria leading toward the recognition of similar deposits in other areas. The chances that similar deposits have been overlooked or given scant attention can well be considered in view of the fact that their potential value may not have been fully appreciated. It is also well to keep in mind that it is human nature to interpret what is seen in terms of past experiences and that both mining engineers and geologists have inherited prejudice regarding molybdenite as a pegmatite mineral. In some reports the term "pegmatite" is applied to the molybdenite deposit even though from the text it is clearly not a pegmatite deposit. Since mineral concentration in pegmatites is known to be spotty, erratic, and without continuity, the tendency to classify most occurrences of molybdenite as of pegmatitic origin naturally discourages their further development. The famous deposit at Climax, Colorado, and the "Questa" deposit have been classed as "pegmatites" in geologic literature but they are now known to be unrelated to this type of occurrence. With appreciation of the nature of mineralization represented at "Questa," a re-study of the known molybdenite deposits might result in the discovery of commercial concentrations of molybdenite.

The value of the description of the occurrence of molybdenite near Questa may well extend beyond the deposit itself and it is hoped therefore that this geologic description, although written primarily to satisfy local needs, may not only be of interest but also an aid to those interested in the discovery of new molybdenite mines.

History

The yellow molybdic ochre that formed as an alteration product at the outcrops of the veins was long regarded as sulphur and gave the name to the gulch on which the mine is located. About the time of the entry of the United States into the World War it was realized that the black substance associated with the "sulphur" was not "graphite" but molybdenite, and the Western Molybdenum Co. of La Jara, Colo., was organized to develop the prospect. No systematic development work was done by this company and no ore was produced. In November 1918 the R[app] and S[avery] Molybdenum Co. of Denver was formed and took over 7 claims from the Western Molybdenum Co., and the new company filed additional claims to increase the holdings to about 300 acres. Development work was done throughout the winter; production began in the spring of 1919 and continued through 1919. The ore was treated at a nearby remodeled gold mill. In 1920 the mine was taken over by the Molybdenum Corporation of America. Operations continued on a small scale until a 40-ton flotation mill was built in 1923.

Previous Reports and Acknowledgments

The deposit was first described by Larsen and Ross[4] in 1920, and further geologic data are given by Carman[5] in a report on mining methods. These two papers are briefly summarized by Vanderwilt.[6] The new Mexico Bureau of Mines[7] refers to the deposit and periodic references to production may also be found in mining magazines and in the Minerals Yearbook and Mineral Resources of the U. S. Bureau of Mines.

In the spring of 1934 the writer spent 4 months, mostly in underground studies of the deposit, although an examination of the surface geology in the immediate vicinity of the mine was also made. A few days were taken for reconnaissance of the surrounding area. The work accomplished during so short a period was made possible through the cooperation of O. R. Whitaker, Consulting Engineer, J. B. Carman, Manager, and C. G. Mohney and A. S. MacArthur of the mining staff. I wish to express strongly my appreciation of the aid given by these gentlemen. The observa-

[4]Larsen, Esper S., and Ross, C. S., The R. and S. molybdenum mine, Taos County, New Mexico: Econ. Geol., vol. 15, pp. 567-573, 1920.

[5]Carman, J. B., Mining methods of the Molybdenum Corporation of America at Questa, New Mexico: U. S. Bureau of Mines Information Circular 6514, p. 3, 1931.

tions and deductions as to ore deposition were freely discussed with them and to these discussions must go much of the credit for the conclusions presented in this paper. However, I must accept all responsibility in the presentation. New development work was examined by the author periodically in 1935-37.

Location and Access

The "Questa" molybdenite deposit is located in Sulphur Gulch about 6 miles west of Red River post office and 7

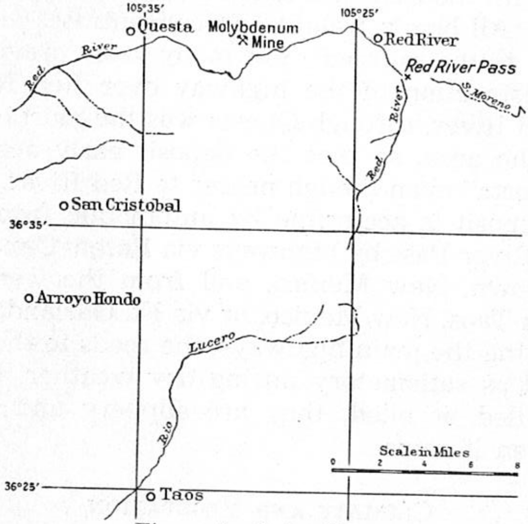

Figure 1.—Index Map.

miles east of Questa, Taos County, New Mexico. (See Fig. 1.) Sulphur Gulch is a small intermittent tributary of the Red River, which flows westward into the Rio Grande and drains a part of the western flank of the Sangre de Cristo Mountains in northern New Mexico. Questa is the center

[6] Vanderwilt, John W., Geology of the molybdenite deposit at Climax, Colorado, and of other deposits producing molybdenite: Am. Inst. Mining & Met. Eng. (Preprint Feb. meeting, 1932.)

[7] Lasky, S. G., and Wootton, T. P., The metal resources of New Mexico and their economic features: New Mexico School of Mines, State Bureau of Mines and Mineral Resources, Socorro, New Mexico, Bull. 7, pp. 120-121, 1933.

of a small Mexican farming community in the widened valley of Red River where it emerges from the mountains. The mountain town of Red River is upstream from the molybdenum mine and is the center of the Red River district, which has had a sporadic history and no important production. The Red River valley has very attractive scenery and pleasant summer climate which has made it a popular tourist center.

The nearest railroad station to the mine is Jarosa, Colo., 25 miles north and west of Questa. Jarosa is the terminal of the San Luis Valley Southern Railway which connects with the Denver and Rio Grande Western Railroad at Blanca. All heavy freight and concentrates are trucked via Questa to the railroad. For many years previous to the recent construction of the highway over Red River Pass east of Red River, through Questa was the most convenient route to the area, so that the deposit early acquired the name "Questa" even though nearer to Red River. At present the deposit is accessible by automobile from the east over Red River Pass by highways via Raton, Cimarron, and Elizabethtown, New Mexico, and from the west through Questa via Taos, New Mexico, or via Ft. Garland, Colorado. After leaving the main highways, the roads to the mine can be classed as satisfactory during dry weather, but where not gravelled or oiled, they are slippery and muddy in places when it rains.

Climate and Vegetation

The district is located between altitudes of 8,000 to 9,000 feet on the flank of a rugged mountainous range and is subject to the variations of climate characteristic of areas of high altitudes and strong relief. The semi-arid plains to the west also affect the climate. Through the summer the days are hot and the nights are invariably cool. Winter begins rather early but comes slowly. Fall is a protracted period with daytime of summer and winterish nights. Hard freezing weather generally is limited to December to February and heavy snowfall is confined to the high divides of the range. Considerable warm weather comes in March but the aspen and willows commonly do not leaf out until May or June. March is a windy period during which dust storms are common, and in May and June local rains are to be expected, but the regular rainy season begins in July. The rains commonly reach torrential proportions, frequently flooding the side streams, otherwise dry. The branching streams, including Sulphur Gulch, on the north side of the Red River are noted for their floods which drain steep slopes of decomposed and soft yellow volcanic debris which is moved in considerable volume to form large alluvial fans at their confluence with the main valley. Alluvial fans more than a mile wide and of great thickness are important features in the valley of the Red River and are mute evidence that floods observed in recent years have been common in years past. During and following a heavy rain the finer yellow silt is unloaded in such quantities into the Red River as to muddy the water downstream as far as the Rio Grande, fully 12 miles distant. In spite of local showers during the summer months, irrigation is necessary to sustain the crops on small ranches scattered along the valley.

The vegetation found on the south- and north-facing slopes is markedly different. The south-facing slopes below 8,000 to 8,500 feet in altitude are covered with scrub oak, juniper, yucca, and sage, while spruce trees and aspen in scattered patches grow at higher altitudes. On north-facing exposures spruce, balsam, and some pine and, in places, aspen cover the slopes. Except in high areas to the east near the crest of the range, grass is found only in small scattered spots so the area as a whole is not good grazing ground.

Regional Geology

Published information concerning the regional geologic features of the Sangre de Cristo Mountains is meager. The core of the range consists of crystalline rocks of pre-Cambrian age. These older rocks are overlain by Carboniferous and younger formations. In places intrusive and extrusive rocks of Tertiary age are common; their distribution, extent, and relationships have not been described.

The trend of the main range is north; studies by others have shown important faults to exist parallel to this trend along both east and west flanks of the mountains to the north and south of the molybdenite area. In my study I found evidence of faults, probably a part of the same tectonic plan, which can be expected to be more or less continuous along the range.

A broad plain covered with gravel and underlain with lava borders the mountains on the west. This plain is the southern extension of the San Luis Valley of Colorado and is cut by the narrow steep-walled canyons of the Rio Grande and its tributaries, in which great thicknesses of basalt lava flows are exposed. A volcanic source of lava is exemplified admirably by Ute Peak, a large volcanic cone south of Jarosa; many other extinct volcanoes stand out conspicuously on the surrounding plains. The volcanic activity belongs to a geologically recent period, which, however, antedates any archaeological records. There is no evidence of basaltic lava flows in the mountains; hence, it is concluded that the mountains stood relatively high above the areas to the west when the lava was exuded from the volcanic vents.

Classification of Rocks in and Adjoining the Molybdenite Area

The U. S. Geological Survey geologic map of New Mexico shows this area to consist entirely of Tertiary volcanic rocks. However, the detailed study in Sulphur Gulch and the reconnaissance studies along the Red River from Red River post office to Questa showed the following rocks, beginning with the oldest: (1) Biotite schist and gneiss, quartzite schist, hornblende gneiss, and gneissic granite; (2) sedimentary rocks; (3) basic dikes and sills; (4) albite granite; and (5) volcanic rocks. The albite granite and volcanic rocks are undoubtedly the Tertiary volcanic rocks indicated on the New Mexico geologic map, but they do not occupy the entire area. Three isolated occurrences of albite granite were noted along the Red River, (1) a small stock in Sulphur Gulch, (2) a second smaller and dike-like body about two miles downstream, and (3) the largest, also a small stock, lies 3 to 5 miles downstream from Sulphur Gulch and 2 to 4 miles east of Questa. This third occurrence of albite granite does not extend far north of the Red River, but it continues at least 2 miles to the south and fully 2,500 feet above the river. The areas of volcanic rock seem to be more continuous than the albite granite.

The rocks which occur in the immediate vicinity of the mine have been grouped into a more simple and practical classification as follows: (1) Green rock; (2) albite granite called red rock; and (3) volcanic flows, tuffs and breccias. The "green rock" consists of schist, gneiss, sedimentary rocks, and basic dikes and sills—all chloritized. With the chlorite is considerable pyrite, and alteration processes tend to mask the true character of these rocks, which is therefore evident only outside the altered zone.

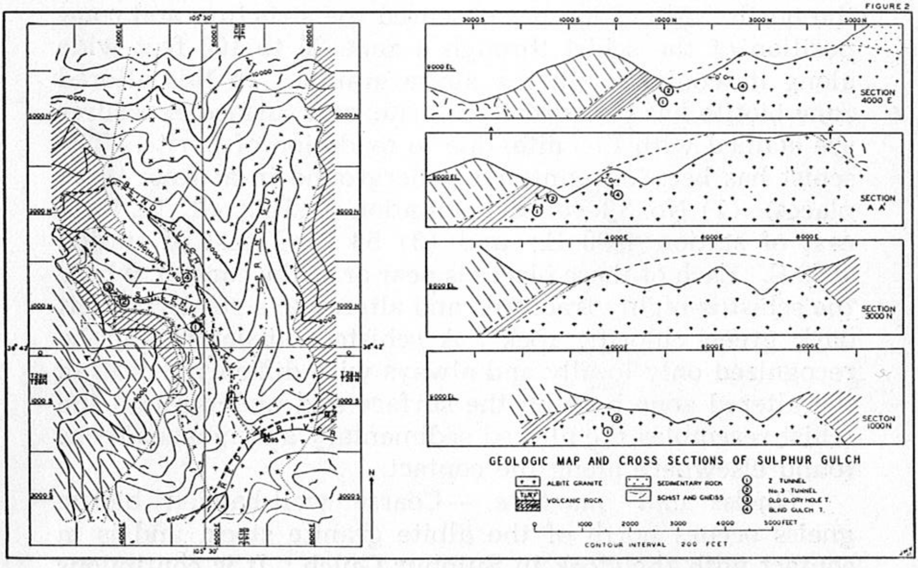

Fig. 2.—Geologic map of Sulphur Gulch (plan and cross sections).

The volcanic rocks are highly altered, generally to yellow clays which remain as conspicuous outcrops, and thus are distinguished readily from the other formations. Details of the plan of the stock of albite granite in Sulphur Gulch with the generalized geology surrounding the stock are shown in Figure 2.

SCHIST, GNEISS, QUARTZITE, AND GRANITE

Schist, gneiss, quartzite, and granite are the predominating surface rocks over large areas in the Sangre de Cristo Range. They are pre-Cambrian in age and in the molybdenite area represent the oldest rocks on which the sedimentary rocks were deposited, and into which younger igneous rocks have been intruded.

Schist.—Schist occupies only a small area both on the east and west sides of Sulphur Gulch where it is in contact with the albite granite. It consists chiefly of biotite and quartz with schistosity well developed and devoid of banding. Schistosity trends N. 50° to 60° E., with steep dips to the north. Alteration has obscured the structure and composition of the schist through a zone 25 to 100 feet wide along its contact with the albite granite. In this altered zone biotite has changed to chlorite, and surface exposures are stained with limonite, due to oxidation of pyrite. The schist has been encountered underground in at least three places: (1) No. 3 level east of station 4945 E.; (2) W. level east of station 4890 E.; and (3) 58 level east of station 4660 E. Each of these places is near or at the contact, where the schist is highly fractured and altered to a relatively soft dark green chloritic rock. A schistose structure can be recognized only locally and always with difficulty. Within the altered zone both on the surface and underground the schist resembles the altered sedimentary and igneous rocks found elsewhere along the contact.

Gneiss and quartzite.—Coarse well-banded biotite gneiss occurs north of the albite granite stock, and is in contact with the stock in Sulphur Gulch. It is continuous to the north across the divide into Cabresto Creek and apparently is a part of an extensive area of gneissic rock found in the valley of Cabresto Creek. Poor outcrops prevented satisfactory observations of strike, which seems to be north or northeast with nearly vertical dips. It is similar to the schist in composition except for an appreciable amount of feldspar in addition to the biotite and quartz. The actual contact of gneiss and albite granite is not exposed and the degree or character of alteration, if any, is concealed by the mantle of disintegrated and decomposed rocky soil.

A massive, relatively coarsely crystalline quartzite, almost devoid of structure and only locally showing the sugary texture diagnostic of quartzite, lies west of the hornfels and conglomerate, hereafter described, at the head of Sulphur Gulch. The rock is nearly pure quartz. In places muscovite has developed along fractures and locally a small amount of biotite gives the rock a faint schistose structure. Small and scattered lenses of biotite schist occur in the quartzite, indicating an intimate relationship between these older rocks. The lenses of schist strike northeast and dip steeply to the northwest, but the formation of quartzite as a whole strikes more nearly north or a little west of north with steep westerly dips. Similar rocks at the head of the Red River and to the south have been described as pre-Cambrian quartzite by Gruner.[8] The quartzite apparently is not closely affiliated in age to the other sedimentary rocks in the area. It is, therefore, grouped here with the pre-Cambrian, though some may question its age.

Coarse hornblende gneiss, in which hornblende and feldspar are the chief minerals, is in contact with the albite granite southeast of the mouth of Sulphur Gulch. Its extent, which was not determined, appears to be limited. No alteration of this rock was noted where it is in contact with the granite. The hornblende crystals, which are dark green in color and with faces measuring about 3mm by 4mm, are estimated to make up 60 to 80 per cent of the rock. The coarse texture and predominating dark color, set with

[8]Gruner, J. W., Geologic reconnaissance of the southern part of Taos Range, New Mexico: Jour. Geol., vol. 28, pp. 731-742, 1920.

scattered areas of white feldspar, distinguishes the hornblende gneiss from all other rocks in the area.

Gneissic rocks are found in a transition zone between the biotite schist and gneissic biotite granite on the slopes north of the Red River and west of Sulphur Gulch. These rocks seem to be phases of the schist. They have not been recognized in the mine workings.

Gneissic granite.—Gneissic granite is found southeast, south, and southwest of the area of albite granite in Sulphur Gulch. The gneissic structure is uniformly developed through alignment of the biotite folia which strike nearly east and dip vertical. Fractured surfaces parallel to the folia have the appearance of a massive biotite granite. Orthoclase and quartz make up the bulk of the rock.

The gneissic granite superficially resembles the albite granite. However, important differences are consistently present, of which the most important are: The gneissic granite is everywhere gneissic and never porphyritic, the feldspar is white, and large quartz grains are always conspicuous, whereas the albite granite-porphyry is never gneissic and commonly porphyritic, the feldspar generally is pink, and quartz though plentiful is relatively fine-grained and occurs either as a filling of interstices between feldspar grains or as distinct phenocrysts. In addition, the gneissic granite contains more biotite than the albite granite, a difference which is, however, less apparent than the other distinguishing features. Gneissic granite has not been encountered in the mine; it crops out well south of the present workings.

Sedimentary Rocks.—Sedimentary rocks are common about 4 miles south of the area on the high divides, as shown on the U. S. Geological Survey geologic map of New Mexico. They were not known to exist within the molybdenite area until outcrops were discovered in the course of this geologic study, in Sulphur Gulch and its tributaries, and along the road on the north side of the Red River about 2½ miles to the west of Sulphur Gulch. The full extent, structural relationships, and age of these sedimentary rocks are not clear from the meager outcrops observed. In both places the exposures are poor and often surface float is the only guide. Furthermore, the sedimentary rocks in Sulphur Gulch are highly metamorphosed so that many of the sedimentary characteristics are obscured.

In Sulphur Gulch the sedimentary rocks are conglomerate and hornfels. Quartzite was not found but much of the hornfels is sandy. Outcrops to the north are confined to a narrow belt that extends from near the Red River to the divide between the Red River and Cabresto Creek as shown on the geologic map (Fig. 2). An extension of these beds to the southwest is doubtful but a limit to the north was not established. The conglomerate consists of well-rounded pebbles of granite, schist, gneiss, and quartz averaging 2 to 6 inches across, resting on pre-Cambrian schist and gneiss. In places boulders 2 feet across were noted. The matrix is a feldspathic grit so thoroughly recrystallized and cemented to the pebbles that fractures along the boundaries of grains or pebbles are uncommon and pebbles rarely weather out intact. The rock as a whole is dark green to black, due to the chlorite, which is abundant both in the matrix and in all of the pebbles, except quartz. Hornfels, a metamorphosed shale, lies west and stratigraphically above the conglomerate. It is green to black, dense-grained, and except for a lack of phenocrysts, resembles certain igneous rocks. The boundary between conglomerate and hornfels is poorly defined and in places they are interbedded. These rocks are exposed in No. 3, W, and 58 levels of the mine west of the schist described on p. 610, and in No. 4 and 5 crosscuts of Z tunnel.

Sedimentary rocks unaltered by metamorphism were found exposed over a small area only on the north side of the Red River near the highway about 2½ miles west of Sulphur Gulch. They consist of conglomerate and red shale or mudstone, and strike northwest, dipping about 50° westerly. The composition of the conglomerate is similar to the conglomerate in Sulphur Gulch described above, and the question naturally arises whether these formations are equivalent. Such a correlation seems reasonable, but it must be remembered that the conglomerate and hornfels at the head of Sulphur Gulch may be related to the quartzite (presumably of pre-Cambrian age) found nearby and described in an earlier paragraph. Moreover, if they are related in age to the older rocks, they should exhibit at least some schistose structure, none of which was found. I am of the opinion that the conglomerate and shale or hornfels are not pre-Cambrian in age. This lack of schistose structure suggests a younger age, probably Carboniferous (Magdalena), as beds of this age and similar in composition are known to occur resting on pre-Cambrian formations on the higher ridges only a few miles to the south.

Basic Dikes and Sills

A detailed study of the dikes and sills common to the area was not made. They appear to vary in composition from diorite to granodiorite. Some diabase was recognized. The dikes and sills are quantitatively unimportant and have no close relationship to mineralization.

The dike and sills are invariably porphyritic. Rock regarded as diorite is nearly black, with inconspicuous phenocrysts of augite or hornblende. Granodiorite porphyry is easily recognized by its crystals or phenocrysts of white feldspar 2 to 4mm across, set in a dark gray groundmass in which quartz phenocrysts are entirely lacking. Larsen and Ross[9] have described the granodiorite in the mineralized area as follows:

> It is everywhere considerably altered. It is made up about half of stout crystals of plagioclase about a millimeter in length that are now changed to albite with much sericite, imbedded in a finer grained matrix of quartz and orthoclase. There is considerable chlorite and sulphides. Silicification has occurred throughout the rock and small bands are preserved where all the minerals composing it have been changed to a mass of interlocking quartz grains. Veinlets of calcite and pyrite are even more common than in the alaskite [albite granite].

Away from the mineralized area the general appearance of the granodiorite, except for a lack of alteration products, is the same.

[9]Larsen, E. S., and Ross, C. S., The R. and S. molybdenum mine, Taos County, New Mexico: Econ. Geology, vol. 15, No. 7, pp. 570-571, 1920.

The upper part of the slope on the north side of the Red River and east of the intrusion of albite granite shows the largest exposure of granodiorite porphyry. Here, this rock is in or under volcanic breccias as a relatively large sill; or, possibly a small stock. Elsewhere float is widely distributed but all the outcrops observed were dikes less than 20 feet wide. The distribution, extent, and plan of these dikes cannot be determined satisfactorily owing to the scarcity of outcrops.

A dike of diabase porphyry was observed on the north side of the Red River about 2 miles west of Sulphur Gulch. The rock is fine-grained, almost black, and contains numerous inconspicuous phenocrysts of hornblende. The laths of plagioclase are readily discernible by the reflections of light from cleavage faces on fresh fractured surfaces. Diabase porphyry in this area is much less common than granodiorite porphyry. Both are definitely older than the albite granite for they are intruded by it.

Volcanic Rocks

Rhyolitic tuffs, flows, and breccias cover several square miles both to the east and west of the area of molybdenite mineralization. The tuffs are highly altered and they form very conspicuous outcrops of light-gray and yellow clay on both sides of the Red River a few miles east of Sulphur Gulch. West of Sulphur Gulch the tuffs are confined to the north side of the Red River. One outcrop of altered tuff, visible for many miles from the west, occurs just east of Questa between Cabresto Creek and the Red River and serves as an effective beacon to mark the debouch of these streams from the mountains.

A detailed study of the lithology of these rocks was not made. Reconnaissance observations made of several slopes showed flow breccias, agglomerates, and tuffs. The flows are a dull-reddish color and in places contain an appreciable amount of black glass with well defined flow structure.

The alteration of these rocks is characteristic of mineral deposits formed near the surface and, although the tuffs show the greatest changes, some of the flow rocks and agglomerate are also highly altered. Examples are found of types of alteration common to both siliceous and more basic igneous rocks. Pyrite is abundant and chlorite is conspicuous in places. Some carbonates and sericite formed; and considerable silicification occurred. Spongy quartz, superficially resembling geyserite, is common in the tuff in the form of irregular masses and distinct veins, some of which have been prospected; they show a little green fluorite with minor amounts of sphalerite, galena, and chalcopyrite. Specularite is not uncommon and both gold and silver are reported. Gypsum is abundant, particularly in areas of altered tuff, and water draining such areas is bitter and unpalatable. Exposures of the altered volcanic rocks, due to the oxidation of pyrite, are somewhat similar in appearance to the area of molybdenite mineralization. Molybdenite, however, has not been found in any of the volcanic rocks.

The nature of these accumulations of volcanic rocks is not clear. Two possibilities are suggested: (1) Filling of old valleys as large as or larger than present valleys in the area, and (2) that these tuffs and flows are near and in part mark the craters or necks of ancient volcanoes; one area occurs at the head of Sulphur Gulch and extends westerly, and a second is located just west of the town of Red River and extends westerly to within a few miles of Sulphur Gulch. As a tentative conclusion, I favor the latter interpretation. This viewpoint is based on the character of rock alteration, which is a type common in or near volcanoes, and on the observation that alteration affected the solid rocks; had the tuffs alone been affected, alteration could have occurred before they were deposited in their present position. Another feature which I think adds proof to my tentative conclusion is the complete lack of bedding structure of the tuffs, in a vertical range aggregating over 2,500 feet. The flows also lack the characteristic tabular form, and flow lines dip as often steep as flat. Had this material been transported any appreciable distance lines of stratification should show and certainly in a few places the tabular form of flows should be well defined.

The inclusions in the flows and agglomerates are also of siliceous material. Larsen[10] has identified these rocks as quartz latite and andesite. The abundance of black glass in some of the flows indicates that they are rhyolite. In many places rhyolitic material appears to predominate over quartz latite and andesite but rock alteration, which occurred on a large scale, has so obscured the original features of the rocks over large areas that a reliable determination of the original composition cannot be made without much additional study.

Albite Granite

Three distinct areas of albite granite (exclusive of small dikes) have been recognized. A small stock crops out in Sulphur Gulch (see Fig. 2) where it is the host rock for the molybdenite. A second area occurs on the north side of the Red River valley 2 miles west of Sulphur Gulch, and a third, probably the largest of the three, lies 2 miles farther west in the vicinity of Bear Canyon. At Bear Canyon the granite does not extend far north of the Red River but to the south of the river it rises abruptly to altitudes fully 2,500 feet above the valley. This area is of interest because in numerous places on the west side of Bear Canyon and at a place locally known as "Steve's prospect" on the west flank of the intrusion, the granite contains white stringers of quartz, in some of which small, commercially unimportant concentrations of molybdenite show. Similar occurrences of molybdenite are common in Sulphur Gulch.

An outstanding feature of the albite granite is its variation in texture from a well crystallized rock to a porphyry, in which numerous crystals of orthoclase or quartz (or both) are set in a groundmass of fine-grained quartz and feldspar. The relation of these variations to the contact is not clear, but dikes away from the contact are invariably well defined porphyries. A second important feature is the

[10]Larsen, Esper S., and Ross, C. S., op. cit., p. 570.

lack of uniformity in the distribution of biotite, which, although generally present, is scarce or lacking in the finer grained phases of the rock. Pyrite is widely disseminated through the granite and there is some evidence that it is a product of alteration of biotite; if so, the original amount of biotite may have been appreciably greater than it is at present. Pinkish feldspars, orthoclase and albite, predominate, and quartz though less conspicuous is abundant. The rock was called soda-potash alaskite porphyry by Larsen and Ross[11] who described it as follows:

> The alaskite porphyry at the mine is a pale flesh pink rock of medium grain having phenocrysts with a maximum diameter of about 4mm. The following is the approximate mineral composition:

Quartz	32.00
Orthoclase	20.00
Albite	47.00
Magnetite	0.50
Chlorite	0.20

> Insignificant amounts of apatite and zircon were observed. This is a rather unusual granite in that felsic minerals form fully 99 per cent of the rock mass, and since it is composed almost entirely of quartz and alkalic feldspars it should be classed as an alaskite.

The absence of biotite is not general, and although the rock is an alaskite in places, the term is not applicable to all of the intrusions. In places the quantity of biotite is appreciable in amount and in Cabresto Creek as much as 5 to 10 per cent of biotite was noted. For this reason I believe it preferable to use the name albite granite for the intrusions as a whole, and alaskite as one of its phases. The alaskite is generally fine-grained and porphyritic, with pink feldspar and quartz phenocrysts in a fine-grained pinkish groundmass of quartz and albite. The granite and alaskite grade into each other and the finer-grained variety, alaskite, is not everywhere confined to the actual margin of the intrusion. In places well-crystallizezd granite is frozen to the "green" wall rock and even is found in small dikes in the wall rock near the contact. The outcrops of albite granite and alaskite in Sulphur Gulch are such, as will be brought out later, that most of the rock exposed is

[11] Op. cit., p. 569.

rather close to the margin of the intrusion—which may account for the apparent wide distribution of porphyry, or finer-grained rock. Dikes at a distance from the main intrusion invariably show a well-defined groundmass.

Several thin sections of the albite granite of Sulphur Gulch were examined and the essential minerals are orthoclase, albite, quartz, and biotite or chlorite, the chlorite being an alteration product of biotite. The grain size averages about 3 to 4mm across, but a small percentage of the grains are only about 1mm across, which is approximately the size of the grains of the groundmass of the porphyritic phase. Both orthoclase and albite are clouded by dust-like and unidentified inclusions developed by alteration. Sericite flakes are sparingly developed and are entirely absent in most of the thin sections.

Form of the albite granite stock in Sulphur Gulch.—The form of the intrusion of albite granite in Sulphur Gulch was studied in detail. Its relation to ore bodies that have already been mined is clear and it is hoped that a description of this relation may prove a guide to future exploration for more ore. A series of cross sections (see Fig. 2) showing the altitude of the contact were drawn along north and east coordinates of the geologic map of Sulphur Gulch. The available data give only a generalized plan of the surface of the stock of albite granite. Since the contact surface is intrusive in origin, its form cannot be projected any great distance with safety; and although the general form as shown in the cross sections is believed to be correct, local detail can be determined accurately only by further mine development.

Structure

No direct relationship between the regional structures and the molybdenite mineralization has been recognized. If any relationship does exist any attempt at interpretation is stopped by our lack of detailed knowledge of the regional structure. Time did not permit the study of this problem.

Some interesting data uncovered in the course of the study of local features, and a summary of the publications on the regional geology, which are few, are given here for whatever broad value they may have and a possible local value not yet appreciated.

Regional Structural Features

The structural features of the Sangre de Cristo Range in the vicinity of the Red River have not been described. Generalized sections of the range to the south and east of Taos as given by Darton[12] show a central uplift of several thousand feet. This uplift trends northerly or parallel to the main range and is cut both on its east and west flanks by steeply dipping faults producing a horst on a large scale. To the northwest of La Veta Pass in Colorado, large thrust and normal faults, resulting in complicated structures, are known. Intrusives are common in scattered areas throughout the range and vary in composition from basic to siliceous rocks. Faults and intrusions are a common geologic feature of the Sangre de Cristo Mountains.

Important faulting is in evidence in the vicinity of Sulphur Gulch. The attitude of the sedimentary rocks in Sulphur Gulch, tentatively correlated as Magdalena in age, indicates that there have been displacements of at least 2,500 and possibly 5,000 feet. The beds along the Red River west of Sulphur Gulch also indicate either (1) faults with large vertical displacements or (2) sharp folds with large vertical components. These features are probably related to the regional structures.

The elliptical intrusion of albite granite shows longer north-south axes than east-west axes and this condition is no doubt an expression of the principal north-trending structure of the Sangre de Cristo Range. Veins in the mine and dikes of alaskite porphyry, the schist, and the gneissic granite all trend nearly east-west.

[12] Darton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, p. 273, 1928.