U.M.

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by John Walter Gruner for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

W H Emmons
Chairman

F.H. MacDougall

Carl O Dunbar

_____________1918

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given John Walter Gruner final oral examination for the degree of Master of Science. We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

__________191

W H Emmons
Chairman

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Geologic Reconnaissance of the Southern Part of the Taos Range, New Mexico.

A Thesis Submitted to the Faculty of the Graduate School

of the

University of Minnesota

by

JOHN W. GRUNER

In partial fulfillment of the requirements for the degree

of

Master of Science.

1919.

Geologic Reconnaissance of the Southern Part of the Taos Range, New Mexico.

John W. Gruner.

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Geologic Reconnaissance of the Southern Part of the Taos Range, New Mexico.

Introduction and Location.

The Taos Range is a part of the Sangre de Cristo Range which is the southernmost chain of the Rocky Mountains and has a general north-south direction. Not more than about two fifths of the Sangre de Cristo Range extend into New Mexico. The larger portion, the Culebra Range and the Sierra Blanca, lies in southern Colorado. The Culebra Range is narrow, hardly exceeding 12 miles in width, where it crosses the boundary line into New Mexico. But here it splits into two great uplifts, the Taos Range and Cimarron Range, which find their continuation in the Mora Range and Las Vegas Range respectively. The Taos Range proper is about 30 to 35 miles long and has an average width of 15 miles. Its northern limit is Costilla Creek, its southern Pueblo Creek, or as sometimes stated, Ferdinand Creek. The latter boundary line is the better in the opinion of the writer, for reasons to be mentioned later.

In 1879 J. J. Stevenson explored a large portion of this region geologically[1/], but not the area to which this paper is limited.

1/ Stevenson, John J., Report upon geological examinations in Southern Colorado and Northern New Mexico, 1878-1879: Report U. S. Geog. S. west of the 100th Meridian, vol. 3, Supplement, 1881.

The inaccessibility of the country and its altitude must have been even more effective barriers then to any attempts to disentangle the minor geologic features of the Taos Range than they are today.

The region described in this report is situated in North Central New Mexico. Its northern limit lies 25 miles south of and parallel to the Colorado line. All of the area mapped is in Taos County with the exception of a few square miles along its eastern border that lie in Colfax County.

Physiography and Topography.[1/]

1/ The attached topographic map was made by the writer who used as basis a map compiled by the U. S. Land Office and the U. S. Forest Service, from which the location of the Rio Hondo as far as Twining, and of Pueblo Creek as far as the sharp bend were copied. The peak which is called Taos Peak by Stevenson, is generally referred to as Wheeler Peak now. The writer of this paper thought himself justified in adopting the following names for a number of topographic features in order to be able to describe the geology of the area with greater clearness. They are: Opal Peak, Fairview Mountain, Indian Creek, and Starvation Creek.

The southern part of the Taos Range, as seen from the Rio Grande Valley to the west of it, offers an imposing view. From an altitude of about 7,000 feet, the elevation of the valley above sea level, a number of peaks rise to snowy heights within a distance of a few miles. Pueblo Peak, with its pyramidal shape and heavily wooded slopes, is specially prominent at the southern end of the range, though the altitude of this peak (12,100 feet) is exceeded by that of four peaks northeast of it. (See topographic map.) These latter are closely grouped together and form the topographic center of the region from which many minor ridges and the principal streams branch out.

Wheeler Peak (13,250 feet), the highest and northernmost of the four peaks, and Old Mike (13,000 feet), one mile south of it, lie on the main range or axis which runs from the northern limit of the area mapped, southward through Bull of the Woods, Wheeler Peak, Old Mike, Lew Wallace Peak, Larkspur Point and Burned Ridge, to Pueblo Creek. Two to three miles to the east of the main range a much lower parallel range forms the divide between the Rio Grande and Mississippi drainage basins. The Red River Canyon and the upper Pueblo Canyon lie between the two ranges. The two canyons which run in opposite directions are separated by Red Dome, one mile east of Old Mike. From the latter a ridge extends also west to Lucero Peak, and still farther in that direction to Vallecito Peak. The latter is three miles distant from Old Mike. A chain of lower elevations also links Larkspur Point with Pueblo Peak, which lies four miles west of the latter. This ridge is the divide between the Lucero Creek and the lower Pueblo Creek.

The mountain front is deeply incised by the Pueblo Creek, Lucero Creek and Rio Hondo. These streams carry an abundant water supply during all seasons.

The Pueblo Creek, the longest of the three, originates south of Old Mike and Red Dome and flows five to six miles in a southerly direction. Near the southern border of the area mapped it turns sharply westward and keeps this trend to the mouth of the canyon south of Pueblo Peak. The Lucero Creek, which has its chief source on the southeast slope of Lucero Peak and emerges from the mountains just north of Pueblo Peak, is, in its lower course, roughly parallel to the Pueblo Creek, but being much shorter it has a steeper gradient than the latter. The Rio Hondo follows a similar direction between its two chief sources, the South Fork and Lake Fork, which come from the north sides of Vallecito Peak and Lucero Peak respectively. Below the junction of the South Fork, the Rio Hondo flows southwest and leaves the mountains three miles north of the mouth of the Lucero Canyon. The Red River (called "Colorado Creek" by Stevenson[1/]) which drains the east slope of Wheeler Peak,

1/ Op. cit.

has a northerly direction before it turns westward and breaks through the main chain of the mountains below Red River City, eight miles north of the northern limit of the area mapped. Only a few miles of the headwaters of the Red River are in this quadrangle.

On the east of the Taos Range the broad Moreno Valley, which has an elevation of 8,000 to 9,000 feet, separates the Taos Range from the Cimarron Range which is nearly as high. On this eastern slope of the range, water courses are rather scarce, a condition not surprising in the semi-arid mountains of the Southwest where precipitation on the west slopes exceeds that on the east slopes as a rule.

Where the angle of slope permitted the accumulation of soil, dense forests of spruce and fir cover the mountains to the timber line at an elevation of nearly 12,000 feet. Above this line the glacial amphitheaters that cluster about the highest peaks, give evidence of very recent powerful glacial erosion. A living glacier is described by Siebenthal only 50 miles farther north in Culebra Range at an elevation of 12,500 feet.[2/] Beautiful

2/ Siebenthal, C. E., Glaciation in the Sangre de Cristo Range, Colo.: Jour. Geology, vol. 15, 1907, pp. 15-22.

little lakes formed by the deposition of small terminal moraines across the upper canyons, add much to the distinctly Alpine scenery. For centuries the Pueblo Indians who live in their villages at the foot of Pueblo Peak, have made these mountains their hunting grounds. Few prospectors have visited this region, and no mines are operated there today. Stevenson was the first to write on the geology of the region.[1] Lindgren gives an account of the geology in the Rio Hondo Canyon.[2]

1/ Op. cit.
2/ Lindgren, W., and Graton, L. C., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, 1910, p. 83.

Descriptive Geology.

General Relations.

The Taos Range is built up of three great rock systems. The pre-Cambrian gneisses, schists, and granites constitute the basement and greater part of the core of the uplift. Upper Carboniferous strata of great thickness are turned up on the east and south side of the range, reaching up on its flanks to an altitude of 12,200 feet. These older systems are intruded by stocks and dikes of granite and rhyolite porphyry respectively. No Cretaceous formations were observed by the writer in Taos Range proper. The nearest outcrop was noticed at Elizabeth Town in the Moreno Valley, east of the area mapped. The structure of this valley has been called a "graben" by Lindgren.[3]

3/ Op. cit., p. 94.

Along the western slope of the mountains large alluvial fans spread over the plains toward the Rio Grande for a number of miles, where they are finally encroached upon by the basalt flows of the Rio Grande Valley. The Pueblo Creek, Lucero Creek, and Rio Hondo have eroded shallow valleys into the detritus fans, but where these streams, combined into one, as Taos Creek, enter the area of the basalt flows, a typical box canyon has been cut deeply into the underlying Tertiary sediments.

In Stevenson's report[1] the mountains north and west of

1/ Op. cit., pp. 41-42.

Pueblo Creek are assigned to the "Taos axis," those south and east of that creek to the "Mora axis." It was believed then that the Taos axis does not continue beyond the Pueblo Creek, but that a new one, the Mora axis, begins at the head of the Red River and runs southward, parallel to the Taos axis on the west, until the latter vanishes. No such structural division could be noticed by the writer between the Taos Range and Mora uplift south of it. The misconception was probably due to the belief that the Pennsylvanian strata exist also on the west side of the range.[2] The

2/ Op. cit., p. 42.

sedimentary outliers on the main range, to be described later, when viewed from the distance, easily give such an impression. No new axis begins in this district, but the Taos axis pitches steeply toward the south and the pre-Cambrian rocks disappear at the junction of the Pueblo Creek and the Indian Creek beneath the Pennsylvanian strata which form here an uninterrupted anticline across the range.

In the region mapped this anticlinal structure is absent. No Pennsylvanian sediments were found on the western slope north of Pueblo Creek. The mountains present a bold fault scarp facing west. Whether sedimentary rocks of Pennsylvanian age underlie the thick debris fans and basalt flows, or not, is unknown at the present time. But farther north, in Colorado, Siebenthal mentions their occurrence on the west side of Culebra Peak, and the anticlinal structure of the Sangre de Cristo Range at that latitude.[3]

3/ Siebenthal, C. E., Geology and water resources of the San Luis Valley, Colo.: U. S. Geol. Survey Water Supply Paper 240, p. 34, 1907.

Stratigraphy.

Pre-Cambrian Crystalline Rocks.

In the following lines an attempt will be made to describe the occurrence and character of the pre-Cambrian crystalline rocks. Their structure and exact sequence could not be worked out in the short time that was at the disposal of the writer. The most ancient rocks are amphibolite and chlorite schists and gneisses that grade into greenstone in places. Granitic gneisses occupy a rather obscure position with respect to the more basic varieties, and may, in some cases, be of the same age as the batholithic granites underlying the older schists. In one instance, on Old Mike, this relationship was proved. Here the gneiss could be traced to its parent rock, the granite beneath. The latter is a part of the great batholith which forms the core of the mountains. It is intrusive into the ancient schists and gneisses. Flanking and abutting against the gneisses and granites, quartzites and schists, undoubtedly of sedimentary origin, are found. (See figure 1) Judging from their attitude and advanced stage of metamorphism, they are probably older than the batholithic granite. Unfortunately no contact between the two was seen. A number of basic dikes intrude the granite of the batholith and are most likely the youngest pre-Cambrian rocks of the region.

Ancient Schists and Gneisses.

These "oldest" rocks (probably Archean) cover the larger portion of the northwestern half of the area mapped. They form an almost continuous outcrop along the western scarp of the range and cap all of the higher peaks with the exception of Old Mike.

Gneiss on Pueblo Peak and its western slope.

The top and western slope of Pueblo Peak, as far as they could be examined, consist chiefly of gneiss that has a very steep northwesterly dip.

Petrography: Though rather dark in color, as a whole, it is an acid granitic gneiss. Its texture is dense and medium/to fine-grained. The arrangement of the minerals in bands is distinct. Under the microscope all the larger grains are anhedral. Pink orthoclase, often twinned on the Carlsbad law, predominates, though granulated quartz is present in nearly as large a proportion. Some of the feldspar grains are shattered and their fragments strung out parallel to the banding of the rock. Oligoclase, in somewhat smaller crystals, is not uncommon. All the other constituents are finely granular and form aggregates of quartz, sericite, biotite, and some chlorite. Epidote, calcite, and apatite occur in small amounts. Magnetite is almost absent. The shattered appearance of many large feldspar crystals leads to the conclusion that they are primary, whereas the other constituents probably represent a recrystallization product.

Gneiss at the mouth of the Lucero Canyon.

North of Pueblo Peak, from the mouth of Lucero Creek to a point about half a mile upstream, a light yellow gneiss is exposed on both sides of the very narrow steep-walled canyon. It rests upon younger pink granite as may be observed by following Lucero Creek upstream. The contact between the two rocks is concealed. No schist is found in this locality associated with the gneiss. The possibility that the latter is a marginal gneissoid phase of the younger batholithic granite must be admitted.

Petrography: This crystalline may be appropriately called granitic gneiss. Medium-grained in texture, it shows an arrangement of the minerals in indistinct bands. Its yellow color is due to microscopic dust which seems to penetrate most of the grains. Microscopic examination reveals an aggregate of well interlocked, inequigranular crystals of quartz, oligoclase, and orthoclase. The two latter are present in about equal amounts. The orthoclase is not twinned. Green biotite and epidote are not sufficiently abundant to be called essential minerals. From their concentration in narrow subparallel bands composed of very small interlocked flakes and grains with occasional subhedral titanite crystals, their secondary origin may be inferred. Numerous oligoclase grains are "faulted" across the twinning lamellae, but otherwise show no alteration. The larger quartz grains exhibit undulatory extinction and many liquid inclusions.

Gneisses and schists in the Rio Hondo canyon.

The gneiss just described continues to outcrop along the western slope of the range, as far as the northern limit of the district, in a belt that reaches a width of one mile in the Rio Hondo Canyon. The dip gradually decreases toward the north and does not exceed 20° on the north bank of the Rio Hondo. Here layers of dark amphibolite alternate with benches of this same light yellow gneiss, the formation as a whole dipping 20°S. 60°W. The thickness of the layers varies greatly, and often they assume the character of narrow amphibolite dikes in the gneiss. The contact is sharp and often remarkably straight. Vein-like intrusions from the younger granite batholith beneath into these gneisses and schists are numerous. They are usually pegmatitic in texture and composition and vary in width from a fraction of an inch to several feet. The amphibolite resembles in texture a schist, in some places, a gneiss in others. Following the Rio Hondo upstream, one passes through an area of granite about three miles wide. At South Fork amphibolite reappears to be replaced again by granite a short distance above South Fork. At Almozzet (Amizett) amphibolite takes again the place of granite and continues to outcrop across the main range east of Twining. Intrusions of light gray granite are so numerous and of such dimensions, especially in the vicinity of Twining, that it becomes difficult to decide which of the rocks predominates in this particular locality. The following is a description of an intermediate textural variety of the amphibolite.

Petrography: As may easily be seen in the hand specimen, this even-grained, dark gray gneiss is chiefly composed of small, evenly sized hornblende needles and shorter, white feldspar crystals. Though there exists a distinct subparallel orientation in the minerals, especially the hornblende, the thin rows of the latter alternating with others of feldspar are too narrow to appear as bands to the naked eye. In the thin section about half of the rock consists of green, strongly pleochroic hornblende (Z blue green, Y yellow green, X yellow). Twinning is very common, and inclusions of rounded minute quartz (the only quartz present) and of feldspar are very numerous in the hornblende. Andesine is dominant among the feldspars. Only a few crystals of a somewhat more acid plagioclase are present. Carlsbad twins are frequently observed besides the universal polysynthetic twinning. Inclusions of hornblende in the plagioclase are not uncommon. Apatite and zircon grains (without halos) are scattered through the rock, especially the hornblende. Titanite in characteristic diamond-shaped crystals is observed along the edges and in the hornblende. The latter shows some incipient alteration to chlorite, and the feldspars to sericite and kaolin.

Gneisses and schists of Vallecito Peak.

The drainage basins of the Lake Fort and South Fork, with the exception of a narrow ridge that separates the former from the Lucero Creek, are almost entirely covered by ancient metamorphic rocks. Vallecito Peak is capped by gray-green gneiss which becomes so fine grained and fissile in places that it must be called schist. The sheeting of it, with a dip of 50° to 60° N.15°W., is well shown in Plate I, A. which also illustrates the imposing pyramid crowning the peak, a topographical feature of value as a prominent landmark. The rock specimen described below comes from the south side of the pyramid and is typical for this area.

Petrography: This rock in the hand specimen is of greenish gray color and has a distinct gneissoid structure. As a whole it is fine grained. The bands consist of rows of hornblende alternating with quartz and feldspar. Veinlets of epidote traverse the rock in various directions. Minute quartz veins are also noticeable. Under the microscope feldspars, hornblende, quartz, and epidote are recognized as essential minerals. The feldspars, constituting probably 40 per cent of the rock, admit of no detailed study because their grains are so minute and clouded that only two or three were found that show indistinct polysynthetic twinning (probably oligoclase). The quartz crystals are also microscopic in size, granulated as a rule, but occasionally a band of larger, interlocked anhedra, parallel to the rock cleavage may be observed. The green hornblende needles are largest. Many are twinned and contain numerous inclusions of feldspar, epidote, and magnetite. The latter, as well as apatite grains, are relatively abundant. Epidote is sprinkled through the rock in minute subhedral crystals, besides its occurrence in fissures described above. In the latter it is accompanied by chlorite. Zircon in minute euhedral grains is scattered through the slide. Sharply defined quartz bands are bordered by broad zones of feldspar on each side, and these in turn by rows of subparallel hornblende needles which make up one fourth of the rock at least.

Gneisses and schists between the South Fork and Lake Fork.

A narrow ridge of the gneiss just described connects Vallecito Peak with the chain of mountains which lies between the South Fork and Lake Fork. From Lucero Peak, at the southern end of the chain, to Fairview Mountain, amphibolite schists and greenstone outcrop. Sheeting of the rocks is very prominent. Their dip is very steep and has a general northerly or northwesterly trend. In some places distinct sheeting at right angles to the first has resulted in the formation of huge columns, parallel to the dip.

South of Lucero Peak the schist is in contact with pink granite of the great batholith. Vein-like intrusions along fissures and planes of foliation from the latter are almost universal in this locality, as a matter of fact in the whole region. This intrusive process has affected the lower members of the overlying ancient crystallines everywhere, and the number and size of the granitic and pegmatitic intrusions offer a criterion for the estimation of the thickness of the overlying gneisses and schists. From the relatively broad top of Lucero Peak the chain contracts in several places to extremely narrow serrate ridges. Near Fairview Mountain the crest descends several hundred feet and widens considerably. The schist outcropping here is very dark green and massive. On the north slope of Fairview Mountain the rock loses some of its schistosity and becomes a banded gneiss. The contact between the light and dark, relatively broad bands is very sharp, but the cleavage in this direction is poor. In the depression between this slope and the "hills" which form the northward continuation of the ridge toward Almozzet and consist also of amphibolite schists and gneisses,a pink gneissoid granite outcrops. It is probably a part of the granitic batholith. The schist on Fairview Mountain is typical for this area and therefore will be described.

Petrography: This rock is very fine-grained and hard. The well developed schistosity as observed in the field is hardly less conspicuous in the hand specimen. Microscopically the rock is seen to contain about 50 per cent of green hornblende crystals. These, like all the other minerals, are anhedral in outline and never twinned. They are larger than the feldspars and the rather uncommon quartz grains which fill the interstices. The minute feldspar grains show no twinning except in two particles in the slide. The feldspar is basic, judging from their extinction angle. Epidote crystals covered with a thin white film (leucoxene?) are scattered through the section. Minute biotite scales are also common. Relatively little magnetite and some zircon grains, the latter in minute prisms, are present. The hornblende needles are arranged in distinct bands with their longer axes subparallel to the rock cleavage.

Gneisses and schists between Bull of the Woods and Wheeler Peak.

The occurrence of amphibolite schists at Twining and upon the main range above this camp has been mentioned under the heading "Gneisses and schists in the Rio Hondo Canyon." Amphibolite and greenstone form also prominent exposures on the east side of the Lake Fork, from Bull of the Woods southward to Wheeler Peak. A large area of gneiss lies midway between these two mountains. But this rock is much less basic than the amphibolite and corresponds in composition to quartz-diorite or monzonite. It is medium-grained in texture and of gray green color. The banding is distinct. A number of granitic intrusions in this rock establish its age as greater than that of the batholith.

Approaching Wheeler Peak from the area just described, an outcrop, half a mile wide, of granite is crossed. The latter disappears under the ancient rocks of Wheeler Peak about half a mile north of this peak. From here to the divide, between Lake Fork and Lucero Creek, chlorite-biotite schist, a very hard and resistant rock, caps Wheeler Peak, the highest mountain of the whole Taos Range. The schist has a steep, nearly vertical, dip toward the north.

Petrography: The color of this rock is greenish gray. The crystalline is very fine-grained in texture and shows distinct schistosity, but due to its massiveness it does not cleave readily. The essential minerals are labradorite, biotite, and chlorite. Labradorite constitutes about 50 to 60 per cent of the rock. It occurs in very small crystals that show in the majority of the grains elongation and polysynthetic twinning subparallel to the rock cleavage. The brown biotite and its alteration product, chlorite, are intimately interlocked in the shape of relatively long flakes of biotite alternating with chlorite, some of which seems to be still in an intermediate stage of alteration, judging from its optical anomalies. Both minerals have their cleavage parallel to the schistosity of the rock. Numerous epidote grains are scattered through the specimen. Magnetite and apatite grains are common. Sericite occurs only as a secondary mineral in a few labradorite crystals.

Schists and greenstone between the Salazar Canyon and Lucero Canyon.

The plateau south of Lucero Peak, between the Salazar and Lucero Canyons, is covered with a dark green schist and greenstone that is probably equivalent in age to the schist on Wheeler Peak. A "sheet" at least 200 to 300 feet thick, of dark schistose rock overlies the granitic batholith. Though close inspection of the nearly perpendicular walls of the sheet is impossible, ramifying dikes and sills from the granite beneath can easily be seen in it from some distance. The rock described below is typical for the western margin of the outcrop. It is a hornblendite.

Petrography: In the hand specimen this rock is very dark green, nearly black, and has a distinct, but rather uneven and rough cleavage. It is very fine and even grained. Epidote and quartz veinlets, as a rule parallel to the schistosity, are frequently observed in the field. In the thin section the rock is seen to consist of 60 to 70 per cent of needle-shaped hornblende, 15 to 20 per cent epidote, filling the interstices between the latter, and 5 to 10 per cent magnetite, the grains of which are often strung out in bands through the rock without definite orientation. The hornblende is very strongly pleochroic (Z blue green, Y yellowish green, X light yellow). Some crystals show twinning, others wavy extinction. Orientation parallel to the rock cleavage is not very pronounced. Epidote, colorless in the thin section, fills the spaces between the hornblende needles. Apatite is relatively abundant. Zircon in minute characteristic crystals occurs in the hornblende.

Altered diabase between Lew Wallace Peak and Old Mike.

Just north of Lew Wallace Peak and separated from it by a minor depression lies a relatively small mass of an altered diabase. Resting on and intruded by the batholith, this outcrop resembles the remnant of an ancient flow. No cleavage or regular sheeting is observed in it. Whether this rock bears any genetic relation to the sheet just described, on the opposite side of Lucero Canyon, or not, could not be determined.

Petrography: Macroscopically this rock shows a very fine-grained, dense texture, greenish gray color, and numerous calcite veinlets. Under the microscope it is seen to consist chiefly of andesine, hornblende, quartz, and epidote. The andesine occurs in very small grains and a few larger anhedra. Besides polysynthetic twinning, Carlsbad twins are common. The larger crystals are full of very small rounded quartz, hornblende, and apatite inclusions. The green, very small hornblende needles are strongly pleochroic, and without parallel orientation, but often "bunched" together. Some of them have undergone alteration to chlorite. Minute epidote, magnetite, apatite, and zircon grains, named in the order of their abundance, are scattered through the rock. The dark minerals compose about one third of the diabase. Very small quartz grains fill the interstices between the feldspars. Hydrothermal alteration was probably a strong factor in the alteration of this rock.

Nowhere in the ancient rocks described above, were any close folds or signs of distortion and twisting seen, as might be expected in schists, and as were actually observed in the metamorphosed sedimentary rocks.

Metamorphosed Sedimentary Rocks.

The metamorphosed pre-Cambrian sediments were probably derived from the ancient schists and gneisses. They occupy belts of greatly varying width between the Pennsylvanian series, on the southeast, and the granite batholith, on the northwest. The assumption that the batholithic granites are younger than the metamorphosed sediments is based upon the attitude of these formations. No contact was seen in the field. The formations are chiefly composed of quartzites and quartz and chlorite schists.

Quartzite between the main range and Pueblo Creek.

The area of quartzite - the latter will be called Pueblo quartzite hereafter - as outlined on the map, claims accuracy only along the western margin where it is overlain by Pennsylvanian outliers. The eastern limit could only be estimated. Therefore the outcrop may be considerably narrower. The region is extremely rough and difficult of access below the timber line. The dip of the quartzite is steeply eastward, varying from 45° to 90°. The strike is N.15°E. Jointing at right angles to the beds is the rule. Plate I,B shows a nearly perpendicular exposure of quartzite, 300 feet high, northeast of Ben Hur Lake. Glaciers have cut precipitous gorges into the layers of the quartzite here, at Blue Lake, and Sacred Lake. No trace of the bedding of the original sandstone was detected, perhaps due to the possible identity of the original bedding and the sheeting. The attitude and character of the quartzite strongly suggests this possibility to the writer. The layers as they exist today, are of variable width. Some are thin and split into slabs, others are thick and massive. The color of the formation as a whole, is yellow, but the southern end of it becomes reddish and purplish gray.

Petrography: Without the field evidence the origin of this quartzite could hardly be established with certainty. In color the rock varies from pale pink to gray and yellowish white. Microscopically the almost pure quartzite reveals a holocrystalline medium-grained texture. The size of the grains averages 0.75 mm. in length, their width varying from one third to one half of their length. All grains are arranged with their long diameter parallel to the rock cleavage. (See figure 2). This feature in connection with universal wavy extinction, is very striking. The large grains are well interlocked, as a rule, but occasionally bands of minute granular quartz with a few flakes of sericite and epidote fill the interstices between some of the grains which show very many liquid inclusions, arranged in thin lines of no definite direction. A little hematite dust is scattered through the quartzite.

Quartz and chlorite schists between Sacred Lake and the Starvation Creek.

Southeast of Sacred Lake the very steeply dipping quartzite overlies a very much folded and twisted, thinly laminated chlorite schist. The foliation of the latter, as a whole, is parallel to that of the quartzite. The slightly westward dipping Pennsylvanian outlier mentioned on a previous page overlies and conceals the schist on the west, leaving only a very narrow outcrop of a few feet for examination. What appears to be a continuation of the quartzite and schist is seen half a mile southwest of this locality, just below Larkspur point. Here steeply tilted schist forms a cliff of conspicuous silver gray color. Strike and dip of the sheeting is very similar to that of the quartzite. This rock is of gray color and rather soft. Its schistosity is well developed. Under the microscope it is seen to consist of very small grains and flakes of chlorite, epidote, acid feldspar, and quartz. It may properly be called a chlorite epidote schist. Evidence of hydrothermal alteration is particularly strong in this rock.

Another outcrop of quartz-schist is just southwest of Larkspur Point. The position of the beds could not be determined here. Southwest of Pueblo Peak, just north of the limit of the Pennsylvanian sediments, steeply inclined quartz-schist forms sharp craggy outcrops and cliffs. The dip is about 80° in a northerly direction. The formation flanks the Pueblo Peak parallel to the fault line for an unknown distance toward the west.

Petrography: In the hand specimen this green gray rock, with silky luster, shows excellent cleavage. It is very fine and even grained and of great hardness, due to the quartz that makes up most of the schist. The parallelism of the elongated quartz grains to the rock cleavage is conspicuous. Minute liquid inclusions, some with gas bubbles, abound in them. Occasionally a grain of feldspar, recognized by its twinning, is found among the quartz. Very numerous flakes of sericite parallel to the schistosity lend the luster to the rock. In the hand specimen patches of chlorite flakes, a quarter of an inch in diameter, are common and give a mottled appearance to the schist. Grains of apatite, magnetite, and flaky hematite are scattered through it and show a particular affinity for the chlorite patches.

Intrusive Granites.

The distribution and composition of the granites suggest a close genetic connection between the individual areas. It is highly probable that all belong to one great batholith which arched up the overlying formations and metamorphosed the sediments.

Granite in the Rio Hondo Canyon.

One of the best exposures of this batholith is along the Rio Hondo. Between a point about one mile from the mouth of the canyon, to South Fork, and also west of Almozzet for a distance of about two miles, a light gray biotite granite outcrops. It weathers easily and forms curiously shaped columns and pinnacles in some places. The specimen described comes from a point near Almozzet. Petrography: This granite has a light gray color and is exceedingly coarse in texture. Feldspar crystals, several inches in diameter, are common. The constituents as seen under the microscope are orthoclase, quartz, oligoclase, biotite, magnetite, titanite, and apatite and their alteration products sericite, chlorite, epidote, and kaolin. The two feldspars are occasionally intergrown. Zonal structure is common especially in the euhedral crystals. The anhedral quartz grains show very many lines of liquid inclusions. Extinction is mottled and wavy in numerous grains. Granular quartz and feldspar fill interstices and fissures. The biotite is a very dark brown variety constituting about 5 per cent of the granite. Its grains are relatively small, distorted, and bent, and partly altered to chlorite. The latter is pseudomorphic after biotite. Magnetite and apatite grains of relatively large size are common.

Granite and primary gneiss in the Lucero Canyon, Salazar Canyon, and on Old Mike.

Along Lucero Creek, from a point about half a mile east of the mouth of the canyon, to the foot of Old Mike a pinkish, more or less gneissoid granite outcrops. The latter is also the predominant rock in the Salazar Canyon, and from here a belt of it passes south of Lucero Peak along the serrated divide which lies between Lucero Creek and Lake Fork, and is wholly composed of granite to Old Mike. The sheeting of the rock has a N.-E. strike and nearly vertical dip. In composition the granite is very similar to that in Rio Hondo Canyon, but it is not so coarse grained. The orthoclase and microcline crystals are pink. Metamorphism has been extensive, because much of the quartz is granular and has wavy extinction, and nearly all of the biotite has been altered to chlorite.

The rocks from Old Mike and Red Dome show every gradation from a typical granitic gneiss to a biotite granite. A characteristic which rocks from this vicinity exhibit is extensive hydrothermal alteration. Red Dome, as the name implies, is red in color, due to a gossan that covers the granitic core of the mountain. East of the latter the granite abuts against the Pennsylvanian sediments, west of it it changes gradually into granitic gneiss which caps the very top of Old Mike. Its sheeting has a N.-E. strike and a steep southeasterly dip, corresponding somewhat to that of the Pueblo quartzite on the downthrown side of the same fault.

Petrography of Old Mike gneiss: This is the metamorphic product of the underlying granite. Macroscopically it shows indistinct banding. It is red in color like all rocks between Red Dome and Old Mike, and medium grained. The color is due to many veinlets of hematite penetrating the rock along fissures and cleavage planes. Microscopic examination shows large anhedra of feldspar surrounded by finely granular aggregates of quartz, chlorite, sericite, muscovite, calcite, and hematite. Untwinned orthoclase predominates, but microcline is common, and oligoclase is present in small amounts. Apatite is seen in the section, but no biotite or magnetite. Leucoxene, probably the alteration product from ilmenite, occurs as a yellowish aggregate in one or two places in the slide.

Granite on the Red River.

Medium-grained biotite granite varying in color from pink to greenish gray, also covers a large part of the Red River Canyon, especially on the west side. A detailed examination was impossible in this part of the district for reasons already mentioned.

Granite south of Larkspur Point.

Half a mile west of Larkspur point pink granite outcrops on the steep slope above Indian Creek, and also on the opposite side of the ridge above Lucero Creek. South of Larkspur point the continuation of this outcrop is found in contact with remnants of ancient schist that caps a part of Larkspur point. Farther toward the southeast the gneissoid granite is exposed along the northeastern tributary of Pueblo Creek, for a distance of two and a half to three miles.

Petrography: This pink granite is medium to coarse grained and very hard. Microcline is the predominant feldspar, but polysynthetically twinned anhedral oligoclase crystals are common. The quartz crystals are somewhat smaller than the feldspars and have numerous liquid inclusions and wavy extinction. Much smaller biotite flakes occur between the large anhedra, together with granular quartz chlorite, calcite, and epidote aggregates. Apatite, some magnetite, and a few zircon grains are scattered through the rock. A number of feldspar crystals are bent and show also signs of hydrothermal alteration.

Basic Dikes.

A number of basic dikes are intrusive into the granite of the batholith. Their age is probably pre-Cambrian. The most prominent one occurs just east of the highest point of Pueblo Peak and has a width of 100 to 150 feet. Its trend corresponds to that of the others, which have a NW-SE direction. In composition and texture it approaches a gabbro. In the northwest wall of Salazar Canyon south of Vallecito Peak, a dike similar in all respects is found. Another one of much finer grained basic material outcrops west of Old Mike. Its attitude could not be determined with any degree of certainty.

Unclassified pre-Cambrian Rocks.

Two pre-Cambrian inliers outcrop on the Pueblo Creek. The larger one lies between Burned Ridge, on the east, the Indian Creek, on the north, and the Pueblo Canyon, on the south. A fault, probably of small displacement, delimits the outlier on the east. Quartz and mica schists, and some amphibolite, are the only rocks which came under the writer's observation. They are probably of sedimentary origin. The rocks have a northerly strike and a very steep westward dip.

The other inlier, much smaller in area, outcrops two miles west of the junction of the Pueblo and Indian Creek. It is composed of similar schists. Their attitude could not be determined. Pennsylvanian limestone overlies these latter metamorphics.

Carboniferous Sedimentary Rocks.

Pennsylvanian Series.

General character.

In the district mapped all sedimentary consolidated rocks belong to the Pennsylvanian series. Stevenson[1/] described them as

1/ Op. cit.

Carboniferous, attempting no further divisions ~~then~~. Later writers, especially W. T. Lee,[2/] who examined parts of this series farther

2/ Lee, W. T., Geology and paleontology of Raton Mesa and other regions in Colorado and New Mexico: Prof. Paper 101, 1918, pp.41-42 east and north, recognized them as belonging to the Pennsylvanian series only. A number of fossils, collected by the ~~present~~ writer near the base of the sedimentary series, belong to the Pennsylvanian fauna. Six species were identified: Lopophyllum profundum, Siminula subtilita, Spirifer cameratus, Spirifer rockymontanus, Productus cora, Productus semireticulatus.

No generalizations concerning the thicknesses and divisions of the series can be given in this paper with the exception of the statement that by far the larger portion of the beds are composed of clastic material, and that the Pennsylvanian rests unconformably upon the pre-Cambrian rocks in all places examined. The lowest member is usually a basal conglomerate grading into a sandstone, but in some localities limestone overlies directly the pre-Cambrian, and the sequence is reversed. It is very common to see a limestone in sharp contact with a coarse clastic in some places. On the other hand, formations hundreds of feet thick are found in which the transitions from one member into another are very gradual. Lithologically very similar beds of clastic material occur at many different horizons of the series and some of them are of such thickness that even considerable displacements by faults may be easily overlooked. The fact that all the faults seen by the writer in the sediments are normal, and that evidence of folding due to lateral compression is absent, seems to indicate that the Taos Range, if not the whole Sangre de Cristo Range, was formed solely by intrusive activity, probably in early Tertiary time.

Distribution of the sediments.

The sedimentary rocks cover portions of the Pueblo Creek and Red River drainage basins, and extend far beyond the southern and eastern margin of the area mapped. While the thickness of the formations may be estimated at several thousand feet, at least 2,500 feet in the southeast corner of the district, erosion has reduced the thickness of the sediments toward the northwest to less than 300 feet above Sacred Lake.

Pueblo Creek basin.

The contact of the sediments with the pre-Cambrian rocks follows approximately a line from the southwest corner of the quadrangle to a point on Starvation Creek, about one mile south of Pueblo Peak. A normal fault of unknown displacement, probably relatively small, has sharply upturned the sandstones and limestones against quartz-chlorite schists west of Starvation Creek. A few hundred feet downstream the formation begins at the bottom of the creek with 100± feet of dense gray non-fossiliferous limestone, the base of which is not exposed. The limestone is traversed by numerous white calcite veinlets. On it rests a dense sandstone that is brownish red when weathered. Since this rock caps most of the ridges and is of great thickness, it deserves special attention. It will be referred to as Burned Ridge sandstone hereafter, for it is very well exposed over the greater part of that ridge.

Petrography of Burned Ridge sandstone: This sandstone is very dense and massive, of brownish gray-green color and rather fine grained. It is an arkose sandstone. In the thin section the quartz and feldspar grains are seen to be angular to subangular in shape, of even size, and the quartz grains make up about 80 to 85 per cent of the rock. They are so well interlocked that secondary growth of the quartz has undoubtedly taken place, though the original outlines of the grains can not be detected. Perhaps 10 to 20 per cent of the rock is relatively fresh orthoclase and acid plagioclase, the latter being recognized by its sharp twinning lamellae. A few very small biotite flakes are scattered through the rock. The cement to which the color of the rock is due consists of microscopic aggregates of chlorite, kaolin, hematite, and sericite. The chlorite predominates in the cement.

The dip of the strata on Starvation Creek is 20° to 30° S. 20° W., decreasing rapidly toward Pueblo Creek where it does not exceed 10°.

In the low saddle, midway between Pueblo Peak and Larkspur Point, the same Burned Ridge sandstone outcrops. Its dip is 20° to 25° S. 15° E. While its thickness could not be determined here it probably is not great, judging from its position between the pre-Cambrian formations and the absence of synclinal structure. On the high ridge east from this exposure, toward Larkspur Point, two outliers of the Pennsylvanian are found. Here about 30 feet of gray non-fossiliferous limestone rest on pink pre-Cambrian granite. The limestone is overlain by a greenish gray calcareous grit which will be named Burned Ridge grit, and its composition described in detail, for it is of wide extent and great thickness, not only in this district but beyond its limits. At certain horizons this grit is replete with fossil fragments, especially well preserved crinoid stems.

Petrography of Burned Ridge grit: This calcareous grit is medium to coarse grained, greenish in color on a fresh surface and weathers to a reddish brown. Under the microscope a surprisingly large amount of calcite cement, perhaps 25 to 30 per cent, is observed. The imbedded grains vary in size, averaging about 1.0 mm. in diameter. They are all angular. Quartz grains are abundant, but feldspar grains are almost as common. They are fresh and by their twinning readily recognized as orthoclase, microcline, and acid plagioclase in nearly equal proportions. A few microperthite grains are also present. Besides the ordinary quartz grains which often exhibit wavy extinction, fragments of gneiss consisting of finely granulated quartz are abundant. They remove any doubt as to the origin of the grit from the pre-Cambrian crystallines. The grains have been deposited with their long diameters parallel to the bedding planes of the strata. The cement is calcite with only a little chlorite, kaolin, and sericite.

The Burned Ridge grit of the above outliers becomes gradually coarser toward the top of the formation and changes to a conglomerate which contains subangular pebbles of quartz, gneiss, granite, and schist, named in the order of their abundance. They do not exceed a diameter of one inch, but attain greater dimensions on Burned Ridge. The cement in which they are imbedded consists of calcareous grit identical in composition and texture with the one just described. Even in this coarse material fragments of fossils are abundant in places.

About one mile south of Larkspur Point, where the strata rest on pink granite, the beds dip steeply southward. The basal conglomerate, clearly derived from the pre-Cambrian rocks beneath, grades into a sandstone. The latter is overlain by 20 to 30 feet of gray massive limestone. Upon this bed lie the typical Burned Ridge sandstones, grits, and conglomerates. They are of great thickness and constitute no definite,sharply separated members. Conglomerates may occur at any horizon in this formation, but they are found usually between the grits. A bed of blue fossiliferous limestone, eight feet thick, outcrops within the grits on Burned Ridge, one and one half miles due south of Larkspur Point. Here the strike of the beds has swung from the original E-W direction to a NW-SE trend, the dip being steeply southwest. This attitude in connection with the dip of this formation in the opposite direction on the southwest slope of Burned Ridge, near a point where a fault(?) crosses Meyer's Creek, indicates a synclinal structure whose axis runs at right angles to Burned Ridge and pitches southeast. To the northeast of Burned Ridge, between Larkspur Point and the Pueblo Creek, the sediments have been eroded, exposing red pre-Cambrian granite beneath. The line of contact could not be followed on account of dense forest amd extremely rough topography.

For the same reasons, exposures on the Pueblo Creek are of little value. The beds as a rule have a southerly dip west of the bend of the creek. Shaly sandstones alternate with massive beds of grit. Occasionally impure limestones and carbonaceous shale bands, interstratified with the sandstones, are observed.

Red River basin.

At the head of the Pueblo Creek the Pennsylvanian rests on pre-Cambrian quartzite (Pueblo quartzite). A N-S fault crosses the divide between the Red River and Pueblo Creek, bringing the sandstones and grits into juxtaposition to the granite on the west. A little farther north two minor step faults cross the ridge from northwest to southeast. The beds are fissured considerably between these faults. The crevices are lined with comb-quartz and the whole formation shows signs of extensive silicification. North of this exposure the sedimentary rocks are confined to the area east of the Red River, except on the Elm Creek where the sediments flank the east slope of Wheeler Peak to an altitude of 11,500 feet. The Red River has cut a deep canyon into the sedimentaries and, farther north, into the underlying granite, exposing on the east slope, which is very steep, a thickness of nearly 1,000 feet of the Pennsylvanian. (See Plate II,A). Just east of the mouth of the Elm Creek, six species of Pennsylvanian fauna (see page 24) were collected near the base of the series from a dark gray argillaceous limestone. About 200 feet above this limestone, the following approximate section is exposed:

Red sandstone, very fine grained	100-150 ft.
Arkosic, light colored sandstone, at least (See plate II,A)	200
Gray, fossiliferous limestone	50±
Dark gray shale, carbonaceous in places	50±
Light gray quartz conglomerate	40±
Concealed base	.....

These beds dip about 10° to 12° east.

Outliers between Bull of the Woods and Lew Wallace Peak.

A number of outliers of the Pennsylvanian are situated on the east slope of the main range and extend from Bull of the Woods to the head of Indian Creek. They convey an idea as to the extent of erosion since early Tertiary time, when the Taos Range was probably uplifted. One of these remnants has the shape of a crescent one horn of which rests against Red Dome, while the other caps Lew Wallace Peak. To the northwest the convex side of the outlier is cut off by a fault and abuts against the granite of Old Mike. A partial section of the formation, as measured west of Blue Lake, is given. The beds have a dip of 5° to 10° due west.

Elevation, 12,225 feet

Light gray, fossiliferous limestone grit	80± feet
Gray, shaly limestone	50
Pink, coarse grained sandstone and arkose	30±
Dark red, calcareous shale	80±
Light gray, coarse sandstone	20
Gray shale, laminated	12
Pinkish, coarse sandstone and arkose	8
Blue gray, calcareous shale	10
Light gray, coarse grained sandstone	25
Red sandstone and conglomerate	65
Blue, fossiliferous, argillaceous limestone	20
Light gray, cross bedded sandstone	11
Blue, laminated shale	15±
	426±

Elevation 11,800 feet. Concealed base.

Above Ben Hur Lake the beds are similarly arranged. Here the unconformable contact between the Pennsylvanian and the pre-Cambrian Pueblo quartzite is exposed. A coarse yellow sandstone forms the basal member of the series. The bedding planes of the sandstone and the quartzite meet at an angle of almost 90°.

Outlier at Sacred Lake.

The most interesting remnant of sediments, a block faulted down on at least three of its four sides, lies between Sacred Lake, Larkspur Point, and the Lucero Creek. (See structure section, figure _/_). It rests against Pueblo quartzite on the east, schist on the south, and granite on the north. The beds have a dip 10° to the west above Sacred Lake, whereas they dip 5° to the east on the

Lucero Creek. The axis of the syncline approximately coincides with a line connecting Larkspur Point with Lew Wallace Peak. A partial section measured just south of Sacred Lake, is given below:

Elevation of capping arkose, 11,953 feet.

15.	Light gray, very hard and massive arkosic sandstone	15 feet
14.	Brownish gray, shaly limestone	30
13.	Lime cemented conglomerate (description below)	20
12.	Puddingstone conglomerate	10
11.	Dark red, very dense shale	20
10.	Light gray arkosic sandstone	12
9.	Puddingstone conglomerate	25
8.	Gray, massive, argillaceous limestone	45
7.	Light brown, medium-grained, calcareous grit	20
6.	Grayish green shale, non-laminated	6
5.	Puddingstone conglomerate (very coarse)	25
4.	Brownish-gray, gritty limestone, fossiliferous	21
3.	Red shale, somewhat arenaceous	9
2.	Puddingstone conglomerate (extremely coarse)	32
1.	Dark red, very dense, massive shale	15+
		305 feet

Concealed base about 100± feet above schist.

From bed No. 4 the following species were collected: Spirifer cameratus, Spirifer rockymantanus, Productus semireticulatus.

The light gray, arkosic sandstone, No. 15, which caps the outlier, is not confined to this horizon in the latter, but occurs once more in this formation, lower down in the outlier, (No.10) It is also a prominent member of the other outliers and in the formation exposed east of Red River. Vertical joints in this bed are rather far apart and of irregular spacing.

Petrography: This arkose or arkosic sandstone is a very hard, dense clastic of rather uneven grain. Some grains reach a diameter of 2 mm. The color of the rock is nearly white except for the presence of scattered small red feldspar grains. The larger feldspar particles are all altered considerably. In the thin section they are seen to exceed the much more abundant quartz grains somewhat in size. Like the latter they are angular in shape. Acid plagioclase and orthoclase are present in about equal proportions. No dark colored mineral occurs in the rock with the exception of hematite which "coats" a few of the feldspar grains. The cement consists of an aggregate of kaolin, minute quartz particles, and sericite flakes which are also very abundant in the altered feldspars. Some of the larger quartz grains have undulating extinction. Many fill out the interstices between the individual grains so perfectly that secondary growth must have raken an active part in the evolution of this arkose.

Of special interest in the outlier are the five members listed as puddingstone conglomerates on account of their unusual texture and composition. "Breccias" probably would have been a more appropriate name for them. Their color as a whole is dark red. Joints and bedding planes are few and far apart in the three lower members. The lowest one (No. 2) of the formation consists of very angular "pebbles" and fragments of green chlorite and gray quartz schist and gray slate, varying in size from mere sand grains to great boulders three to four feet in diameter. They are imbedded in a red argillaceous and arenaceous cement which makes up 80 to 85 per cent of the volume of the conglomerate. The second puddingstone bed (No.5) is of very similar appearance, with this difference, however, that the boulders are smaller and probably do not exceed a diameter of 12 inches. In the third member (No.9) the groundmass is rather calcareous in composition. Its color is somewhat lighter and numerous feldspar grains give to it arkosic character. Schist and slate fragments, usually platy, are abundant, whereas quartz and gneiss pebbles are almost absent. This is true of all puddingstone beds. The highest member of the conglomerates (No.13) is thinner than the others. In composition and texture it is as interesting under the microscope as in its field relation.

Petrography of conglomerate: Coarse angular grains of feldspar and smaller ones of quartz with wavy extinction are imbedded in red calcite cement which constitutes about 30 to 40 per cent of the whole rock. Besides the very coarse breccia already described, fragments of which reach six inches in diameter in this bed, small platy fragments of dark gray schist and slate are very abundant. Small particles of gneiss consisting of granulated quartz are common in the slide. Many of the feldspar grains are much altered and filled with secondary quartz, sericite, chlorite, and hematite. Those that can be recognized are orthoclase and acid plagioclase. Calcite forms the cement. Small fossil remains are abundant in it. They are easily detected by the limonite and hematite stains which outline their shape, and what appears to be their ornamentations, in the calcite. Limonite and kaolin veinlets penetrate the cement in many places and often surround the large grains of feldspar and quartz.

Post-Paleozoic Igneous Rocks.

Though outcropping in areas five to seven miles apart, the Red River rhyolite flow, the intrusive Opal Peak porphyry, and the numerous rhyolitic dikes are chemicaly and mineralogically much alike and probably of the same age. They are certainly post-Carboniferous, for one of the dikes cuts the Pennsylvanian beds on the divide of the Rio Grande and Mississippi basins, east of Saw Mill Creek. Extensive andesite flows occur five to six miles north of this exposure, near Red River City. They are of early Tertiary age, and probably contemporaneous with the rhyolite.

Rhylite flow on the Red River.

Only a part of the rhyolite flow on the Red River lies in the area mapped. It forms a thick sheet, which has been deeply incised by the West Fork of Red River and its tributaries. The vertical distance from the lowest exposure in the canyon to the highest on the hill, north of the West Fork, has been estimated at 500 to 600 feet.

Petrography: This rock is light gray in color and differs from other rhyolites of the region by the fact that quartz phenocrysts are smaller and less common in it. Under the microscope numerous euhedral phenocrysts of orthoclase and oligoclase, 1 to 2 mm. in diameter, with Carlsbad and polysynthetic twinning respectively, are observed. Much smaller, platy, biotite euhedra are common. They are frequently surrounded by what appears to be hematite flakes. The microcrystalline groundmass has a mottled appearance between crossed nicols, due to the micro-pegmatitic intergrowth of a large portion of the feldspar and quartz in somewhat rounded "spots."

Stocks and dikes near the Rio Hondo.

The porphyry of Opal Peak outcrops between Rio Hondo on the north, South Fork on the east, and Arroyo Seco on the south. Lying between the darker gneisses and granites the beautiful white color of the porphyry permits the sketching in of the stock from some distance. Plate II,B shows the extreme ruggedness of this area. Cuchilla de Media, farther west, while not so high as Opal Peak, is one of the prominent landmarks of the Taos Range. The porphyry here is sheeted like that of the rest of the stock and forms a knife-blade-like ridge 500 to 600 feet high. In spite of this apparent hardness of the rock, not a single specimen of porphyry was found that would not crumble into loose sand upon a blow with the hammer. No dark minerals were observed in the rock, only quartz and altered feldspar grains.

Just east of the South Fork a number of rhyolite porphyry dikes with a northwesterly trend and vertical dip cross the Rio Hondo. They are intrusive in the schists and granites and reach a width of 75 to 100 feet. They are undoubtedly closely connected with the porphyry stock.

Petrography: This grayish-white rhyolite porphyry is dense and compact in the hand specimen. The crypto-crystalline groundmass contains numerous small feldspar and quartz phenocrysts which do not exceed a diameter of 2 mm. Under the microscope these are seen to be predominantly orthoclase and oligoclase crystals, euhedral in outline. The latter show Carlsbad twinning besides the polysynthetic twinning. The quartz phenocrysts are rounded considerably and have corrosion rings. Magnetite and apatite occur in very small euhedral grains. The micro-crystalline groundmass is composed of intergrown feldspar and quartz. The rock has undergone extensive alteration. Irregular aggregates of chlorite, epidote, sericite, and kaolin flakes and grains are quite common in the feldspar phenocrysts and groundmass.

Other rhyolite porphyry dikes.

Southwest of Cuchilla de Media dikes of rhyolite porphyry in the ancient gneisses have a northwesterly trend and an intermediate eastward dip. In the schists and gneiss of Vallecito Peak, Fairview Mountain and the ridge between the latter and Lucero Peak, white rhyolite dikes are common. They attain a width of 120 feet and strike northwest. Their dip is steeply westward, as a rule. Slight mineralization of the rhyolite porphyry and the pre-Cambrian wall rock is noticeable and has induced prospecting in a few places. A dike with curious dendritic iron (and manganese?) stains outcrops on the divide between the Lake Fork and Lucero Creek. It has a northwesterly strike and nearly vertical dip. The very much altered white rhyolite porphyry contains numerous minute grains of pyrite. Otherwise this rock resembles the rhyolite at South Fork in composition and texture.

Geological History.

While the pre-Cambrian history of the Taos Range must necessarily remain rather obscure until further investigation and correlation with other regions, some of the events may be enumerated with more or less accuracy. Nothing is known about the origin of the ancient gneisses and schists. During the long erosion interval that exposed them and probably reduced the ancient mountains to base level, thick clastic deposits of sandstone and shale accumulated along the eastern and southern margin of the area, now occupied by the granite batholith.

Upon this time of great erosion, a period of intense orogenic movement followed, probably accompanied or closely succeeded by the intrusion of enormous volumes of granitic magma into the overlying schists, gneisses, and sediments, metamorphosing, especially the latter, to quartzites (Pueblo quartzite), schists, and slates. There is little doubt that a mountain range, perhaps of equal magnitude to the Taos Range, occupied at least a portion of the same territory as the Taos Mountains today. A number of basic dikes pushed their way into the batholith while the latter was probably still hot. No record of the geologic events that followed is preserved until Pennsylvanian time. But it may be assumed that the early and middle Paleozoic time was chiefly one of erosion. The occurrence of Cambrian and Silurian quartzites(?) on Rito Seco, in the Culebra Range, is mentioned by E. C. van Diest,[1/] but since no fossils were found in

1/ van Diest, E. C., Notes on the geology of the western slope of the Sangre de Cristo Range in Costilla County, Colo.: Proc. of Colo. Sci. Soc., 1894, pp. 76-80.

the Culebra rocks, and the Carboniferous strata seem to overlie them conformably, they probably belong to the Carboniferous system.

At the beginning of the Pennsylvanian period the present site of the range most likely formed the eastern shore of a considerable land mass west and northwest of it. Siebenthal, in his study of the San Luis Valley, has come to the same conclusion.[1] The very coarse

1/ Siebenthal, C. E., Geology and water resources of the San Luis Valley, Colo.: U. S. Geol. Survey Water Supply Paper 240, pp. 50-51, 1907.

and angular basal conglomerates of the Pennsylvanian leave no doubt as to the near shore conditions that existed during their formation. The deposition of the puddingstone conglomerates and breccias, and such boulder beds (some boulders with a diameter of 25 to 50 feet), as S. F. Emmons mentions farther north, on the east side of the Sangre de Cristo Range,[2] can have been brought about only by talus

2/ Emmons, S. F., Orographic movements in the Rocky Mountains: Geol. Soc. Amer. Bull., vol. 1, pp. 245-286.

and wash from a precipitous coast directly into deep or quiet water. The fact that the pebbles of all conglomerates consist of pre-Cambrian schists, gneisses, quartzites, and granites, suggests a land surface composed chiefly of these rocks. The enormous thickness of the strata leads also to the conclusion that a gradual sinking of the coast and progressive submergence from the east to the west took place during this period. Although direct evidence is lacking that the western slope of the Taos Range was covered by sediments, there is good reason to believe that this was the case, because north and south from the area mapped Carboniferous formations are found on the west side of the range.

A more difficult problem arises from the question when deposition of sediments ceased and erosion began. Stevenson speaks of the Jura Trias "Red Beds," that occur farther east and south, as resting conformably upon the Carboniferous.[1] Lee, on the other hand, would rather assign them, at least partly, to the Pennsylvanian system.[2] He also favors the assumption that during Cretaceous time the

1/ Op. cit., p. 85.
2/ Op. cit., p. 39.

sea covered practically all of the territory now occupied by the southern Rocky Mountains.[3] Until further evidence is found, to

3/ Lee, W. T., Relation of the Cretaceous formations to the Rocky Mountains in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 95, 1916, p. 40.

prove that this assumption is correct, the present writer is inclined to believe that the site of the Taos Range proper, during the Cretaceous, was not, or only for a short epoch, an area of deposition for the reason that no Cretaceous sediments have been discovered on the west side of the Culebra and Mora Ranges as far as can be learned from the available literature. It is also improbable that a considerable thickness of Cretaceous sediments in addition to thousands of feet of Pennsylvanian and pre-Cambrian rocks were eroded from the Taos Range, while the Cimarron Range, ten miles farther east and of the same age, should have remained covered with very thick and extensive Cretaceous formations. The latter being dominantly clastic must have been derived from a near source on the west that was probably a land mass composed of Pennsylvanian and crystalline rocks.

Near the end of the Cretaceous period this land(?) was raised to considerable height, and at the same time or during early Tertiary, deep seated intrusive activity resulted in the uplift of the Sangre de Cristo Range. A part of the magma reached the surface and formed flows, of which the rhyolite flow on Red River is one. Since that time erosion has been at work continually. Glaciation in recent time has been an especially powerful agent in the process of destruction of the mountains.

Economic Geology.

It is not likely that this district will ever attain great importance in regard to mineral resources. Three deserted mining camps on the Rio Hondo tell of an attempt to extract gold at South Fork and Almozzet, and copper at Twining. Lindgren has described these occurrences.[1]

1/ Op. cit., p. 84.

A number of short prospect tunnels are situated in and close to some of the rhyolite dikes near Fairview Mountain and Lucero Peak where pyritization has altered the schist. Another claim is at the head of Elm Creek, near the base of the Pennsylvanian, where a narrow vein of barite and galena outcrops in the sediments. The Indians are said to oppose any prospecting in the Pueblo drainage basin. Placer gold has been reported "somewhere" on the Pueblo Creek.

Acknowledgments.

In conclusion the writer wishes to thank Dr. Charles T. Kirk, formerly of the University of New Mexico, and Prof. F. F. Grout, of the University of Minnesota, for their many helpful suggestions during the progress of this work.

Plate I.

A. Vallecito Peak from divide between Salazar Canyon and South Fork. Ancient gneisses and schists dipping northwest. White rhyolite dike dipping west in cliff to left of peak.

B. Pueblo quartzite on Ben Hur Lake. Looking northeast. Unconformity on left. Pennsylvanian beds nearly at right angles to sheeting of quartzite.

Plate II.

A. Pennsylvanian Strata on East Bank of Red River. Looking north. Beds dip east. Visible portion consists mostly of arkosic sandstone and calcareous grit.

B. Opal Peak. Looking northeast. Center of porphyry stock with nearly vertical sheeting.

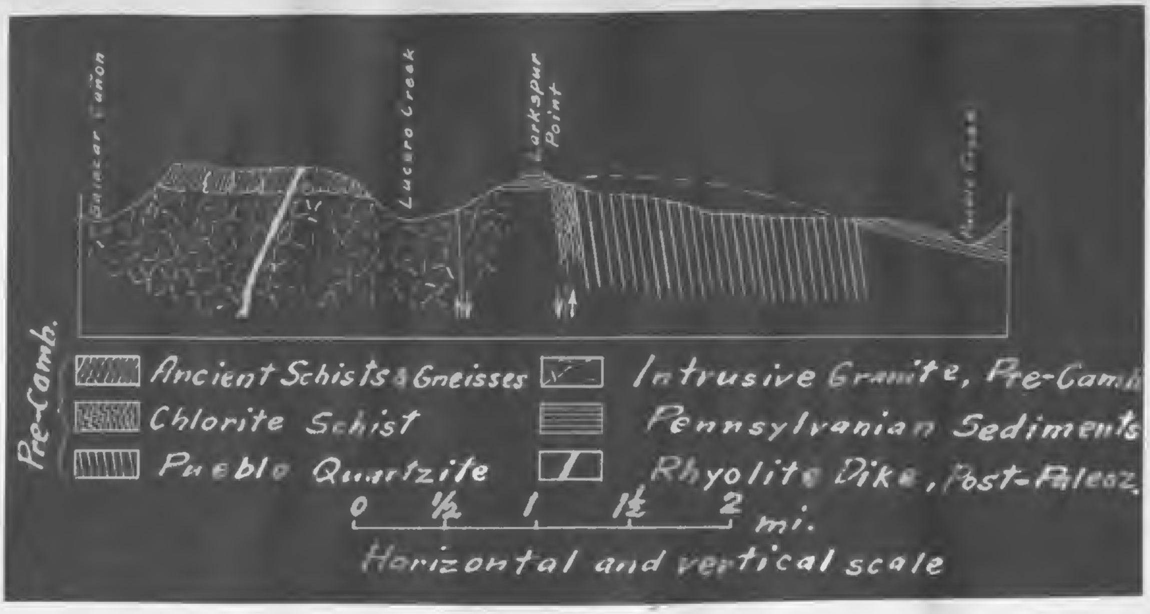


Fig. 1. Cross section from Salazar Canyon to Pueblo Creek, along line A-B on map.

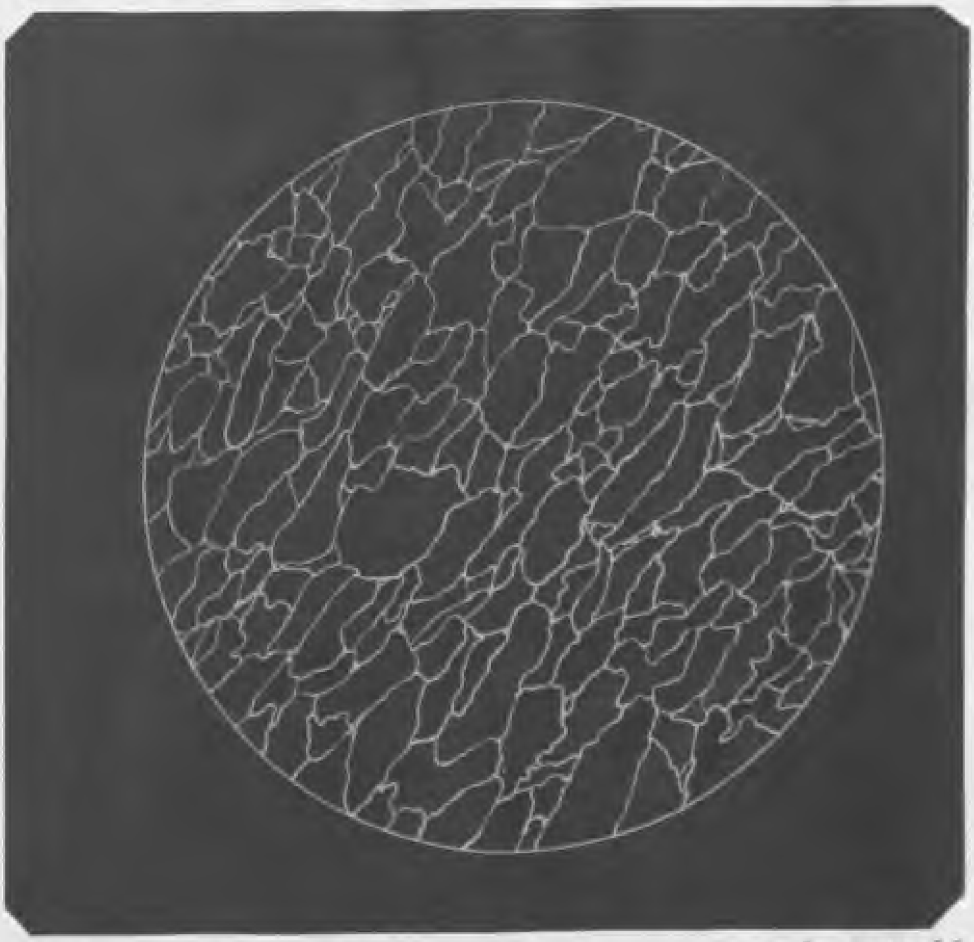
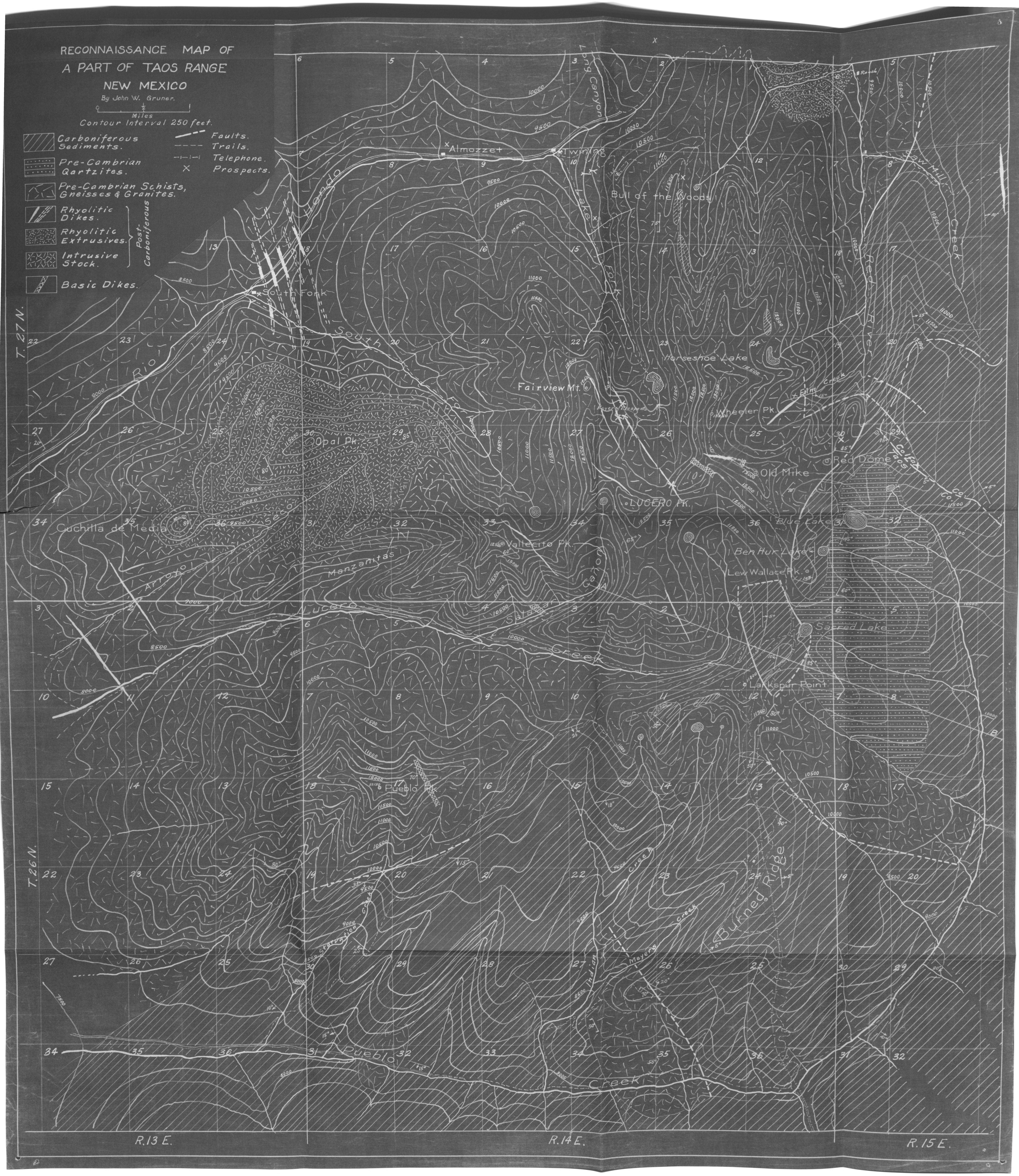


Fig. 2. Sketch showing elongation of quartz crystals parallel to sheeting in Pueblo quartzite. Magnified 20X.


RECONNAISSANCE MAP OF
A PART OF TAOS RANGE
NEW MEXICO
By John W. Gruner.
Miles
Contour Interval 250 feet.
Carboniferous Sediments.
Pre-Cambrian Quartzites.
Pre-Cambrian Schists, Gneisses & Granites.
Rhyolitic Dikes.
Rhyolitic Extrusives.
Intrusive Stock.
Post-Carboniferous
Basic Dikes.
Faults.
Trails.
Telephone.
Prospects.
Almozzet
Twining
Long Canyon
Lake Fork
Bull of the Woods
South Fork
Rio Hondo
Red River
Saw Mill Creek
Horseshoe Lake
Fairview Mt.
Wheeler Pk.
Opal Pk.
Red Dome
Old Mike
LUCERO PK.
Cuchilla de Media
Blue Lake
Vallecito Pk.
Ben Hur Lake
Lew Wallace Pk.
Manzanitas
Arroyo Seco
Lucero
Salazar Creek
Sacred Lake
Larkspur Point
Pueblo Pk.
Burned Ridge
Indian Creek
Meyers Creek
Pueblo Creek
T. 27 N.
T. 26 N.
R. 13 E.
R. 14 E.
R. 15 E.