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Geology of Costilla and Latir Peak Quadrangles, Taos County, New Mexico

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Geology and ore deposits of the north half of the Taos Range of the Sangre de Cristo Mountains and the Costilla Plain to the west

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Abstract

This report covers the geology and ore deposits of the northern half of the Taos Range of the Sangre de Cristo Mountains (a fault-block range) and the Costilla Plain (a bolson) to the west. The purpose of the survey was to delineate any areas of ore mineralization and to gather detailed information on the geology. The study was made by the New Mexico Bureau of Mines and Mineral Resources in cooperation with the U. S. Geological Survey. The area covered, Costilla and Latir Peak quadrangles, is in the northern part of Taos County, New Mexico, between latitudes 36°45' and 37°00' and longitudes 105°15' and 105°45'. Field work began in the summer of 1947 and continued during the summers through 1950.

Principal topographic features of the two quadrangles are the rugged Sangre de Cristo Mountains and the Costilla Plain, the latter including the Rio Grande gorge. Elevations range from about 7,500 feet on the Costilla Plain to over 12,700 in the mountains.

The Costilla Plain and Sangre de Cristo Mountains have quite different geologic settings. In the mountains, Precambrian rocks crop out over two-thirds of the area. Tertiary volcanics, intrusives, and interbedded sediments crop out over much of the remaining area. Scattered outcrops of Permo-Carboniferous sediments also occur, and Quaternary deposits of stream gravel, fan gravels, glacial debris, etc., locally cover the older rocks.

The Precambrian rocks include amphibolites and hornblende schists, interlayered quartzites and quartz-mica schists, metagabbro, and massive quartzite intruded by granite. The granite is the predominant rock type. The Tertiary volcanics are andesite, latite, and rhyolite flows, tuffs, and breccias, with interbedded siltstones, sandstones, conglomerates, and basalt flows. The percentage of sediments increases northward, where the sequence is known as the Amalia formation. The Tertiary volcanic activity was accompanied by the intrusion of latite sills and dikes, rhyolite plugs and dikes, monzonite porphyry dikes, and granite stocks. The exact age and correlation of most of the Tertiary rocks are questionable.

The Costilla Plain, in contrast, is covered by a thick sequence of late Tertiary to Quaternary gravels and interbedded basalts.

The region has been subjected to at least six periods of deformation. Precambrian rocks were first tightly folded into northeast trending folds, then intruded by granite, and later folded along axes that trend from north to 20 degrees west. Thrust faults and extensive granulation occurred during the late phase of the Precambrian deformation. Uplift of the region in Carboniferous-Permian time is indicated by the conglomeratic nature of the Carboniferous-Permian sediments and by the absence of recognizable Pennsylvanian marine rocks. During the Laramide

revolution, the metamorphic rocks and Precambrian granite were thrust over the sedimentary rocks to the east. Late Tertiary normal faulting elevated areas of Precambrian rocks and lowered the areas that now are covered mainly by volcanic rocks. The Sangre de Cristo Mountains were raised over 7,000 feet and tilted to the east in the Pliocene and Pleistocene.

The Precambrian metamorphic rocks in general show low-grade metamorphism, although near Precambrian granite bodies thermal re-crystallization has produced coarse sillimanite and muscovite gneisses. Migmatite rocks are common in the amphibolite and hornblende schist near Precambrian granite. Mylonite schists are locally abundant in the Precambrian rocks. The Tertiary intrusives had little metamorphic effect on the intruded rocks.

In the southern part of Latir Peak quadrangle, the Tertiary volcanic rocks were altered by hydrothermal solutions. Chlorite, pyrite, and quartz are the principal alteration minerals. A small amount of gold mineralization accompanied or followed the alteration solutions.

The survey indicates that the favorable areas for future economic mineral exploration are the alteration area south of Ortiz Peak, and the small pegmatites southeast of Costilla. Approximately 10,000 acre-feet per year of undeveloped ground water could be made available on the Costilla Plain by shallow 250-foot wells.

Introduction

This report describes the geology and mineral deposits of the northern half of the Taos Range of the Sangre de Cristo Mountains, a fault-block range with complex geology, and the Costilla Plain, a bolson, to the west.

The study was made by the New Mexico Bureau of Mines and Mineral Resources in cooperation with the U. S. Geological Survey. Field work began in the summer of 1947 and continued during the summers through 1950.

This brief report is designed as an explanatory text to accompany the geologic map and sections of the Costilla and Latir Peak quadrangles. The map represents the rugged western part of the Sangre de Cristo Mountains immediately south of the Colorado border in New Mexico.*

LOCATION AND ACCESSIBILITY

The Costilla and Latir Peak quadrangles are in the northeast part of Taos County, New Mexico, between latitudes 36°45' and 37°00' and longitudes 105°15' and 105°45', and include an area of about 467 square miles. The region is served by State Highway 3, which runs from Questa north along the western front of the Sangre de Cristo Mountains to the town of Costilla. State Highway 196, a graded road, extends from Costilla approximately 10 miles east along the Rio Costilla. Most of the remaining roads are primitive and generally in poor repair. The principal towns in the area are Costilla (population 500) and Cerro (population 350). Jarosa, Colorado, 8 miles from Costilla, is the nearest railroad loading point.

PREVIOUS WORK

Previous geologic work within the quadrangles has been confined mainly to reconnaissance mapping. The only published geologic map of the area, scale 1:253,000, was compiled by J. J. Stevenson (1881) as part of the Wheeler survey. The traverses made by Stevenson were mainly along the mountain front and principal streams. Stevenson's rock descriptions are accurate for the areas covered. Kirk Bryan (1930, pp 116-118) has described the basalts and gravels west of the mountain front. Additional work was done by Upson (1939, pp 721-736), who outlined the physiographic subdivisions of the area, and also described early Tertiary redbeds (Upson, 1941, pp 577-589) northeast of Costilla.

*The names Rio de la Yutas and Rito de la Medio, which appear on the map, should be corrected to Rio de los Yutas and Rito del Medio respectively.

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Geography

SURFACE FEATURES

Maximum relief within Costilla and Latir Peak quadrangles is about 5,500 feet, with the lowest point, 7,150 feet, on the Rio Grande at the southern border, and the highest point, I2,723-foot Latir Peak. The region may be divided into three physiographic subdivisions (see fig 1): (1) the Costilla Plains, (2) the Culebra Park, and (3) the Sangre de Cristo Mountains. Elevation of the plains ranges from approximately 7,500 feet, east of the Rio Grande, to 8,500 feet, near the mountains. The Rio Grande gorge and Ute Peak are the two prominent features of the plains. The gorge extends south across the area and ranges in depth from 200 feet, near the Colorado border, to 350 feet, west of Cerro. Ute Peak, a 10,150-foot basalt dome, lies east of the Rio Grande, 5 miles south of the Colorado line. Shallow washes and valleys, 20-100 feet in depth, extend west across the plain to the Rio Grande gorge.

The Culebra Park is located mainly in Colorado and is a continuation of the Costilla Plains that has been faulted up approximately 400 feet by a recent displacement along the mountain front near the town of Costilla. In New Mexico, the park, which is surfaced by basalt and gravels, lies north of the Rio Costilla and Rio de los Yutas.

The Sangre de Cristo Mountains cover the eastern edge of Costilla quadrangle and most of Latir Peak quadrangle, an area of approximately 250 square miles. The prominent features of the Sangre de Cristo Mountains are the steep western front, the high peaks and glaciated valleys, and the Rio Costilla drainage. The Costilla massif is a 14-milelong ridge of granite and metamorphic rocks that extends south from the Colorado border across the central part of Latir Peak quadrangle.

Vermejo Park is located along the east edge of Latir Peak quadrangle. Above the Costilla reservoir, the park is formed by the wide glacial outwash basin along the Rio Costilla. To the south, the park is formed by high grass-covered terraces, that slope from the tree-covered ridges down to the Comanche Creek canyon.

CLIMATE

The region is semiarid, although the range in altitude produces large variations in temperature and precipitation. The annual precipitation varies from 10 to 25 inches. Temperatures in winter range from -25°F to 50°F, those in summer from 30°F to 90°F. The higher precipitation and lower average temperatures occur in the mountainous areas. From May to October, the moisture falls as rain or hail except on the high peaks, where snowstorms may occur throughout the year.

VEGETATION

The vegetation is varied and consists mainly of sagebrush and piñon on the Costilla Plains, 7,500-8,500 feet; scrub oak and pine on the western mountain front, 8,000-9,000 feet; mixed forest of Douglas fir, spruce, aspen, and highland meadows throughout the mountains, 8,500-11,500 feet; and alpine grass and plants above 11,500 feet.

Geology

SEQUENCE OF ROCKS

INTRODUCTION

The Costilla Plain and Culebra Park have a very different geologic setting from that of the Sangre de Cristo Mountains. In the Sangre de Cristo Mountains, Precambrian metamorphic rocks (amphibolites, schists, and quartzites) and granite crop out over two-thirds of the total area of the mountains in the two quadrangles. Tertiary volcanics (andesite, latite, and rhyolite) and interbedded sediments crop out over much of the remaining area. Scattered outcrops of Permo-Carboniferous sediments occur in the southern part of the area mapped, and a few small Tertiary granite stocks and monzonite porphyry dikes intrude the older rocks.

In contrast, the Costilla Plain and Culebra Park are covered by a series of late Quaternary-Tertiary basalts and interbedded gravels. East of the Rio Grande, fan gravels cover the basalts.

Bedrock in Costilla and Latir Peak quadrangles is for the most part poorly exposed, and actual contacts between the various rock units are usually difficult to find or trace. As no fossils were found in any of the sedimentary rocks, correlation and dating of the formations are only approximate.

PRECAMBRIAN ROCKS

Undifferentiated Metamorphic Rocks (p€m)

The oldest rocks in Costilla and Latir Peak quadrangles are amphibolites and hornblende schists, interlaid quartzites and quartz-mica schists, and layers of massive quartzite. The amphibolites, schists, and small lenses of quartzite make up the undifferentiated metamorphic rocks (p€m) shown on the map (see pl I). Where possible, the quartzite exposures have been mapped as a separate unit (p€q).

Outcrops of the metamorphic rocks are scattered throughout the part of the Sangre de Cristo Mountains covered by this report. The rocks are best exposed along the north bank of the Rio Costilla, near the mouth of Comanche Creek. A section across the strike of the layers from north to south consists of approximately 300 feet of amphibolite, with pegmatite stringers; 400 feet of massive quartzite; and 1,000 feet of quartz-mica schist and gneiss interlaid with fine-grained quartzite and intruded by many small pegmatites.

Metamorphic rocks are also exposed 6 miles south of the town of Costilla, and along the west front of the mountains in the southeast corner of Costilla quadrangle. Small areas of amphibolite and schist are scattered along the top of the Costilla massif and are probably roof pendants preserved in the border of Precambrian granite.

Amphibolite and hornblende schists. These rocks are best exposed on the Costilla massif east of the Rio de los Yutas. They are also exposed 2 miles northeast of Latir Peak, and southwest of the Costilla reservoir.

The amphibolite and hornblende schists are massive to well-foliated rocks that range from black to dark green. The mineral contents of the amphibolite and schist are similar. An attempt was made to separate these two units in the field, designating as amphibolite the rock which is nonfoliated and low in megascopic quartz, and as hornblende schist the foliated quartz-plagioclase rock. However, the reconnaissance nature of the survey and limited outcrops made the separation of the two rock units impractical; accordingly, they are included with the undifferentiated metamorphic rocks on the geologic map.

A specimen of amphibolite from an exposure 2 miles northeast of Latir Peak is dark, fine-grained schistose rock containing approximately 55 percent dark-green to brown amphibole, 35 percent andesine (?), 7 percent quartz, and 2.5 percent sphene, apatite, and epidote.

The amphibolites and hornblende schists may have been derived from basic volcanic rocks, but in Costilla and Latir Peak quadrangles primary textures and structures are not apparent. They are believed to be the oldest of the exposed Precambrian rocks. In exposures 2 miles northeast of Latir Peak, the amphibolite appears to be overlain by the quartzite.

Quartz-mica schist and gneiss. A thick exposure of pinkish quartz-mica schist and gneiss occurs south of the massive quartzite on the Rio Costilla. The schist contains layers of fine-grained quartzite, pegmatites, and lenses of granite. In some zones, pods of quartz 0.5-5 inches in diameter are abundant. These metamorphic rocks probably were derived from shales, fine-grained sandstone, and conglomerates. However, the intrusion of granitic material and accompanying recrystallization apparently altered the original rock, and in places the schist grades into granitoid rocks. In some layers, small nodules of garnet contain yellow tourmaline. The quartz-mica schist and related rocks lie above the massive quartzite north of the mouth of Comanche Creek; elsewhere, the schist was not found in this association.

Cabresto (?) Metaquartzite (p€q)

The Cabresto metaquartzite was named for exposures along Cabresto Canyon, along the south edge of Costilla quadrangle. Thick layers of quartzite also are exposed in seven other localities within Costilla and Latir Peak quadrangles. The quartzite in these areas ranges from 200 to over 1,000 feet in thickness. This quartzite probably is equivalent to the Cabresto metaquartzite of the type locality.

The quartzite is gray to cream and usually composed of 2- to 10-foot layers of coarsely crystalline glassy to milky-white quartz. The massive layers contain scattered muscovite flakes and are separated by thin muscovite and biotite-magnetite-garnet bands. In places within the massive quartzite, magnetite grains are arranged in narrow layers that are 2 inches to more than 1 foot apart and that parallel the mica layers.

Relict structures were recognized in only two exposures, on the high ridge half a mile south of the Colorado border in the center of Latir Peak quadrangle, and on the ridge south of Rito Primero in the southeast corner of Costilla quadrangle. In the first locality, elongated quartzite cobbles and pebbles are abundant in the lower part of the outcrop. At the second locality, massive quartzite appears to be overlain by quartzites in which none of the sedimentary textures or bedding has been destroyed. The quartzite from the Rito Primero locality possibly should be correlated with the younger metasediments of questionable Paleozoic age.

When examined microscopically, the rock is a mosaic of quartz grains, which often show wavy extinction. Original grain boundaries and cement have been destroyed. The quartzite contains from 85 to 95 percent quartz, 0-10 percent sillimanite and kyanite, 2-10 percent muscovite, and 1-3 percent magnetite. Dark-reddish garnet crystals and biotite occur in many of the narrow magnetite bands. Chlorite locally replaces biotite.

A muscovite-albite gneiss that contains varying amounts of fine crystalline graphite is interlaid with the Cabresto (?) quartzite south of Rito Primero. Pegmatite lenses of quartz and albite, lying parallel to the foliation, are scattered throughout the outcrops. The graphite gneiss was not found exposed east of Latir Peak but extends south of Costilla quadrangle. The gneiss is believed to have been formed from an organic shale that was intruded by small granite pegmatites and subsequently recrystallized by high temperatures. Biotite is common in the more granitic areas of the gneiss; in places, the rock appropriately may be called a biotite gneiss.

Muscovite flakes, up to one-half inch in diameter, and sillimanite needles have been formed in the quartzite adjacent to the Precambrian granite by thermal metamorphism. The high percentage of muscovite and sillimanite developed near the granite indicates that at least part of the muscovite and sillimanite may have been formed in the quartzite by introduction of material from the Precambrian granite.

The exact relationship of the massive quartzite layers to the amphibolites and hornblende schists is in doubt. However, the hornblende schist is associated closely with the Precambrian granite and in several exposures appears to underlie the quartzite.

The massive quartzite is believed to lie below the quartz-mica gneiss and the graphite-mica gneiss. The questionable Paleozoic sedimentary rocks and the Tertiary sedimentary rocks and volcanics lie unconformably above the quartzite and mica schists.

Precambrian quartzite layers are exposed in scattered areas in northern and central New Mexico and southern Colorado. A direct correlation between the quartzite of Costilla and Latir Peak quadrangles with exposures in surrounding areas cannot be made at the present time.

Granite (p€gr)

In the two quadrangles, granite and granite gneiss cover roughly two-thirds of the Sangre de Cristo Mountains. The largest area under-lain by granite is the Costilla massif, where for over 100 square miles it is the predominant rock. Other areas, where Precambrian granite is the principal rock, are along the west front of the mountains from Little Latir Creek to north of Rito de la Jara, and in Latir Peak quadrangle east of Comanche Creek.

The mineralogy of the granite is relatively uniform, though the texture of the rock varies from fine-grained to pegmatitic. The most characteristic phase of the rock is a medium-grained, pinkish to cream granitic-appearing material. Areas of pegmatite are scattered through-out the granite exposures. The pegmatite phase is best developed along the Rio Costilla near the mouth of Latir Creek, and along the mountain front south of Little Latir Creek.

In general the granite is composed of pinkish microcline, glassy quartz, white albite, greenish-brown biotite, muscovite, apatite, sphene, and magnetite. The relative proportions of these minerals are different from place to place. In most places, biotite increases in the more gneissic phase and is often absent in the pegmatitic material. The biotite is altered commonly in varying degrees to chlorite. The feldspars occur as rounded, irregularly sized grains with good cleavage planes. Grain size of the feldspars ranges from about 3 mm in diameter in the medium-grained rock to 1-2 inches in diameter for the pegmatite phase.

Specimens examined under the microscope show granulation and partial recrystallization of the mineral constituents. The biotite is commonly alined along small shear planes. Much of the albite is turbid and corroded, with the development of small muscovite flakes in and around the crystals. In contrast, the microcline is usually clear and not corroded. Apatite is the only mineral that consistently shows crystal faces. The secondary minerals epidote and chlorite occur in varying amounts. The approximate mineral composition of the medium-grained granite is 35 percent microcline, 20 percent albite, 35 percent quartz, 5 percent biotite, 3 percent muscovite, 2 percent apatite, sphene, and magnetite.

The Precambrian granite intrudes the amphibolites, quartzites, and quartz-mica schists. Zones of mixed rocks or migmatites were formed in the metamorphic rocks adjacent to the granite. The early Tertiary (?) sediments and Tertiary volcanic rocks lie unconformably above the granite. The volcanic rocks have been faulted down between the massive granite exposures. Before the granite areas were uplifted, sedimentary rocks and Tertiary volcanics undoubtedly covered most Precambrian rocks.

Pegmatites (p€p)

Pegmatite dikes having sharp intrusive contacts occur in the Precambrian rocks. A swarm of these dikes crops out for a distance of 5-6 miles along the top of the Costilla massif. Pegmatite dikes also are well exposed in the vicinity of Rito de los Cedros and north of the mouth of Comanche Creek.

The pegmatites are white to pink and range from thin stringers 3-4 inches wide to large lenses 50 or more feet wide and over 2,000 feet long. The composition of the pegmatites is simple; the common minerals are quartz, one or two feldspars, and some muscovite. Intergrowths of quartz and albite are common. Magnetite and garnet are often found near the border of the pegmatites. Black tourmaline crystals occur in a large pegmatite exposed north of Latir Peak.

Many of the pegmatites are zoned into a quartz core and surrounded by an albite-quartz border. A pegmatite which crops out on the ridge west of the head of the south fork of Rito de los Cedros contains three distinct zones. The border zone up to 1 foot thick contains graphic granite and muscovite. Next is a 2-foot zone of white albite, quartz, and muscovite. The core is white quartz. A beryl crystal 6 inches long and 2 inches in diameter was found in the albite-quartz-muscovite zone. Small crystals of yellow chrysoberyl also occur in this zone.

The pegmatite dikes intruded the Precambrian granite and "undifferentiated metamorphics," but none of the younger rocks. Many of the dikes trend parallel to the schistocity of the older rocks.

Metagabbro (p€g)

Isolated exposures of altered gabbro and diabase occur in the Precambrian rocks. One of the best exposures of metagabbro is north of the junction of Comanche Creek. Generally, the rocks are not foliated, and their original texture often is preserved, though the pyroxenes have been altered to hornblende, and the plagioclase replaced by albite and clinozoisite.

The metagabbro and related rocks cut the Precambrian granite and metamorphic rocks. They are classified tentatively as Precambrian in age, as they were not observed cutting Paleozoic rocks.

PALEOZOIC ROCKS

Sangre de Cristo Formation (CPsc)

Arkosic sediments thought to belong to the Sangre de Cristo formation of Carboniferous-Permian (?) age crop out along Rito de Juan Ballejos and Rito de Paraiso, on the west slopes of Little Baldy Mountain. The contacts are mostly obscured, though in the vicinity of Little Baldy Mountain the sediments are overlain by the Entrada sandstone.

The thickness of the sediments could not be measured within the quadrangle.

The rocks are well-cemented, reddish arkosic shales, sandstones, and conglomerates, and are composed of Precambrian debris.

Permian rocks are in contact with an eastward thrust block of Precambrian granite along the east boundary of Latir Peak quadrangle. The sedimentary rocks on Rito de Juan Ballejos and Rito de Paraiso are surrounded by Precambrian granite and probably represent a fenster.

Isolated exposures and areas covered with float of metamorphosed shale, sandstone, and conglomerate are found stratigraphically above the older metamorphics and below the Tertiary volcanics. The poor exposures make correlation difficult. These rocks, however, have been included with the Sangre de Cristo formation, and indicated as CPsc (?), although possibly of different age. The best outcrop is east of the canyon formed by Rito del Medio. The shale is siliceous and has a conchoidal fracture. The sandstone and conglomerates are well cemented; sedimentary rock structures have not been destroyed.

TERTIARY ROCKS

Early Tertiary (?) Sediments (Ts ?)

Gray to dark-red thin-bedded sandstones, shales, and conglomerates are exposed on the divide east of Little Latir Creek, on the south fork of Little Latir Creek, and along the lower part of Rio de los Yutas. About 1,000 feet of sedimentary rocks is exposed on Little Latir Creek, whereas in the Rio de los Yutas locality the exposed rocks are about 300 feet thick.

The rocks are composed of Precambrian debris. On lower Latir Creek, conglomerates with cobbles up to 6 inches in diameter are inter-bedded with red sandstones and shale. Along Rio de los Yutas, the rocks consist of thin-bedded sandstones, which contain lenticular lenses of limestone.

No fossils have been found in the rocks. As the rocks apparently underlie the Tertiary volcanics, they are assigned tentatively to the early Tertiary. From their lithology and stratigraphic position, the rocks are possibly equivalent to early-Tertiary redbeds described by Upson (1941, pp 577-589) as the Vallejo formation, and by Smith (1938, pp 940-944) as the El Rito formation.

Andesite Flows and Pyroclastics (Ta)

Andesite breccias, tuffs, and flows are exposed over most of the area between Comanche Creek and Rito Latir, and south of Rio Costilla to the southern boundary of Latir Peak quadrangle. This same andesite extends across lower Comanche Creek to one-fourth mile south of the Costilla reservoir. Andesite flows and breccias occur southwest of the Rio Costilla, near Rito Ballejos. Fine-grained andesite and whitish tuff are exposed along Rito del Sanchez and north of the north branch of Little Latir Creek. Andesite tuff, fine-grained siltstones, conglomerates, and thin basalt flows are exposed on the slopes of Latir Peak and along Lake Fork Creek.

Many of the andesite flows change in thickness from a few feet to several hundred feet in a comparatively short distance. The tuff beds and breccias vary in a similar manner. At most places, the lack of continuous exposures, together with faulting, makes it impossible to map them separately. In the areas exposed, the andesite complex ranges in thickness from around 20 feet to over 2,500 feet. The breccias consist of angular fragments of andesite, from I inch to I foot in diameter, in fine-grained purple to green matrix. The andesite-flow material is in general a fine-grained purplish rock. Though certain flows are porphyritic and contain phenocrysts of plagioclase and hornblende, much of the aphanitic groundrnass is usually glassy and contains disseminated hematite.

The tuff beds exposed in the vicinity of Latir Peak contain layers of sedimentary rock and basalt. A section north of Latir Lakes contains the following units measured from the bottom: 30 feet of fine purple tuff, 2 feet of arkosic conglomerate, 5 feet of siltstone, 60 feet of fine purple tuff, 70 feet of andesite breccia, 100 feet of vesicular basalt, 40 feet of purple tuff, and 200 feet of green tuff. A white to gray tuff is exposed along Rito del Sanchez and in other scattered localities. This tuff contains fragments of andesite and Precambrian rock embedded in a fine-grained ash matrix. The thick layer of andesite that overlies the white to gray tuff is slightly porphyritic, with an aphanitic groundmass. The phenocrysts are about 55 percent andesine and 5 percent augite. The augite has generally altered to chlorite and hematite. The ground-mass is cloudy, partly glassy, and full of scattered hematite. The andesine usually occurs as Carlsbad-albrite twins, and is clear and unaltered except along fractures.

The age determination and correlation of the andesitic rocks are difficult, even in areas of good exposures. The andesite complex lies unconformably above the Precambrian granite and metamorphic rocks, Carboniferous-Permian (?) rocks, and early Tertiary (?) sedimentary rocks. Many of the contacts with the older rocks are along faults. Such fault contacts are well exposed west of Rito del Sanchez and near the mouth of Rito de Juan Ballejos. The andesite flow and white tuff possibly interfinger with part of the Amalia formation in the vicinity of Rito del Sanchez. Tuffs and sediments near Latir Peak lie above the early Tertiary (?) sediments and have been intruded and overlain by Latir Peak latite. Dikes of Latir Peak latite intrude the andesite series south of Rio Costilla, and in places have formed large sill-like bodies between units of the andesite. Rhyolite tuffs and flows (?) lie above the andesite series east of Latir Lakes and in the area south of Rio Costilla. The andesites are cut by dikes of rhyolite and monzonite porphyry.

The andesite series is believed to be at least in part older than the Amalia formation. Volcanic activity apparently was spread over a considerable period of time, though most of the deposition of the unit was confined probably to the mid-Tertiary.

Latir Peak Latite (Tlp and Tlpi)

The Latir Peak latite is named after Latir Peak, where the rock is well exposed. The latite makes up most of Latir Peak and the high ridges that lie south of the peak. The Latir Peak latite occurs in scattered exposures from east of Latir Peak to Comanche Creek. One of the largest exposures is near the headwaters of Cabresto and Bitter Creeks, along the southern edge of Latir Peak quadrangle.

The Latir Peak latite is porphyritic, with an aphanitic to glassy groundmass. The color of the rock in most of the outcrops is light gray, but near Latir Peak much of the rock is reddish. The texture and composition of the Latir Peak latite vary; specimens from some localities are andesitic in composition. The latite contains phenocrysts of plagioclase, quartz, biotite, and hornblende in a groundmass of feldspar and quartz. The plagioclase phenocrysts, which are between oligoclase and andesine in composition, make up about 35 percent of the rock. Biotite phenocrysts form approximately 5 percent of the rock. Hornblende forms about 2 percent of the rock. The groundmass is often glassy.

The Latir Peak latite occurs as thick flows, sills, and dikes. The rock is intrusive into rocks of pre-Tertiary age and is closely associated with the andesite series of mid-Tertiary (?) age. Dikes of Latir Peak latite cut the andesite breccias near the head of Cabresto Creek, 3 miles south along Rito Latir, and west of the junction of Rito Latir and Rio Costilla. Sill-like bodies occur near the head of Cabresto Creek, north of the junction of Comanche Creek and Rio Costilla, and north and south of Rito Latir, 1 mile east of the Latir Lakes.

The latite body that makes up Latir Peak is intrusive into andesite tuffs and sediments. Contacts between the andesite tuff and the Latir Peak latite generally are badly fractured and sheared. The andesite is fine grained near the borders and becomes coarser towards the center of the intrusive body. North of Latir Lakes and in other areas around the intrusive, the intruded tuff and sedimentary rocks have been baked a brick red.

The age relations between the Latir Peak latite and rhyolite volcanics are confused. In three places, sills of the Latir Peak latite are believed to be intruded between the rhyolite material and the older andesite flows and tuffs. If so, the Latir Peak latite is younger than at least part of the rhyolite. In many areas, however, the rhyolite seems to overlie the latite.

Rhyolite Tuffs and Flows (Tr)

Rhyolite tuffs and flows are well exposed near the Latir Lakes, on both sides of Rito Latir. Similar rocks crop out on the south bank of Rio Costilla. Several exposures occur along the southern edge of Costilla and Latir Peak quadrangles.

The rhyolite ranges from 1,000 to 1,500 feet thick east of Latir Lakes, and from a few feet to about 500 feet thick in other areas. East of Latir Lakes, the unit is made up of rhyolite tuffs and breccias, including a lower, partly welded, 200-foot layer. In most of the other exposures, a tuffaceous lower phase is capped by an aphanitic gray felsite, with small quartz phenocrysts and numerous lithophysae.

The rhyolite tuff lies above andesite tuffs and sedimentary rocks north of Latir Lakes. South of Rio Castilla and in the vicinity of Rito de Fernandes, the rhyolite tuffs and felsite appear to overlie the andesite series.

Many of the contacts between the rhyolite and other rock units are badly faulted and poorly exposed. The rhyolite tuff is similar to the fused tuff of the Amalia formation; it is believed that they may interfinger. Although in most areas the rhyolite apparently overlies the Latir Peak latite flows, from presently available data it is believed that the rhyolite tuff and felsite may be older than at least part of the intrusive bodies of the Latir Peak latite. Thus, the observed field relationships give only an incomplete picture of the age relations of the rhyolite and Latir Peak latite. The rhyolite tuffs and flows are younger than the andesite breccias and flows. North of Latir Peak, the rhyolite tuff lies above amygdaloidal basalt.

Rhyolite Intrusives (Tri)

Exposures of numerous rhyolite dikes and plugs are found associated with the Tertiary volcanic and intrusive rocks.

Large dikes of rhyolite porphyry crop out on the high ridges between Little Latir Creek and Rito del Medio. These dikes are porphyritic, with phenocrysts of orthoclase and rounded quartz crystals set in an aphanitic groundmass. The dikes are similar in composition to the Tertiary granite exposed along the lower part of Rito del Medio, and cut the andesite tuffs.

Rhyolite plugs are well exposed at the mouth of Comanche Creek and 1 ½ miles up Rito Latir. They are aphanitic light-purple to pink rocks which contain small phenocrysts of quartz and feldspar and show well-developed flow banding. The plugs on Comanche Creek intrude Latir Peak latite and andesite tuffs. The Rito Latir plug cuts Precambrian granite, andesite breccia, and rhyolite tuff.

An outcrop of rhyolite approximately 1½ miles in diameter lies east of the Rio Costilla, 2 miles southeast of Amalia. The exposure is about 500 feet thick. The rhyolite is fine grained, light gray to cream in color, and contains phenocrysts of feldspar, biotite, and quartz. The phenocrysts of biotite, which are up to 1 mm in diameter, give the rock a salt-and-pepper appearance. The exposure may be part of a gently dipping sill which was intruded between Precambrian granite and the overlying Amalia formation.

Some of these rhyolite intrusives may represent feeders for the rhyolite flows, although clear-cut relations are lacking.

Basalt (Tb)

A thick flow of basalt is exposed below the Costilla dam and extends south to Rito Gonzales. Basalt flows are also well exposed north of Rito Latir. These basalts are in part amygdaloidal and contain altered olivine phenocrysts. The basalt lies above rocks of the andesite series and is over-lain by rhyolite, north of Rito Latir, and by Tertiary gravels, below the dam site. Two isolated areas of basalt that may be of the same age crop out in the northeast corner of Latir Peak quadrangle. Basalts which are possibly equivalent along the lower Costilla Valley are included in the Amalia formation.

Amalia Formation (Tam)

The Amalia formation is named for the Amalia post office which lies on the west side of the Costilla Valley, 5 miles southeast of the town of Costilla. The unit is best exposed east of the Rio Costilla, 4-5 miles south of Costilla, New Mexico, and on the north side of the canyon formed by Rito de los Cedros. The formation lies above andesite and andesite tuffs on the west side of the Costilla Valley, near the mouth of Rito del Sanchez. Northwest from the mouth of Rito del Sanchez, and approximately 1 mile south of Rita de los Cedros, the Amalia formation appears to overlap onto Precambrian granite and metamorphic rocks.

The upper beds of the formation grade into, or are overlain by, thick Tertiary gravels. The contact between the two formations is obscured by valley alluvium and slumped gravel material; however, the strike and dip of the formation are similar, and there is some indication that the upper beds of the Amalia formation may grade into the Tertiary gravels. South and east of Costilla, the Amalia formation is overlain unconformably by Quaternary-Tertiary basalt flows, which are believed to be equivalent to the upper basalts of the Hinsdale formation de-scribed by Whitman Cross and E. S. Larsen, Jr. (1935).

The Amalia formation includes interbedded arkosic sedimentary rocks, basalt flows, and rhyolite tuffs. Beds and flows in the formation are often lenticular and irregular. The total exposed thickness is approximately 2,000 feet.

Thick flows of olivine basalt, in places amygdaloidal, are found near the base of the formation. Beds of siltstone, tuff, and pumice, 50-200 feet thick, lie above the basaltic rocks. A 50- to 150-foot layer of welded tuff (Trt) lies above the bedded siltstones and tuffs. This unit is silicified and forms conspicuous outcrops for more than 7 miles along the strike. The welded tuff is overlain by 200-600 feet of semiconsolidated sandstone and conglomerates, which are interbedded with tuffs and, near the top, with thin basalt flows.

The Amalia formation is believed to be of mid-Tertiary or late-Tertiary age. The formation, as described above, does not extend south of the Box Canyon of the Rio Costilla. However, breccias, basalt flows,

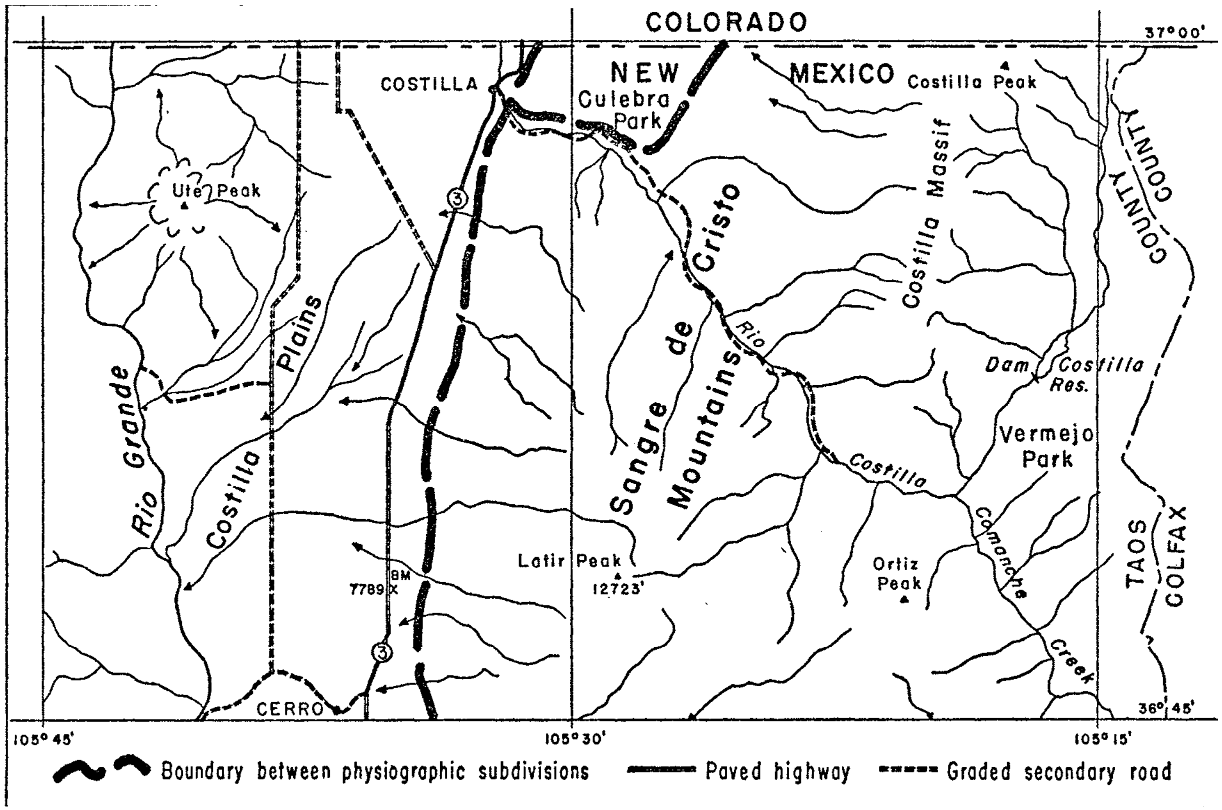

Figure 1

INDEX MAP OF PHYSIOGRAPHIC SUBDIVISIONS OF COSTILLA AND LATIR PEAK QUADRANGLES and thick rhyolite tuffs found in scattered exposures in the southern parts of Costilla and Latir Peak quadrangles, and mapped as part of the volcanic units, are believed to have been deposited contemporaneously with the Amalia formation.

The Amalia formation interfingers with the andesite series, Latir Peak latite, and rhyolite volcanics, and thus is contemporaneous with the period of volcanic activity.

Granite (Tgr)

Granite is exposed along the mountain front in the southeast corner of Costilla quadrangle. The rock forms steep cliffs north of Rito Primero and along the Rito del Media. The granite is also exposed half a mile south of the mouth of Primero Canyon and along Lake Fork Creek.

The rock is a cream to light-pink, medium- to coarse-grained porphyritic granite. Orthoclase, from 2 to 8 mm in size, is the predominant feldspar, making up about 40 percent of the rock. The rest is made up of approximately 25 percent quartz, 25 percent white albite, 5 percent biotite, 3 percent hornblende, and 2 percent sphene and magnetite. Crystals of albite, biotite, and hornblende range up to 2 mm in diameter.

The age relationship between the volcanics and the granite is obscured. The granite definitely intrudes the Precambrian rocks and late Paleozoic (?) rocks. South of Rito Primero, the granite is in contact with a latite dike, which appears to have been intruded along the contact of the granite and metasediments to the east.

Along the south edge of Costilla quadrangle, in the only area where the granite and volcanic extrusives are in contact, the granite appears to intrude the Latir Peak latite.

Rhyolite porphyry dikes that crop out northeast of the granite exposures are similar in composition to the Tertiary granite and may be of the same age. These porphyry dikes cut volcanic tuff and breccias of possible mid-Tertiary age.

Monzonite Porphyry Dikes (Tmp)

Dikes of monzonite porphyry occur along Cabresto Creek on the south edge of Latir Peak quadrangle, and small porphyry dikes are scattered throughout the volcanic rocks south of Rio Costilla. The gray to dark-gray rock is usually porphyritic and is made up of orthoclase phenocrysts, one-half to 1 inch in diameter, in a coarse groundmass of white plagioclase, orthoclase, quartz, and biotite. Rounded quartz grains up to one-half inch in diameter commonly are present. The monzonite porphyry dikes cut the rhyolite conglomerate of the Amalia formation and are probably one of the youngest intrusive rocks in the area.

Late Tertiary Gravels (Tg)

Thick layers of coarse semiconsolidated gravels and sand are ex-posed along the Rio Costilla, southeast of Amalia and east of Costilla reservoir. The deposits range in thickness from a few feet to over 1,000 feet. The sediments are composed mainly of Precambrian debris, in places containing boulders up to 3 or 4 feet in diameter. The sediments lie above the Tertiary volcanics and the Amalia formation.

These sediments were derived probably from areas of Precambrian rocks which had been uplifted in late Tertiary time. They are, possibly, equivalent in part to the Santa Fe formation, which lies below the basalts in the Rio Grande depression. North of Costilla reservoir, the upper part of the sediments has been covered by glacial debris and valley alluvium.

QUATERNARY-TERTIARY ROCKS

Basalts (QTb)

Thick flows of basalt underlie the Costilla Plains. The basalt is well exposed in the Rio Grande gorge and north of Amalia to the Colorado border. The basaltic dome of Ute Peak has been included with the basalt flows on the map. Most of the basalts are rich in olivine and light to dark gray in color. The basalt has been correlated by Atwood (1932) with the basalt in the Hinsdale formation of the San Juan region.

On the plains, the basalt flows lie above and are interbedded with semiconsolidated sandstones and conglomerates. In the vicinity of Amalia, a basalt flow unconformably overlies the Amalia formation. The basalt in the Amalia area has been raised at least 400 feet above the Costilla Plains by faulting.

QUATERNARY ROCKS

Andesite (Qan)

Dikes of gray porphyritic andesite cut the Quaternary-Tertiary basalt flows. Cerro Chiflo, an east-west trending ridge along the south-west corner of the area mapped, is held up by a dikelike body of this rock.

Coarse Fan Gravels (Qg)

Layers of coarse gravels, sands, and clay extend along the front of the Sangre de Cristo Mountains. Deposits of gravels and glacial debris, which lie from a few feet to over 300 feet above the present mountain valleys, were mapped with these deposits. On the Costilla Plain, the lower fan gravels are interbedded with upper basalt flows of the Rio Grande depression.

Valley Alluvium (Qal)

Stream gravels, talus, rock glaciers, and glacial debris of the last glacial stage have been mapped as valley alluvium.

Structure

The exposed geologic structures in Castilla and Latir Peak quadrangles consist of gently dipping basalts and gravels, on the west, and the complex Sangre de Cristo Mountains, on the east. The two areas are separated by a normal fault zone, which trends N. 10° E. and dips steeply to the west. The western basalt-covered block has been lowered over 7,000 feet along this fault.

The Sangre de Cristo Mountains form a narrow band 20-40 miles wide and over 200 miles in length, which extends from east of Santa Fe north into Colorado. In the area of this report, a thrust fault lies along the eastern edge. Along this thrust, the metamorphic rocks have been moved eastward over Paleozoic and Mesozoic sedimentary rocks.

The Costilla massif is a 12-mile-long and 5-mile-wide block of Precambrian rocks, which has acted as a structural high since the Precambrian. The Latir Peak volcanic area consists of layers of tuffs and flows that are intruded by latite sills and dikes and that were piled upon the Precambrian rocks.

FOLDS

Precambrian rocks were folded along a N. 70° E. and a N. 20° W. axis. Rocks which were folded along the N. 70° E. axis are well exposed on the south end of the Costilla massif, north of the mouth of Comanche Creek. The folding along the N. 20° W. axis is best preserved south of Rito Primero, where thick layers of Cabresto quartzite and biotite-muscovite gneiss occur in isoclinal folds.

The extent of Paleozoic and Mesozoic folding is difficult to determine because of the thick layers of poorly stratified volcanic rocks, Tertiary faulting, and limited exposures where sedimentary rocks crop out. Formations which were folded in post-Precambrian time are ex-posed along the eastern edge of Latir Peak quadrangle. In this locality, beds as young as upper Cretaceous have been overturned along an approximate N. 20° E. axis. This folding apparently was associated with the eastward thrusting of the Precambrian rocks.

FAULTS

The rocks in the Sangre de Cristo Mountains are intensely faulted and fractured. The faults may be divided into thrust faults, shear zones, and normal faults.

THRUST FAULTS

The principal thrust of this part of the Sangre de Cristo Mountains lies east of the east boundary of Latir Peak quadrangle. A small fenster exposes Paleozoic rocks east of Comanche Creek, along Rito de Juan Ballejos. The thrust plain trends roughly N. 20° E. and dips at a low angle to the west. C. B. Read has mapped the extension of this thrust across the Moreno Valley, south of the area covered in this report, and north into Colorado.

The thrusting is mainly late Cretaceous and early Cenozoic in age. Precambrian thrusting may be present but is difficult to trace, as in many areas the rocks are displaced and broken by Tertiary intrusives and faulting. Displacement and exact age of the thrusting could not be determined in the area covered by this report.

The difference in structure within the Precambrian rocks east of the Costilla massif indicates that a thrust fault may trend along the Rio Costilla. South of the mouth of Comanche Creek, any indication of this faulting in the older rocks is hidden by the Tertiary volcanics.

SHEARS

Zones of mica schist or mylonite occur in isolated exposures throughout the Precambrian rock outcrops. Often these zones are parallel to the schistocity of the metamorphic rocks, but, as on the west side of the Costilla massif east of Amalia, may cut at right angles to the structure in the enclosing rocks. The zones of mylonite schist probably were formed along shear and thrust faults in late Precambrian time.

Two fault zones, one north of Rito de la Jara and the other north of Little Latir Creek, are indicated by recrystallized mylonitic schist. Both faults trend N. 60° E. and dip 30-50 degrees to the northwest. The trace of the faults cannot be followed to the east, because of the younger rock cover. Drag folds in the fault near Rito de la Jara indicate that the northwest side of the fault moved down and to the southwest, relative to the southeast side.

NORMAL FAULTS

The Sangre de Cristo Mountains have been elevated and tilted east-ward along a zone which approximately parallels the present position of the western mountain front. The evidence of a fault zone along the mountain front is based on faceted ridges, the steplike nature of the topography along the front, and exposures of downfaulted volcanic rocks near the mouth of Rito Primero. The amount of throw along this zone is estimated to be over 7,000 feet. A geophysical survey by the New Mexico Institute of Mining and Technology conservatively estimated that bedrock is over 3,000 feet below the surface of the Costilla Plains. This figure, added to the more than 4,000 feet from the base of the mountains to the top of Latir Peak, gives a rough estimate of the vertical displacement of the late Tertiary erosion surface. The latest displacement along this fault zone is well developed east of the village of Costilla, where the Quaternary basalt flows are broken. The normal faulting along the west mountain front trends north, but may strike locally about 20 degrees to the west or east of north.

Normal faults, which in general trend from N. 40 ° W. to N. 40° E.

and dip steeply to the east or west, occur throughout the Sangre de Cristo Mountains. These faults were formed mainly in the late Tertiary and Pleistocene. Some of the faulting undoubtedly was contemporaneous with the block faulting along the front of the mountains. However, many of the faults probably were formed by forces caused by the intrusion of the Tertiary dikes and sills. Many of these faults could be traced only short distances. For the location, distance exposed, and attitude of individual faults, the reader is referred to the geologic map.

A northward striking normal fault is exposed east of the top of the Costilla massif and is probably one of a series of breaks along which the massif has been uplifted in the Tertiary. The steep dip of Tertiary gravels and volcanics toward the Costilla massif on the west and south-east indicates the presence of normal faults in these areas. South and southwest of the Rio Costilla, several northward trending normal faults are exposed, which have elevated areas of Precambrian rocks. The westernmost fault extends for over 4 miles along the divide west of Rito del Sanchez and has carried the volcanic rocks down against Precambrian granite.

STRUCTURAL FEATURES OF METAMORPHIC ROCKS

Structures of the metamorphic rocks are badly broken in places by Tertiary faulting; therefore, Precambrian structural features are difficult to correlate from exposure to exposure. The Costilla massif, however, was relatively stable and, consequently, was unaffected by the Tertiary deformation. Different structural trends in the metamorphics are recognizable between areas of Precambrian rocks in the Costilla massif south-west of Rio Costilla, along the western mountain front south of Little Latir Creek, and on the divide east of Rito de los Cedros.

In the vicinity of the massif, the foliation of the amphibolites trends N. 50 ° to 70° E. and dips steeply north or south. The strike and dip of the massive quartzite near the Colorado border, and of the quartzite exposed near Comanche Creek, suggest that the Costilla massif is a large anticlinal structure which trends N. 70° E.

The strike of the foliation of quartzite and amphibolite southwest of Rio Costilla is in general northeastward, with dips usually less than 30 degrees. Though the structural trend is similar, the abrupt change from a large anticlinal structure to gently dipping folds indicates that a fault may separate the two areas.

Along the west front of the Sangre de Cristo Mountains, south of Little Latir Creek, the metamorphic rocks are exposed in folds which trend N. 20° W. to due north. The change in structure from a northeast trend to a northwest trend probably represents a second folding of the Precambrian rocks. Additional evidence of two periods of Precambrian deformation at about right angles is shown in an outcrop of biotite gneiss on the lower Cabresto Creek. In this exposure, a series of tight folds, 6 inches to 1 foot across, trend N. 60° E. These folds, in turn, are folded along a N. 40° W. axis that plunges 10-20 degrees to the southeast.

On the divide east of Rito de Ios Cedros, banding in the Precambrian quartzite trends N. 55° E. and dips 60° N. The trend and dip are fairly consistent along the north-south divide, but as the quartzite is followed along strike to the west, it is badly broken and contorted. In one exposure to the west, the quartzite contains small folds whose axes strike N. 5 ° W. and dip 25° W.

STRUCTURAL FEATURES OF SEDIMENTARY ROCKS

The structural history of the sedimentary rocks is incomplete be-cause the outcrops are small and scattered. Sandstone and conglomerate beds that underlie the large thrust probably are overturned. Though the isolated exposures strike from west to northeast, the trend of the Sangre de Cristo formation is about 10° E., the dip of the overturned beds ranging from 20° to 65° W.

The early Tertiary (?) sediments near Latir Peak strike N. 20°-30° W. and dip 70°-75° E. Sediments in the vicinity of Rio de los Yutas trend northeast and dip from 30° W. to 30° E.

Sandstone and conglomerate beds in the Amalia formation usually trend N. 10° W. to N. 15° E. and dip 20°-35° E. A strike of N. 40 ° E. and dip of 40° W. on the Rito de los Cedros are caused by drag along a normal fault.

STRUCTURAL FEATURES OF VOLCANIC ROCKS

Structural features of the volcanic rocks are obscure. The andesite breccias contain a few sandy layers that may indicate the strike and dip, but the andesite flows contain no internal clues to the trend of the formation. Elongated pumice fragments may give an approximation of the attitude of the rhyolite tuff. The Amalia formation contains enough bedded sediments so that its attitude is apparent in most exposures. In general, the Tertiary volcanics strike roughly north and usually dip to the east. Dips usually range from 25 degrees to 30 degrees; the steeper dips up to 80 degrees are probably the result of locally tilted fault blocks.

Alteration and Metamorphism

In general, the metamorphism of the Precambrian rocks is of low or medium grade. The metamorphic process which produced the mineral assemblages was, first, regional in nature and, second, confined to local thermal effects near the Precambrian granite. The regional metamorphism granulated and recrystallized the Precambrian volcanic and sedimentary rocks into amphibolites, quartzites, and schists.

The intrusion of Precambrian granite into the older rocks locally raised the temperature, and higher grade metamorphic rocks were formed. Zones of migmatite were developed in the amphibolite *by* the soaking and lit-par-lit intrusion of granitic materials. The higher ternperature and, possibly, introduction of water vapor from the granite magma produced areas of coarse quartz-mica gneiss within the quartzite. Muscovite flakes as large as inch in diameter were formed near granite bodies. Also, sillimanite and locally tourmaline were formed in the mica schist and quartzites. Epidote is common in the amphibolite and hornblende schists. The epidote is disseminated throughout the rocks and/or spreads out from fractures and quartz veins. The epidote is not common in the migmatite and is believed to be related to the pegmatite intrusive phase which followed the emplacement of the granite magma.

Mylonite zones were developed along faults in the older metamorphic rocks. Fine-grained muscovite-chlorite schist is the common rock in the mylonite zones.

Thermal metamorphism around the younger igneous rocks did not alter appreciably the intruded rocks, and is often difficult to detect. Alteration or metamorphic halos were not recognized around the Tertiary granite. The large Latir Peak latite sill baked the intruded Tertiary siltstone and basalt to a brick red up to 10 feet above the upper contact.

The volcanic rocks near the south edge of Latir Peak quadrangle were altered by late Tertiary hydrothermal solutions or gases. This alteration zone is a northeast extension of a much larger altered area, which lies south of Latir Peak quadrangle. In the altered area, the various rocks are leached and silicified. In places, a white, dense rock is formed, in which the original textures are obliterated. The alteration was con-trolled by faults and fractures. Chlorite, pyrite, kaolinite, sericite, and quartz were the principal alteration minerals formed. Quartz veins that cut or parallel many of the dikes were developed along these fracture zones.

Geologic History

The history of the oldest rocks within the quadrangles began with the extensive deposition of basic volcanic rocks upon an earlier (no longer recognizable) Precambrian surface. Interbedded with the volcanic rocks were thick beds of quartz, sand, siltstone, and clay. The thickness, extensive exposures, and purity of the presently exposed quartzite indicates that a large supply of quartz was available for long periods. The sand was free of impurities near the lower part and became increasingly more argillaceous as deposition continued. In places, organic shales were deposited. Deformation that preceded or accompanied the intrusion of the granite batholith obliterated most of the original textures and structures of the sedimentary rocks. The Precambrian rocks were deformed at least twice and extensively eroded before the deposition of Paleozoic sedimentary rocks.

The history of the Paleozoic rocks is hidden. Sedimentary rocks of questionable Paleozoic age were folded and metamorphosed during pre-Permian time. The Costilla and Latir Peak quadrangles are believed to have been stable areas throughout most of Paleozoic time. Uplift of part of the region in pre-Permian time is indicated by the conglomeratic nature of the Permian sediments. Thin beds of Mesozoic and Cretaceous rocks were probably deposited and later eroded.

During the Laramide revolution, the Precambrian rocks were thrust eastward over Paleozoic and Mesozoic rocks. Erosion during and after the Laramide deformation stripped the Mesozoic and Cretaceous rocks from above the Precambrian thrust block in the Costilla and Latir Peak area. A mature erosional surface probably was formed. In local areas, sand and gravel were deposited. During this period of erosion, the Precambrian rocks were weathered deeply.

At some time in the Tertiary, Eocene (?) or Miocene (?), andesitic and latitic pyroclastics and flows were deposited over most, if not all, of the area. Rhyolite tuffs were piled above the andesites and latites, and both units were intruded by bodies and dikes of latite. Thick flows of olivine basalt were interlaid with the rhyolite. Sand and gravel derived from a positive area of Precambrian rocks were interbedded in local areas with the rhyolite tuff and basalt. The Latir Peak area was probably the center of Tertiary volcanic activity.

Rhyolite plugs and dikes, monzonite porphyry dikes, and granite stocks were intruded near the close of the latite intrusive activity. Large blocks of the older volcanic rocks were uplifted, tilted, and in places badly fractured by the emplacement of the intrusive bodies.

In the late Tertiary, the Costilla massif was faulted up above the volcanics to the south and west. Thick fan gravels derived from the massif and other high Precambrian areas were deposited on the rhyolite tuffs and basalts. In places, the gravels contain Tertiary volcanic debris.

The Sangre de Cristo Mountains then were elevated in relation to the Costilla Plains along an extensive zone of normal faulting parallel to the present mountain front. Normal faults also were developed in the mountains. Tertiary volcanics and the late Tertiary gravels were faulted down against the Costilla massif and other areas of Precambrian rocks.

The mountains were eroded during the Pleistocene by vigorous streams. The elevation of the mountainous areas continued, and in late Pleistocene the higher areas in the mountains were glaciated. During the Pleistocene, the Rio Grande depression was covered with thick flows of olivine basalt. These basalts were interbedded with numerous gravel lenses. As the basalts covered the gravels west of the mountains, wide valleys with gravel terraces and rounded ridges were being developed in the mountains to the east. At the close of the Pleistocene, additional block faulting displaced the basalts along the mountain front. The rejuvenated streams rapidly cut sharp V-shaped valleys into the more mature Pleistocene surface, and the basalts in the Rio Grande depression were covered with several hundred feet of alluvial fan gravels.

Mineral Deposits

Most of the prospecting for ore in the area has been confined to the southern part of Latir Peak quadrangle, on the high divide south of Ortiz Peak, along Gold Creek, and on upper Bitter Creek. The district was prospected actively from 1870 to about 1900. A few prospects, how-ever, have been worked intermittently from 1900 to the present. Placer gold was discovered about 1870 in the creek gravels near La Belle, and for several years placers were the main source of the metal.

The extensive search for lode gold in the district occurred from approximately 1890 to 1904, when the mining camps of Anchor, Mid-night, and La Belle were active. The principal lode mines and prospects were the diggings on Gold Creek, the prospects west of La Belle, the What Is It claim, the Anchor mine, the Edison mine, the shaft and mine east of Midnight, and the Cashier mine.

Production figures for the mines in the area are not available; probably, the gold that was produced was credited to the Elizabethtown district in Colfax County. The small dumps and tailings piles indicate that though the prospects and tunnels are numerous, the amount of ore produced was small.

Gold was the only mineral of economic importance discovered in the district. The veins prospected are mainly within the area of hydrothermal alteration, and undoubtedly were formed during the time of hydrothermal activity. The values of the unoxidized vein material are thought to be very low, as several samples taken from prospects show only a trace of gold. Apparently, the gold was concentrated in pockets during weathering of the quartz veins. The oxidized zone is shallow, probably ranging from a few feet to not over 200 feet in thickness. The gravels along Comanche Creek have not been sampled to any extent and may contain lenses of gold-rich sand.

Four reasons probably explain the low production of the district: (1) the low gold content of the unoxidized quartz veins, (2) the narrowness of the veins and postmineral faulting, (3) the shallow oxidation zone, and (4) the high water table, which could not be controlled by the pumping equipment available to the early-day miners.

During this examination, few veins containing ore minerals were seen in Costilla and Latir Peak quadrangles. Some galena has been re-ported from outcrops of amphibolite on the west side of the Costilla massif. Iron-rich areas are found in places near the amphibolite-granite contact, but no sulphides were seen. Probably, ore deposits, if formed in the area, were eroded from above the extensive exposures of Precambrian rocks.

In general, the pegmatites are not favorable areas to prospect. An exception is the area around the Cedros pegmatite, which contains beryl, chrysoberyl, and scrap mica. Graphite is abundant in the graphite-mica gneiss exposures in the southeastern part of Costilla County; under certain economic conditions, it might be of commercial value.

Practically all the available surface water from the mountains is committed either for domestic use and local irrigation or for irrigation along the lower Rio Grande. Additional irrigation of fertile land on the Castilla Plains could be undertaken by using the underground water between the towns of Cerro and Costilla. Ground water in this area probably is perched above the gently east-dipping basalt flows; the water level ranges from 90 to 250 feet below the surface of the ground. The ground-water recharge to the area is more than 10,000 acre-feet per year; by careful pumpage of properly spaced wells, a large percentage of the land could be irrigated.

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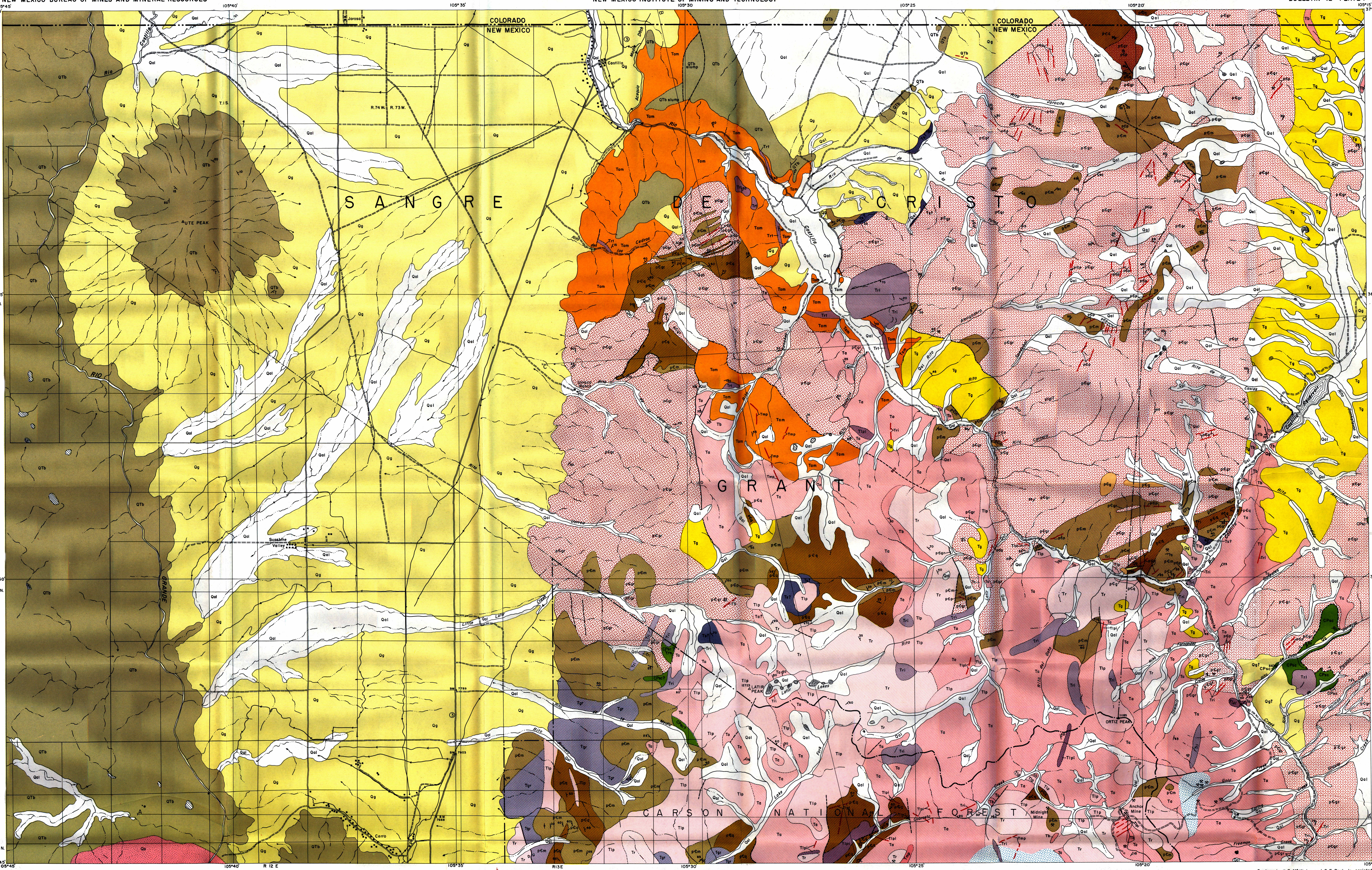
Numbers in boldface indicate main references.



Base map from U. S. Soil Conservation Service sheets 14 and 15

Geology by P. F. McKinlay and C. F. Park, Jr.; assisted by Arthur Lees, Jack Hunt, Kenneth Reim and John Schilling. Surveyed 1947–1950

EXPLANATION

QUATERNARY

Qal — Valley alluvium
Stream gravel, talus and glacial debris.

Qg — Coarse fan gravels
Gravels and sands along the mountain front and 200 to 300 feet above the present stream channels.

Qa — Quaternary andesite
Dikes of gray porphyritic andesite.

QTb — Quaternary basalt
Gray to dark gray basalt flows.

ANGULAR UNCONFORMITY

TERTIARY

Tg — Tertiary gravels
Semiconsolidated conglomerate and coarse sandstone.

UNCONFORMITY

Altered rock
Areas of hydrothermal alteration where the rock units were undifferentiated.

Tmp — Monzonite porphyry
Dikes of gray to dark green monzonite porphyry.

Tertiary volcanic complex and associated rocks
Tam, Amalia formation, *sandstone and conglomerate, basalt flows, and rhyolite tuffs.* Trt, *welded tuff layer.*
Tr, *gray to light-pink rhyolite tuffs and flows.*
Tri, *rhyolite dikes and flows.*
Tb, *olivine basalt flows.*
Tgr, *cream to light-pink porphyritic granite.*
Tlp and Tlpi, Latir Peak formation, Tlp, *light-gray to reddish andesite and latite porphyry flows or sills(?).* Tlpi, *gray andesite and latite porphyry dikes.*
Ta, *red, purple to green andesite flows, sills(?), breccias and tuffs.*

UNCONFORMITY

Ts ? — Early Tertiary(?) sediments
Gray to red sandstones, shale, conglomerates, and thin limestones.

UNCONFORMITY

CARBONIFEROUS-PERMIAN(?)

CPsc — Sangre de Cristo formation
Red arkosic shale, sandstone, and conglomerate

ANGULAR UNCONFORMITY

PRECAMBRIAN

p€g — Metagabbro
Altered gabbro and diabase dikes and stocks.

p€p — Pegmatites
White to pink in color, usually composed of quartz, microcline, orthoclase, and some muscovite with small amounts of garnet and magnetite.

p€gr — Granite
Pink to cream microcline-rich granite and granite gneiss, includes pegmatite material and some migmatite

Metamorphic rocks
p€q, Cabresto(?) quartzite, *gray to cream massive quartzite, in places layers of mica gneiss and graphite mica gneiss*
p€m, *Undifferentiated amphibolite schist and gneiss, mica schist and gneiss, quartzite and migmatites.*

Contact
Dashed where approximately located

Concealed contact

Fault, showing dip
Dashed where approximately located

High angle fault
U, *upthrown side;* D, *downthrown side*

Thrust fault
T, *upper plate*

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

Strike and dip of foliation

Strike of vertical foliation

Dry lake

Intermittent stream

Perennial stream

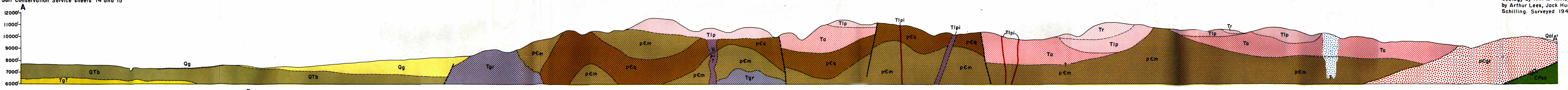
Canal

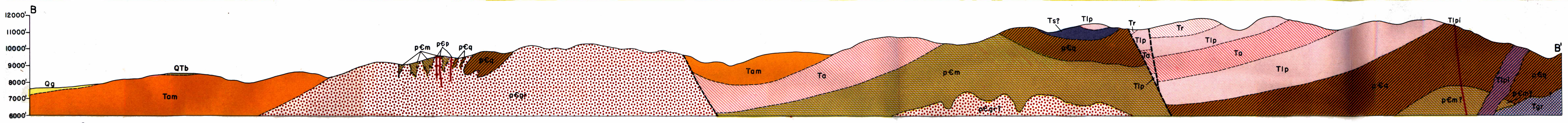
Road

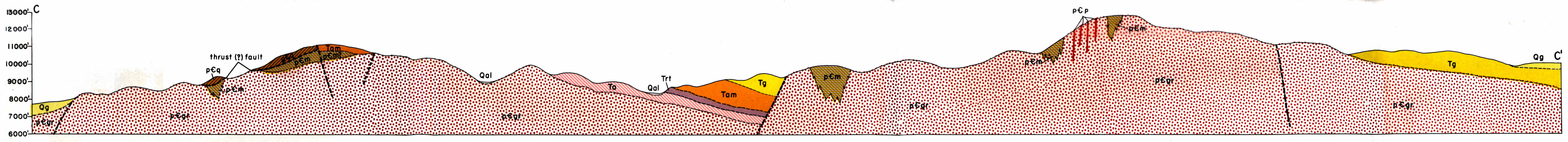
Mines or prospects

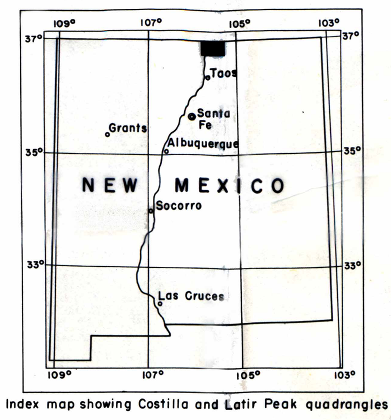
Buildings

True North — Magnetic North — $13\frac{1}{2}°$
Approximate mean declination 1950









Index map showing Costilla and Latir Peak quadrangles

GEOLOGIC MAP AND SECTIONS OF COSTILLA AND LATIR PEAK QUADRANGLES, NEW MEXICO

Scale 1:48000

0 1 2 3 miles