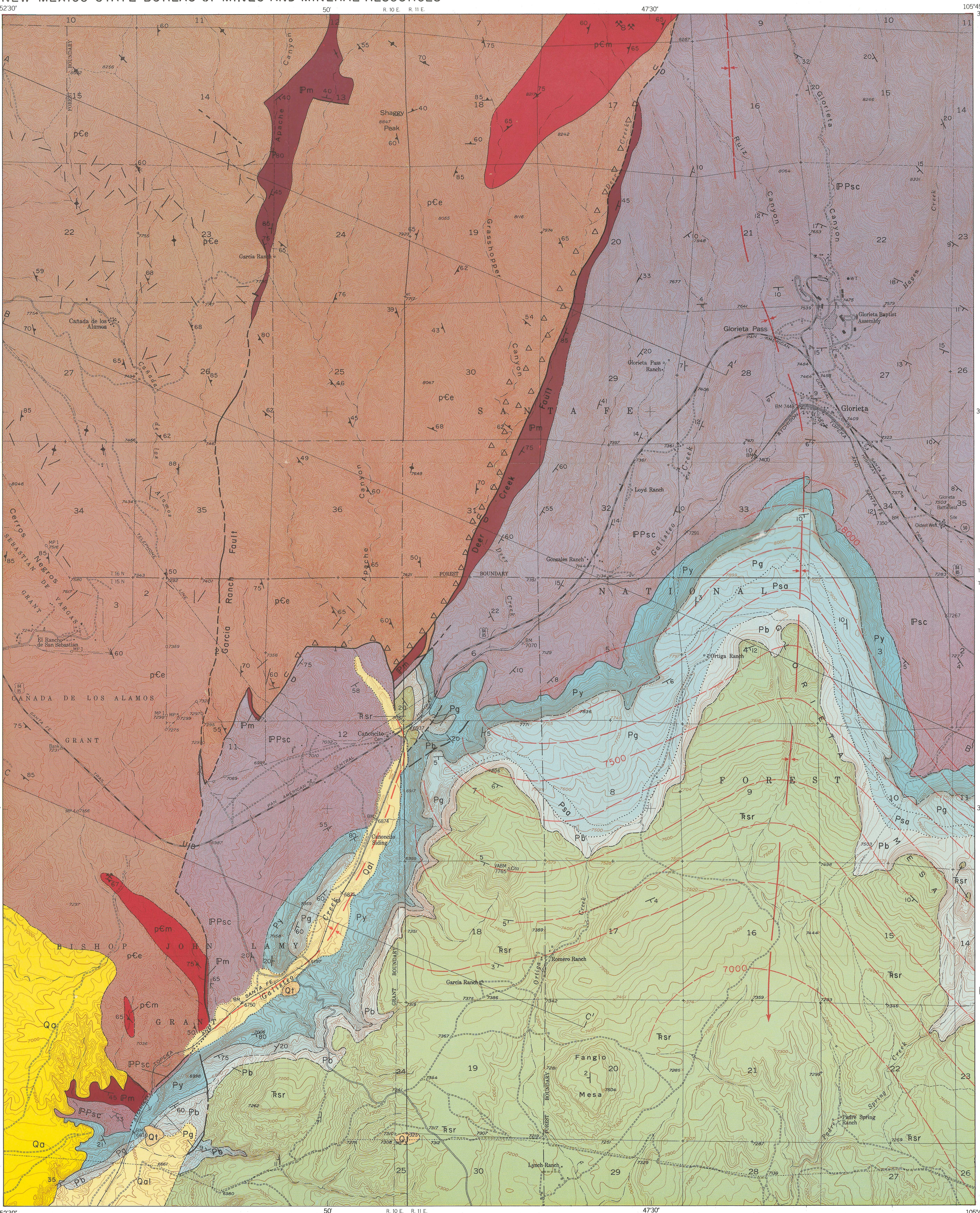


Base from U.S. Geological Survey

GEOLOGY OF THE GLORIETA QUADRANGLE, NEW MEXICO

1972

By Antonius J. Budding

Qal — Alluvium
Sand and gravel along arroyos.

Qt — Terrace deposits
Gravel and sand on erosional surfaces above present drainage.

Qa — Ancha Formation
Sand, silt, and gravel.

QUATERNARY

MAJOR UNCONFORMITY

Ŧsr — Santa Rosa Sandstone
Dark-brown, impure sandstone and conglomerate, alternating with reddish-brown mudstone; at least 200 ft. thick.

TRIASSIC

Pb — Bernal Formation
Light-red, fine-grained sandstone, 80-120 ft. in thickness.

Psa — San Andres Limestone
Dark-gray, fine-grained, argillaceous limestone, 0-20 ft. thick. Included with Glorieta Sandstone southwest of Cañoncito.

Pg — Glorieta Sandstone
Light-yellow to brown, cross-bedded, coarse-to medium-grained quartz sandstone, 80-120 ft. thick.

Py — Yeso Formation
Orange to light-brown, fine-grained, calcareous quartz sandstone, 390-460 ft. thick.

PERMIAN

IPPsc — Sangre de Cristo Formation
Dark reddish-brown mudstones alternating with brown, cross-bedded sandstone and arkosic conglomerate; thickness varies from 435 to more than 2000 ft. thick.

PERMIAN TO UPPER PENNSYLVANIAN (?)

IPm — Magdalena Group
Gray limestone and arkosic limestone, gray shale, and arkosic sandstone, at least 800 ft. thick.

PENNSYLVANIAN

MAJOR UNCONFORMITY

p€e (a, b) — Embudo Granite
Foliated, gray to pink, medium-grained granite; contains irregular bodies and veins of pink to white equigranular leucogranite and also veins of aplite and pegmatite; a: areas with numerous basic dikes (ortho amphibolites); b: brecciated granite near fault zones.

p€m
Metamorphosed sediments and basic volcanic rocks, presently biotite gneiss and plagioclase-rich amphibolite.

PRECAMBRIAN

Contact
Definite, approximate, and concealed.

Fault
Definite, approximate, and concealed. U: upthrown side. D: downthrown side.

Strike and dip of beds

Strike and dip of overturned beds

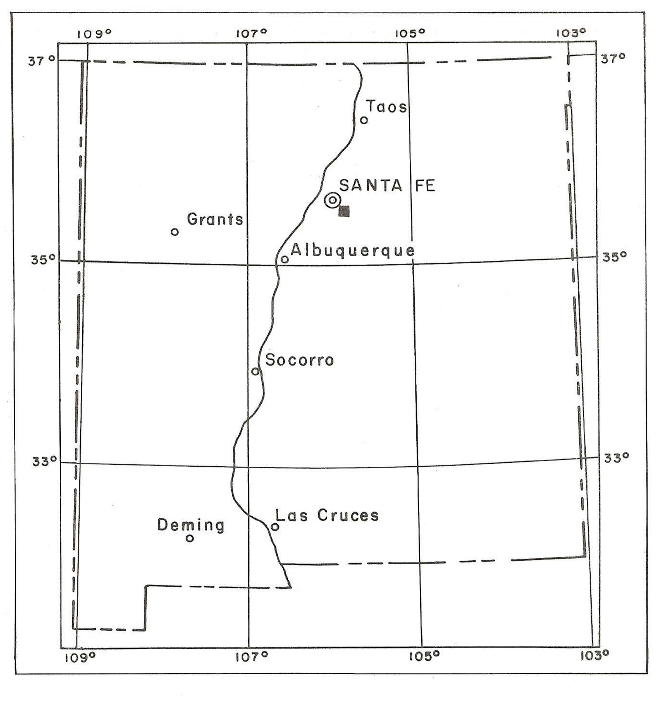
Strike and dip of foliation

Strike of vertical foliation

Structure contour line on base of Glorieta Sandstone in southeast quarter of quadrangle

Trace of syncline showing direction of plunge.

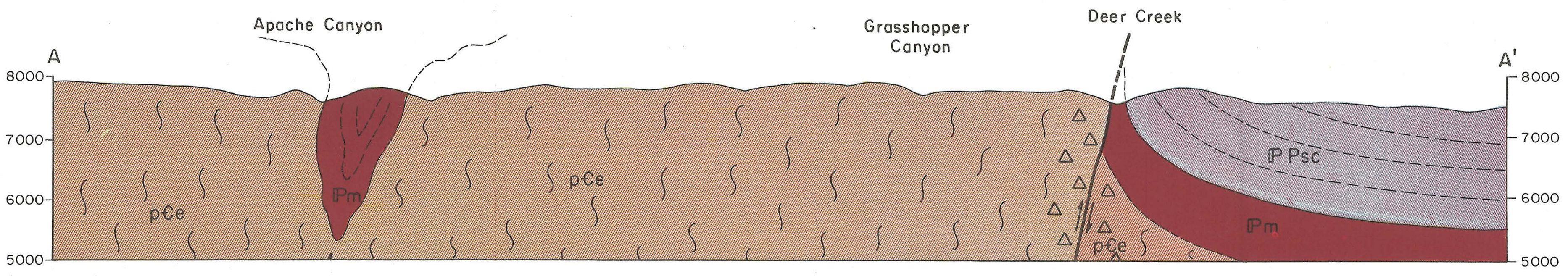
Prospect pit

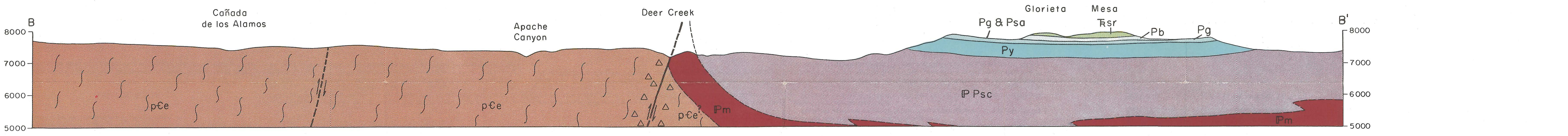


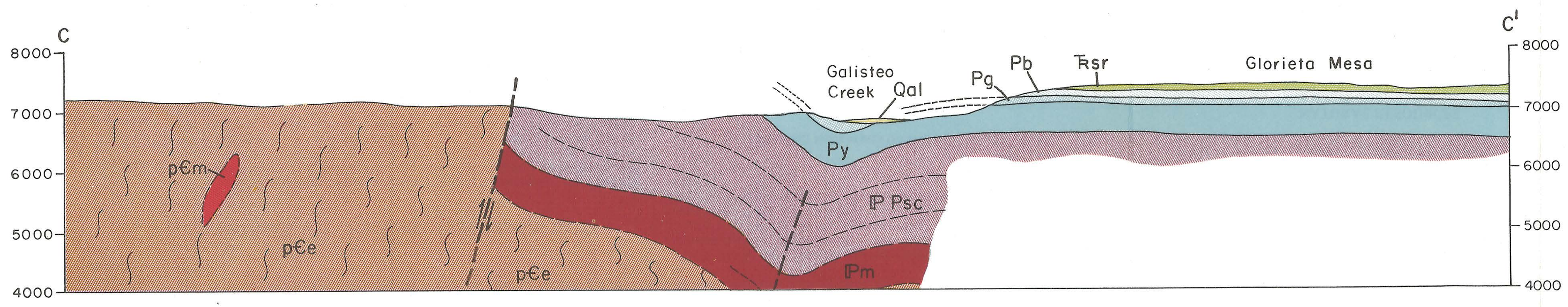
INDEX MAP OF NEW MEXICO

SCALE 1:24000

APPROXIMATE MEAN DECLINATION, 1971







ABSTRACT

The Glorieta 7½-minute quadrangle is about ten miles southeast of Santa Fe, New Mexico. Much of the western part is underlain by Precambrian rocks, predominantly granite of two main varieties: an older gneissic granite, and a younger leucogranite. Also included are remnants of metamorphosed sediments and volcanic rocks, basic dikes, pegmatites, and aplites. Faulting along north-northeast fractures may have already taken place in Precambrian time. One, the Deer Creek Fault, is most likely the southern continuation of the Precambrian Picuris-Pecos fault traced for 53 miles to the north in the Sangre de Cristo Mountains. Marine limestones, sandstones, and shales of the Magdalena Group were deposited in late Paleozoic time. At the close of the Pennsylvanian Period, and continuing throughout the Permian and Triassic Periods, however, sedimentation was mostly terrestrial and littoral resulting in the deposition of the Sangre de Cristo Formation, Yeso Formation, Glorieta Sandstone, Bernal Formation, and Santa Rosa Sandstone. Beginning at the end of the Mesozoic Era and continuing into the Tertiary, both the Precambrian basement rocks and the overlying sedimentary strata were deformed; Precambrian faults were rejuvenated, and folding and faulting occurred in the bedded rocks. Prospects for copper, titanium, and iron are restricted to the remnants of metamorphosed Precambrian sediments and volcanics. Abundant pegmatites have failed to provide minerals of economic importance.

INTRODUCTION

The Glorieta quadrangle is about 10 miles southeast of Santa Fe, in Santa Fe County, and is bounded by lat. 35°30′ and 35°37′30″ N. and long. 105°45′ and 105°52′30″ W. Highways providing access to the area are U.S. 64, 85, Interstate 25, and New Mexico 50. Numerous gravel and dirt roads branch off these main arteries, south to Glorieta Mesa, and north to the Sangre de Cristo Mountains. Road conditions vary but nearly all can be negotiated by truck or four-wheel drive vehicles.

The main drainage course is Galisteo Creek with headwaters to the north. Important tributaries are Deer Creek, Grasshopper Canyon, Apache Canyon, and several smaller unnamed canyons. Drainage of the northwestern portion is by way of Cañada de los Alamos, which joins Galisteo Creek outside the map area. The area east of Glorieta Pass in the northeast is drained through Glorieta Canyon to the Pecos River.

Previous mapping, particularly by Read and Andrews (1944), indicated a zone of structural complexity along Galisteo Creek. This zone may be a southern continuation of the Picuris-Pecos fault zone farther north (Miller, Montgomery, and Sutherland, 1963). Mapping of adjacent quadrangles to the west by Baldwin and Kottlowski (Spiegel and Baldwin, 1963) shows Precambrian and Paleozoic rocks in the Santa Fe area. These rocks are also extensively exposed along the Pecos River to the east, where 2,800 feet of Pennsylvanian rock have been measured (Sidwell and Warn, 1953).

U. S. Forest Service aerial photographs (1:20,000 scale) were useful in locating roads and outcrops and for tracing geological contacts.

The author is indebted to several organizations and individuals for assistance and advice. Glorieta Baptist Assembly provided camping space; and its director, Dr. E. A. Herron, took a keen interest in the progress of the field work. Several undergraduate and graduate geology students of New Mexico Institute of Mining and Technology assisted in field mapping and laboratory studies.

Dr. Alistair M. Reid II, Texaco, Inc., identified some of the Pennsylvanian fossils.

PRECAMBRIAN ROCKS

Rocks of Precambrian age crop out extensively in the northwest half of the quadrangle. Most are granitic in composition, with accompanying dikes and veins of pegmatite and aplite. The granitic rocks consist of an older, gneissic biotite granite, cut by irregular bodies of a more massive leucogranite, poor in dark constituents. Small remnants of pre-granitic rocks, sedimentary and volcanic, occur in different stages of assimilation by the granite.

Basic dikes originally of gabbroic composition, but now represented by orthoamphibolites, are numerous in some parts of the quadrangle. These dikes postdate the foliated granite, but are, in turn, intruded and metasomatized by veins of the leucogranite.

The crystalline rocks are assigned a Precambrian age on the basis of their general nature and similarity to Precambrian rocks in northern New Mexico. They form part of the extensive Precambrian belt underlying much of the Sangre de Cristo Mountains (Dane and Bachman, 1965).

Metamorphosed Sediments and Volcanics

Two distinct bodies of metamorphosed supracrustal rocks (formed at or near the surface of the earth, as sediments and volcanic rocks) are present. The largest, occupying a surface area of about one square mile, is located in secs. 8, 17, and 18, T. 16 N., R. 11 E., between Grasshopper Canyon and Deer Creek. A smaller mass of approximately a quarter of a square mile occurs in sec. 14, T. 15 N., R. 10 E. (unsurveyed).

In the northern exposures, the predominant rock is fine-grained, dark-green, foliated (northeast trend) amphibolite or hornblende schist. The major mineral constituents are bluish-green hornblende and andesine. Quartz occurs as thin lenses or layers of grains with undulatory extinction. Epidote in idioblastic grains is fairly common. Chlorite is a minor alteration product of the hornblende; sphene and opaque iron minerals are accessory constituents.

Some amphibolites display lenticular aggregates, 0.5 centimeter in length, consisting of quartz, plagioclase, and epidote (fig. 1, at rear). Their abundance and size suggest remnant amygdaloidal cavities in metamorphosed volcanic rocks. The small grain size of the amphibolites, less than one millimeter, also suggests volcanic origin. The original rocks may have had andesitic or basaltic composition.

Interlayered with the hornblende-bearing rocks are mica schists and gray quartzites, which represent thin beds of metamorphosed clastic sediments, deposited with the volcanic rocks. The presence of potassium feldspar in the amphibolites in the vicinity of cross-cutting granitic veins indicates a pre-granitic age for this group of rocks.

The southern remnant of metamorphic rocks has a northwest foliation trend, and shows intrusive borders with the granite. Amphibolite and biotite gneiss are the predominant rock types, but amphibolites with plagioclase aggregates are also exposed. The aggregates are lensoid; and the rock is an augen amphibolite. The augen are 1 to 5 centimeters long, rounded to ellipsoidal, and mainly consist of plagioclase (fig. 2, at rear). The matrix is amphibolitic mostly with bluish-green hornblende, basic plagioclase (An_{60}-An_{70}), and quartz. Augen-bearing layers alternate with amphibolites of more normal texture.

Fig. 3 shows the mineral composition of amphibolites and augen amphibolites, the latter being considerably richer in plagioclase. Quartz is a subordinate constituent of the amphibolites. Accessory minerals are apatite, sphene, and opaque iron minerals. Epidote, biotite, chlorite, and prehnite occur in minor amounts.

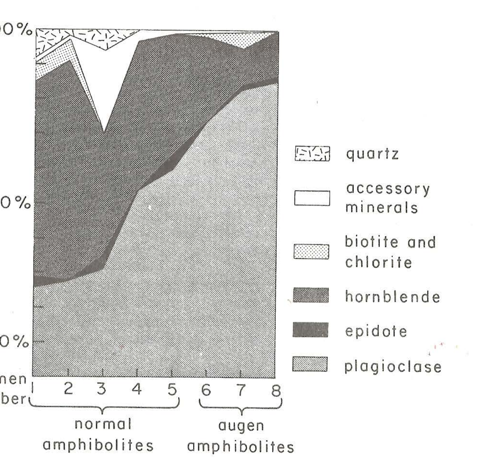


Fig. 3—Modal composition of amphibolites. Augen amphibolites are richer in plagioclase than normal amphibolites and contain as much as 85 percent plagioclase. Specimen 3 is unusual, in that it comes from a mineralized amphibolite rich in sphene and opaque minerals.

The unusual texture of the augen amphibolite is believed to be a preserved primary structure, which consisted of plagioclase aggregates in a basaltic groundmass. Such plagioclase clusters have been described by Baragar (1960, p. 1596) from basaltic rocks and gabbro sills of the Labrador trough in Canada. In the so-called "blotchy basalt," plagioclase aggregates as large as 5 centimeters were noted, whereas in the sills these aggregates attain a maximum size of 15 centimeters. The origin of the plagioclase clots is ascribed by Baragar to partial melting of the mantle, forming a magma with suspended plagioclase crystals.

The plagioclase aggregates in the augen amphibolites may have originated similarly. Metamorphism of the basic flows or shallow sills deformed the aggregates into lens-like shapes and obliterated any compositional difference between plagioclase of the groundmass and the aggregates. A pyroclastic interpretation of the aggregates is not favored, because of the extreme difference in composition between the groundmass and the aggregates; such a compositional difference usually does not exist in a volcanic agglomerate.

Several smaller remnants of metamorphosed supracrustal rocks occur within the granite comprising the major part of the Precambrian of the Glorieta quadrangle. These smaller inclusions show extreme effects of assimilation by the granite.

The presence of metamorphosed sedimentary and volcanic rocks in the Precambrian of the Sangre de Cristo Mountains has been reported by Montgomery (1953) and Miller and others (1963). They subdivided the Precambrian metasediments and metavolcanics into a lower unit, the Ortega Formation, unconformably overlain by the Vadito Formation. The latter contains an upper member of schist, phyllite, and amphibolite. The supracrustal rocks in the Glorieta quadrangle may represent equivalents of the Vadito Formation, but are of higher metamorphic grade (amphibolite-facies metamorphism).

Plutonic Rocks

Most of the Precambrian of the Glorieta quadrangle consists of rocks of granitic composition resembling the Embudo Granite. The main rock type is a gneissic granite, but a younger, even-grained, more leucocratic granite also occurs; pegmatites and aplites in lenses and veins are widely distributed. The gneissic granite is intruded by basic dikes, which in turn, are older than the leucogranite.

Gneissic Granite

The gneissic granite is medium to coarse grained, foliated, and pink to tan, consisting mainly of quartz and feldspars. Biotite and muscovite are the major dark minerals. This granite weathers to rather bold forms. Outcrops, therefore, are plentiful, particularly in canyon bottoms and along intervening ridge tops. Flat areas and canyon slopes are covered by light-brown grus, a loose aggregate of quartz and feldspar grains and highly-weathered granite fragments. Characteristically, oriented fabric is prominently developed, giving the rock the appearance of an augen gneiss in places.

Quartz, with undulatory extinction, comprises 32 to 39 percent of the rock by volume. Subhedral grains of plagioclase (composition near An_{15}) forms 22 to 30 percent of the rock. The gray varieties of foliated granite are richer in plagioclase, almost to the exclusion of potassium feldspar. Anhedral grains of microcline, with cross-hatch twinning, constitute 26 to 32 percent of the rock. The dark mineral is predominantly brown biotite; muscovite is a minor constituent. Calcite, epidote, chlorite (chlorite being an alteration product of biotite), allanite, apatite, sphene, and opaque minerals are accessory constituents.

Basic Dikes

Dikelike bodies of basic composition cut across the foliated granite. These basic dikes are dark green to gray, mottled, coarse to medium grained, mainly green hornblende and basic plagioclase, with a blastophitic texture. The dikes are orthoamphibolites derived from an igneous rock as diabase. The cross-cutting relationships of these orthoamphibolites, with respect to the foliated granite, are well exhibited in a small tributary of Apache Canyon, in the north half of sec. 1, T. 15 N., R. 10 E.

Major mineral constituents are bluish-green hornblende and plagioclase (An_{30} to An_{45}). A small amount of quartz is usually present, together with rare epidote, sphene, ilmenite, and apatite. Potassium feldspar, and biotite with a greenish tinge are more abundant with increasing proximity to leucogranite.

Leucogranites

Even-grained granitic rocks without a directional texture and poor in dark constituents occur as irregular veins and bodies in the gneissic granite and also crosscut the basic dikes as anastomosing veins. No attempt has been made to distinguish between gneissic granite and leucogranite on the geological map.

Major mineral constituents of the leucogranite are quartz (28 to 35 percent), microcline (15 to 48 percent), and plagioclase (22 to 52 percent). Plagioclase shows normal zoning with a core of oligoclase and an albitic rim. Less than 5 percent of the rock consists of minerals other than quartz and feldspars, including biotite, chlorite, opaque iron minerals, sphene, epidote, and apatite. Introduction of potassium into the basic dikes may be responsible for the appearance of microcline and increase of biotite in the amphibolites near leucogranite dikes.

Pegmatite and aplite veins are common throughout the Precambrian granite masses. Whether these bodies are related to the foliated granite or to the leucogranite is not clear. Black tourmaline and large crystals of colorless mica are the only noteworthy minerals in the pegmatite, besides, quartz and feldspars.

Relationship of Precambrian Units

The relics of metamorphosed supracrustal rocks, mostly of volcanic derivation, are almost completely surrounded by the gneissic granite, which postdates the metamorphic rocks. After the crystallization of the gneissic granite, fracturing of the crust allowed the introduction of basic igneous rocks in the form of dikes. A second period of generation of granitic melts formed the leucogranite, and caused mineralogical changes in the basic dikes, such as introduction of potassium feldspar and alteration of the magnesium and iron minerals to biotite. In the southwestern Sangre de Cristo Mountains, two periods of granite emplacement appear to have been separated by intrusion of basic dike rocks.

Miller, Montgomery, and Sutherland (1963) noted the presence of several varieties of granite, grouped as Embudo Granite. Montgomery (1953) considered the different types as related to a common magma source. Because a definite time interval seems to have elapsed between the formation of the older, gneissic granite and the younger leucogranite, during which the basic dikes were intruded, the name Embudo Granite should be restricted to one of the granitic types. Radiometric age dating of the granite varieties would help in unravelling the Precambrian history of the southern Sangre de Cristo Mountains.

PENNSYLVANIAN ROCKS

Pennsylvanian deposits are at least 750 feet thick in the Glorieta quadrangle and are assigned to the Magdalena Group. Predominant lithological types are arkosic limestone, poorly-sorted arkosic sandstones, micaceous sandstone, and rarely exposed black to red shales. The main areas of outcrop are along the upper part of Apache Canyon, along Deer Creek, and near Galisteo Creek, about two and one-half miles north of Lamy.

Miller, Montgomery, and Sutherland (1963) assigned a Morrowan to early Desmoinesian age to the upper part of the section northeast of Lamy, where the Pennsylvanian is unconformably overlain by the Sangre de Cristo Formation. Needham (1937) described fusulinids of Upper Magdalena Group affiliation from arkosic limestones north of Cañoncito.

Alistair M. Reid identified fusulinids from an arkosic limestone and a bryozoan limestone, collected in SE¼, sec. 23, T. 16 N., R. 10 E. The fusulinids in the arkosic limestone are an unnamed species of *Triticites* of early to middle Virgilian age. The bryozoan limestone contains abundant late Virgilian *Triticites.*

PENNSYLVANIAN-PERMIAN ROCKS

An unconformable contact between the Magdalena Group and the overlying Sangre de Cristo Formation is indicated by limestone pebbles in the lower sandstones of the

(continued on reverse side -- lift this corner)

Sangre de Cristo Formation. In the field, however, no angularity was observed along the contact between the two formations. Tectonic activity in the region prior to Sangre de Cristo time seems to have been localized tilting and broad uplift, as shown by the outcrops east of the Glorieta quadrangle and southwest of Las Vegas where the Sangre de Cristo Formation rests directly on Precambrian rocks.

In the Glorieta quadrangle, the Sangre de Cristo Formation is a typical red-bed sequence of dark maroon silts and mudstones, with intercalated brown, cross-bedded sandstones and arkosic sandstones. The sandstones are highly discontinuous, and beds as thick as 20 feet wedge out laterally in a few hundred feet.

The Sangre de Cristo Formation is extensively exposed in the mountains of northern New Mexico and southern Colorado, and was formed as a floodplain deposit on the flanks of the late Pennsylvanian positive areas.

The Sangre de Cristo Formation is estimated to be over 2,000 feet thick near Glorieta, but only 435 feet is present along Galisteo Creek, three and one-half miles southwest of Cañoncito.

PERMIAN ROCKS

Yeso Formation

The Yeso Formation, which conformably overlies the Sangre de Cristo Formation, consists of a sequence of siltstones and fine- to medium-grained, slightly calcareous quartz sandstones. These rocks form a prominent slope on Glorieta Mesa and crop out below the more resistant Glorieta Sandstone. The lower 75 feet of the formation are orange, changing to a light orange to light brown in the upper part of the sequence. In SW¼ sec. 13, T. 15 N., R. 10 E. (unsurveyed) the Yeso Formation has been folded and the sandstones traversed by numerous silicified fractures, causing the formation to stand in relief (fig. 4, at rear).

The Yeso Formation varies in thickness from 460 feet south of Glorieta to 390 feet northeast of Lamy. Needham and Bates (1943, p. 1662) reported a thickness of 301 feet for the Yeso Formation in Glorieta Mesa one mile west of the village of Rowe in western San Miguel County.

Glorieta Sandstone

The Glorieta Sandstone, prominently capping much of Glorieta Mesa, rests conformably on the Yeso Formation. The sandstone is massive and thick bedded and consists of well-rounded, coarse- to medium-grained quartz with a siliceous and ferruginous cement. Locally, the amount of oxidic iron minerals increases considerably, and rounded aggregates of magnetite up to one inch in diameter are present. Cross bedding is widely observed; pebble beds contain fragments composed of quartz, chert, and rare limestone.

The combined thickness of Glorieta Sandstone and overlying San Andres Limestone varies from 140 feet near the town of Glorieta to 80 feet northeast of Lamy. Needham and Bates (1943) designated and measured a type section of the Glorieta Sandstone one mile west of Rowe, San Miguel County, where 136 feet of Glorieta Sandstone is exposed.

San Andres Limestone

Only a thin remnant of this limestone is present with about 20 feet of dark-gray, impure, silty limestone cropping out on Glorieta Mesa. The limestone is poorly exposed; and as it becomes more silty to the west, has not been mapped as a separate unit southwest of Cañoncito, but has been combined with the underlying Glorieta Sandstone.

Bernal Formation

Resting conformably on the San Andres Limestone is a sequence of light-orange to red, fine-grained sandstone and siltstone, here assigned to the Bernal Formation (Bachman, 1953). This formation, formerly known as the upper clastic member of the San Andres Formation, is poorly exposed; thickness varies from about 120 feet on Glorieta Mesa to 80 feet in the southwestern part of the quadrangle.

TRIASSIC ROCKS

Underlying most of Glorieta Mesa, and consequently much of the southeast part of the map area, is the Santa Rosa Sandstone, a sequence of dark-brown, thick-bedded, conglomeratic sandstones and intervening mudstones. These rocks disconformably overlie the Bernal Formation. The sandstones are characterized by their unsorted character, quartz pebbles in the conglomeratic layers, and silicified wood fragments.

CENOZOIC ROCKS

Ancha Formation

In the extreme southwest corner of the quadrangle, sands and gravels of the Ancha Formation unconformably overlie older rocks ranging in age from Precambrian to Permian. These outcrops are the eastern extent of the thick Santa Fe Group and younger rocks underlying the Rio Grande structural depression to the west.

Spiegel and Baldwin (1963) raised the Santa Fe Formation to group status, and separated a lower clastic unit, Tesuque Formation, from an unconformable overlying sand and gravel unit, the Ancha Formation. Galusha and Blick (1971, p. 78) consider the Ancha Formation Pleistocene in age, and do not include these beds in the Santa Fe Group. The Ancha Formation is extensively present in the Seton Village quadrangle to the west. Here, the Ancha is in depositional contact with Precambrian rocks. Its main lithological characteristics are the arkosic nature of the sandstones and the presence of gravel lenses.

Gravels

Terrace deposits, made up of rounded granite and metamorphic rock pebbles and cobbles, occur in several widely-scattered places. Near the northeast corner of sec. 25, T. 15 N., R. 10 E. a small gravel patch overlies Santa Rosa Sandstone at an elevation of 7,300 feet. Gravels of similar type, usually weathered and unconsolidated, occur on the divides between canyons in the western part of the map area underlain by Precambrian rocks. These gravel patches and remnants may represent a northeastern continuation of an old erosion surface, named Plains surface by Spiegel and Baldwin (1963). This surface has a slope varying from 50 feet per mile to 140 feet per mile near the mountains. In the southwest part of the Glorieta quadrangle, a similar surface has a southwest slope of 150 feet per mile, increasing to a south slope of 260 feet per mile in the northwest part of the quadrangle.

Recognition of old erosion surfaces may be an important clue to the superimposed origin of Galisteo Creek. In its lower reaches in the quadrangle at W½ sec. 23, T. 15 N., R. 10 E. (unsurveyed) the sinuous course of this creek is through a steep-walled canyon of Precambrian granite, although much less resistant sedimentary rocks occur a short distance to the southeast. In this vicinity, Galisteo Creek must have incised its course into the resistant Precambrian rocks from some higher level, probably the erosion surface mentioned above.

Small remnants of terrace gravel and alluvium occur from 20 to 40 feet above the present drainage. Alluvial sands and gravels fill the bottom of most canyons; on the geologic map, only the more extensive and continuous cover of alluvium has been indicated.

TECTONICS, METAMORPHISM, AND IGNEOUS ACTIVITY

The southern part of the Sangre de Cristo Mountains has undergone several periods of deformation, some of which were accomplished by regional metamorphism and igneous activity. Within the Glorieta quadrangle, geologic evidence indicates (1) tectonism and magmatic activity during Precambrian time, (2) tectonic activity during late Paleozoic time, and (3) tectonic deformation beginning at the end of the Mesozoic Period.

Precambrian tectonism created regionally-metamorphosed rocks from pre-existing sediments and volcanics, accompanied and followed by granitic and gabbroic magmatism. Faulting took place later when the rocks were more brittle. Tectonic activity during the late Paleozoic was epeirogenic; during this interval some of the Precambrian structural elements may have been rejuvenated. In Tertiary time, further rejuvenation of Precambrian structural elements occurred and the sedimentary cover of late Paleozoic and Mesozoic rocks was folded and faulted.

Precambrian Geological History

Insufficient remnants of metasedimentary and metavolcanic origin are present to reconstruct their distribution prior to the emplacement of the Embudo Granite. In sec. 14, T. 15 N., R. 10 E. (unsurveyed) the general foliation trend of these rocks is northwest, paralleling the foliation of the surrounding granite. However, in secs. 8, 17, and 18, T. 16 N., R. 11 E. the prominent foliation direction is northeast, at an angle to the trend of the foliation in the granite. The lack of parallelism between the foliations in the granite and the country rock suggests either an intrusive or a fault contact. Both trends diverge from the east-trending direction of folds in the metasediments and metavolcanics reported by Miller and others (1963) from the Picuris region and from the Truchas Peak area. Both remnants of metamorphic rocks may possibly represent large xenoliths in the foliated granite.

The foliated granite is characterized by penetrative foliation and the presence of numerous inclusions in different stages of assimilation. These characteristics indicate that the foliated granite has a syntectonic, katazonal origin (Buddington, 1959).

Introduction of the basic dikes of gabbroic composition took place while the foliated granite was in a brittle state. The conversion of gabbro dikes with subophitic texture into orthoamphibolites may well have taken place in conjunction with a general reheating of the foliated granite that accompanied the formation of leucogranite. The emplacement of the leucogranite in irregular patches and veins seems to have been a static process, as the younger granite lacks foliation.

In the northern half of the Glorieta quadrangle, the Precambrian rocks are transected by two major north-northeast faults. The western fault, extending south from sec. 12, T. 16 N., R. 10 E. is named the Garcia Ranch fault. The eastern fault forms the contact between Precambrian and Pennsylvanian rocks and is referred to as the Deer Creek fault. This fault appears to be the southern extension of the Picuris-Pecos fault named by Miller and others (1963). According to these authors, the Picuris-Pecos fault originated in Precambrian time as a strike-slip fault with right-lateral displacement. Verification of this observation is impossible because of the lack of Precambrian outcrops east of the Deer Creek fault in the Glorieta quadrangle. Absence of correlative structural or metamorphic elements on either side of the Garcia Ranch and Deer Creek faults precludes determining the existence of Precambrian slip, as done so convincingly by Miller and others (1963) for the Picuris-Pecos fault. If, however, the Garcia Ranch fault is the southern extension of the Picuris-Pecos fault, the Garcia Ranch fault should have all the characteristics of the Picuris-Pecos fault, including Precambrian age.

Late Paleozoic Structures

In the southern Sangre de Cristo Mountains region late Precambrian and early Paleozoic history are characterized by erosion and little deposition. In Pennsylvanian time, a number of uplifts and intervening basins developed, in which late Paleozoic sediments were deposited. The Uncompahgre uplift in southwestern Colorado was such a positive area; it extends southeastward into northern New Mexico as the Uncompahgre-San Luis prong. According to Kottlowski (1961), the Pennsylvanian rocks in the foothills of the Sangre de Cristo Mountains east of Santa Fe were deposited on the west side of this uplift. Extension of the Uncompahgre prong into the Santa Fe-Cañoncito region was based on mapping by Read and Andrews (1944) who interpreted the contacts north of Cañoncito as depositional contacts instead of fault contacts (fig. 5, at rear). They believed that the Sangre de Cristo Formation was deposited on the Precambrian surface in several areas; that this "Cañoncito axis" was a positive feature during Pennsylvanian time; and that it was a southern extension of the Uncompahgre uplift. Mapping by the author has shown that nowhere in the Glorieta quadrangle does the Sangre de Cristo Formation depositionally overlie Precambrian rocks.

In the Glorieta area, however, evidence indicates late Paleozoic uplift to the west. Estimated thickness of formations at three localities aligned along an east-northeast direction are shown in the accompanying table. These localities are north of Lamy along Galisteo Creek, near the hamlet of Cañoncito, and on the north slope of Glorieta Mesa. The thickness reported for the Magdalena Group is not significant. These values represent minimal thicknesses; a complete section is nowhere exposed. The Sangre de Cristo Formation exhibits much thinning, from the Rowe-Mora basin in the east on to the Uncompahgre axis to the west. A similar change, although not as striking, is indicated by the other Permian formations. During Late Pennsylvanian and early Permian time, the Glorieta area was located on the east slope of the slowly-rising Uncompahgre axis.

Estimated thicknesses (in feet) of Pennsylvanian and Permian formations

	North of Lamy	Cañoncito	Glorieta Mesa
Bernal Formation	–	100	120
San Andres Limestone	0	20	20
Glorieta Sandstone	80	100	120
Yeso Formation	390	–	460
Sangre de Cristo Formation	435	about 2000	
Magdalena Group	>600	>720	not exposed

Laramide Structures

The time interval between Late Cretaceous and middle Tertiary, recognized throughout western North America as a time of deformation, is called the Laramide orogeny. It caused folding and faulting of the rocks of the southern Sangre de Cristo Mountains. Precise dating of the orogeny is not possible in the Glorieta quadrangle, but the Laramide orogeny was probably the major factor rejuvenating Precambrian structures and creating folds and faults within the late Paleozoic and Mesozoic sedimentary rocks.

At the end of the Mesozoic Era, the southern Sangre de Cristo Mountains consisted of a basement of crystalline Precambrian rocks overlain by several thousand feet of sediments, of which the oldest were late Paleozoic. The exact thickness of the sedimentary cover is unknown, but it may have amounted to as much as 10,000 feet. Under the influence of compressive stresses, of which the greatest were oriented in an east-west direction, the sedimentary cover was folded and faulted, while the basement deformed mainly along steep reverse faults, some of which may have been rejuvenated Precambrian structures. As a result of vertical differential movement along basement faults, the westernmost blocks, west of the Deer Creek fault, became elevated and Pennsylvanian and younger sediments subsequently have been removed by erosion, exposing the Precambrian crystalline rocks. Pennsylvanian sediments, however, are preserved in a narrow, tightly-compressed synclinal structure, that coincides farther south with the Garcia Ranch fault. The lateral transition from narrow syncline in the sedimentary cover to a fault in the basement also takes place in the vertical dimension (see cross sections on geologic map). Reverse fault movement along steeply-dipping basement fractures, possibly of Precambrian origin, pinched part of the sedimentary cover into a synclinal structure.

The north-northeast Deer Creek fault also appears to be a reverse fault with the west side upthrown. In the Precambrian rocks to the west, the fault is marked by a breccia or shear zone of varying width, in which the foliation parallels the fault plane. Along the east side of the fault, Pennsylvanian beds have been tilted to the southeast. At a distance varying from 1,000 to 2,000 feet from the fault, dips diminish rapidly and the beds dip gently with angles of 10° to 12° into the Glorieta syncline.

The Glorieta syncline is the major structure in the eastern half of the quadrangle. It is a gentle, southward-plunging synclinal structure. North of Glorieta Pass, the synclinal axis plunges southward at an angle of about 10°. South of the Pass, the plunge diminishes to about eight degrees, while on Glorieta Mesa the plunge becomes less than three degrees.

The synclinal trace does not quite parallel the Deer Creek fault. The Glorieta syncline possibly developed somewhat earlier than the faulting.

A syncline of greater complexity extends southwest of Cañoncito and is considered to be the structural continuation of the Deer Creek fault. West of Galisteo Creek, Glorieta Sandstone and older rocks form the northwest limb with dips as steep as 60° SE. The southeastern limb of this structure is mostly covered by alluvial deposits of Galisteo Creek, but northwesterly dips can be found in the sparse outcrops on the west slope of Glorieta Mesa in sec. 13, T. 15 N., R. 10 E. (unsurveyed).

In sec. 23, T. 15 N., R. 10 E. (unsurveyed), the Glorieta Sandstone is offset by a north-trending fault. This offset is probably related to the proximity of a Precambrian prong in the northwest corner of this section and adjacent sections. The southeastward and upward movement of this block has resulted in the omission of the Magdalena Group and nearly all of the Sangre de Cristo Formation along its southeastern fault border, and may also be responsible for the "wrapping around" of the sedimentary cover in sec. 22, T. 15 N., R. 10 E. (unsurveyed).

The profound fault movements that in the late Tertiary created the Rio Grande rift zone to the west caused the uplift of the Sangre de Cristo Mountains relative to the graben floor. Creation of the rift zone resulted in widespread deposition of clastic rocks of the Santa Fe Group. The Pleistocene Ancha Formation unconformably overlies older rocks in the southwestern part of the quadrangle.

NATURAL RESOURCES

A few small occurrences of metallic ore minerals are restricted to remnants of Precambrian metamorphosed sedimentary and volcanic rock. Localities are indicated on the geologic map.

In SE¼ sec. 8, T. 16 N., R. 11 E. several prospect pits explored sparse copper mineralization in fine-grained amphibolites of igneous origin. Azurite and malachite can be identified as fracture fillings.

Remnants of an old prospect pit occur on the southern slope of a small peak in NE¼ sec. 15, T. 15 N., R. 10 E. (unsurveyed). The country rocks here are also amphibolite, unusually rich in sphene and titaniferous magnetite.

Pegmatite dikes are numerous in the Precambrian granite but have not yielded minerals of economic importance.

Water for ranching is obtained mostly from surface sources, as Galisteo Creek and its tributaries; and on Glorieta Mesa from temporary storage behind small dams. Glorieta Baptist Assembly obtains its water from wells, one of which was drilled in the summer of 1968 to a total depth of 877 feet, completed in mudstone and sandstone of the Sangre de Cristo Formation. The well log classifies 122 feet, 14 percent of the section, as water-bearing. The initial water level in the well was 59.5 feet below ground level. Water is obtained from a perforated section of 10-inch pipe at a depth between 629 and 802 feet below the surface. Pumping tests reveal a specific capacity of 1.1 gallons per minute per foot of drawdown. This yield compares with specific capacities of 0.04 to 0.6 for the Sangre de Cristo Formation, reported by Griggs and Hendrickson (1951) from San Miguel County. Ground water possibly can also be obtained from the limestones and sandstones of the Magdalena Group, from the Glorieta Sandstone, and from the sandstone beds of the Santa Rosa Sandstone.

REFERENCES

Bachman, G. O., 1953, *Geology of a part of northwestern Mora County, New Mexico:* U. S. Geol. Survey, Oil and Gas Inv., Map OM 137.

Baragar, W. R. A., 1960, *Petrology of basaltic rocks in part of the Labrador trough:* Geol. Soc. America, Bull., v. 17, p. 1589-1644.

Buddington, A. F., 1959, *Granite emplacement with special reference to North America:* Geol. Soc. America, Bull., v. 70, p. 671-747.

Dane, C. H., and Bachman, G. O., 1965, *Geologic map of New Mexico:* U. S. Geol. Survey.

Galusha, Ted, and Blick, J. C., 1971, *Stratigraphy of the Santa Fe Group, New Mexico:* Am. Mus. Natural History, Bull., v. 144, art. 1, 127 p.

Griggs, R. L., and Hendrickson, G. E., 1951, *Geology and ground water resources of San Miguel County, New Mexico:* New Mexico State Bur. Mines Mineral Resources, Ground-Water Report 2, 121 p.

Kottlowski, F. E., 1961, *Pennsylvanian rocks in north-central New Mexico:* New Mexico Geol. Soc., Guidebook, 12th Field Conf., p. 97-104.

Miller, J. P., Montgomery, Arthur, and Sutherland, P. K., 1963, *Geology of part of the southern Sangre de Cristo Mountains, New Mexico:* New Mexico State Bur. Mines Mineral Resources, Mem. 11, 106 p.

Montgomery, Arthur, 1953, *Precambrian geology of the Picuris Range, north-central New Mexico:* New Mexico State Bur. Mines Mineral Resources, Bull. 30, 89 p.

Needham, C. E., 1937, *Some New Mexico fusulinidae:* New Mexico State Bur. Mines Mineral Resources, Bull. 14, 88 p.

———, and Bates, R. L., 1943, *Permian type sections in Central New Mexico:* Geol. Soc. America, Bull., v. 54, p. 1653-1667.

Read, C. B., and Andrews, D. A., 1944, *Geology of a part of the upper Pecos River and Rio Galisteo region, New Mexico:* U. S. Geol. Survey, Oil and Gas Inv. Prelim. Map 8.

Sidwell, Raymond, and Warn, G. F., 1953, *Pennsylvanian and related sediments of upper Pecos Valley, New Mexico:* Amer. Assoc. Petroleum Geologists, Bull., v. 37, p. 975-1013.

Spiegel, Zane, and Baldwin, Brewster, 1963, *Geology and Water Resources of the Santa Fe area, New Mexico:* U. S. Geol. Survey, Water-Supply Paper 1525.

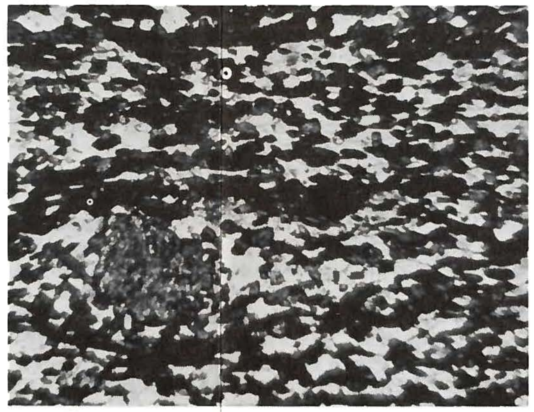


Fig. 1—Thin section of fine-grained amphibolite from sec. 8, T. 16 N., R. 11 E. Dark, prismatic mineral is hornblende, gray porphyroblast is epidote, light-colored matrix consists of quartz and plagioclase. Parallel light, magnification about 40.

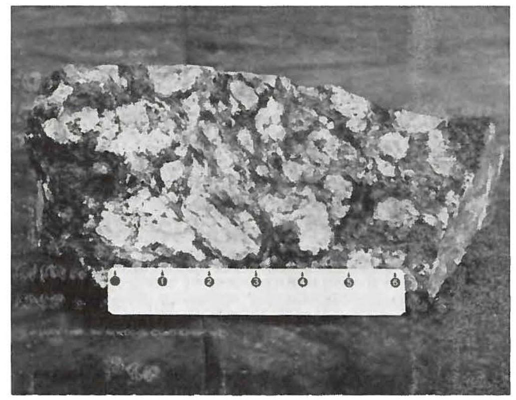


Fig. 2—Photograph of augen amphibolite, scale in inches. Light-colored, rounded aggregates are plagioclase in a hornblende-plagioclase matrix.

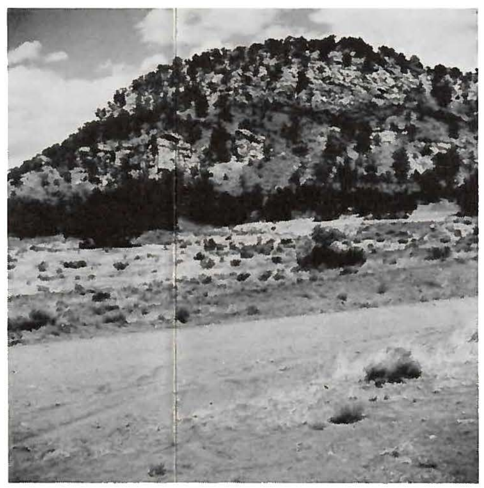


Fig. 4—Yeso Formation, dipping to the southwest, exposed along Galisteo Creek.

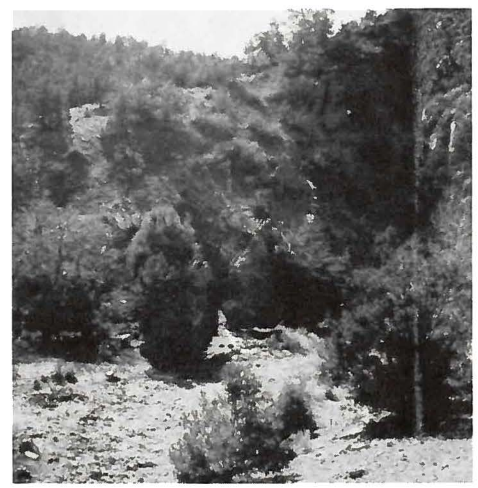


Fig. 5—Fault contact between Sangre de Cristo Formation (left) and Precambrian Granite (right). Fault plane dips about 65° to the south. Photograph taken in Apache Canyon, about 3/4 mile northwest of Cañoncito.