Geology and Mineral Deposits of the Poncha Springs SE Quadrangle, Chaffee County, Colorado

GEOLOGICAL SURVEY PROFESSIONAL PAPER 829

Work done in cooperation with the Colorado State Mining Industrial Development Board

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By RALPH E. VAN ALSTINE

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Description of Precambrian, Tertiary, and Quaternary geology and examined deposits of copper-zinc, fluorspar, gravel and sand, manganese, and pegmatite in part of the Arkansas Valley

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GEOLOGY AND MINERAL DEPOSITS OF THE PONCHA SPRINGS SE QUADRANGLE, CHAFFEE COUNTY, COLORADO

By RALPH E. VAN ALSTINE

ABSTRACT

The Poncha Springs SE quadrangle is in the Arkansas Valley between the Sawatch Range on the west, the south end of the Park Range on the east, and the Sangre de Cristo Mountains on the south. Altitudes in the quadrangle range from 7,000 to 8,800 feet.

The geologic units mapped are Precambrian metamorphic and igneous rocks, Tertiary volcanic and semiconsolidated sedimentary rocks, and unconsolidated Pleistocene and Holocene deposits. The metamorphic rocks are banded gneiss, consisting of gneiss, schist, phyllite, granofels, quartzite, and skarn; hornblende gneiss; and metagabbro. Concordant bodies of metagabbro locally intrude the older gneisses. The total aspect of the metamorphic terrane suggests formation from a mixed section largely composed of basalt flows, tuffs, and sedimentary rocks derived from these volcanic materials. The igneous rocks consist of dikes and sills of granitic pegmatite that cut the metamorphic complex and the metagabbro bodies.

The Tertiary volcanic rocks, Oligocene in age, are, from oldest to youngest, a lower rhyolitic ash-flow tuff, rhyodacite flow and tuff, and an upper rhyolitic ash-flow tuff. Tertiary beds of clay, silt, sand, and gravel of the Dry Union Formation locally contain volcanic ash. These predominantly floodplain, alluvial-fan, pond, and mudflow deposits are Miocene and Pliocene in age, on the basis of vertebrate fossils.

Quaternary deposits, mainly Pleistocene alluvial gravels and Holocene alluvium, fan alluvium, and landslide debris, locally mantle the Dry Union Formation. The Pleistocene gravels formed chiefly as outwash from multiple stages of mountain glaciation in the Sawatch Range to the west.

Structurally, the quadrangle is at the south end of the broad Arkansas Valley, a graben which is one of several units of the north-trending Rio Grande rift system. The major structural features of the quadrangle are Precambrian folds and Tertiary faults.

The landscape in this area is characterized by gently sloping surfaces at 10 levels. The earliest surface is a pediment of Tertiary age; three intermediate surfaces are pediments of early Pleistocene age; and six lower surfaces are on terraces of later Pleistocene age.

Deposits described include base metals (copper-zinc), fluorspar, gravel and sand, manganese, and pegmatite minerals (beryl, columbite-tantalite, feldspar, and muscovite). Copper and zinc have been produced from the once important Sedalia mine northwest of Salida. Substantial deposits of gravel and sand are found, especially in the Pleistocene units, and production has come from three of these units in the quadrangle. The Precambrian pegmatites have yielded a small quantity of the four minerals listed above.

INTRODUCTION

The Poncha Springs SE quadrangle, a 7½-minute map area about 100 miles southwest of Denver, is in the southern part of Chaffee County, central Colorado. It is at the west edge of Salida and covers nearly 60 square miles of T. 49 and 50 N., R. 8 and 9 E., New Mexico principal meridian (fig. 1).

The quadrangle is in the Southern Rocky Mountains and is traversed by the Arkansas and South Arkansas Rivers. The area is just east of the Continental Divide in the Sawatch Range, at the north edge of the Sangre de Cristo Mountains, and at the south termination of the Mosquito or Park Range. It is readily accessible from U.S. Highways 50 and 285, Colorado State Highway 291, and Chaffee County roads.

This report describes the Precambrian, Tertiary, and Pleistocene geology and the examined deposits of copper-zinc, fluorspar, gravel and sand, manganese, and pegmatite minerals. The fieldwork was done between 1961 and 1965. Unless otherwise stated in the text, the rock-forming minerals were identified with a flat-stage petrographic microscope; index oils and compositional curves were also used.

EARLIER REPORTS

Early geologic information on the area under investigation is given in several publications of the Hayden surveys (Hayden, 1869, p. 76–78; 1874, p. 48–50; and 1876, p. 51–53). Cross (1893, 1895) published some mineralogic and chemical data on the Precambrian and Tertiary rocks of the Salida area. The Sedalia copper-zinc deposit northwest of Salida

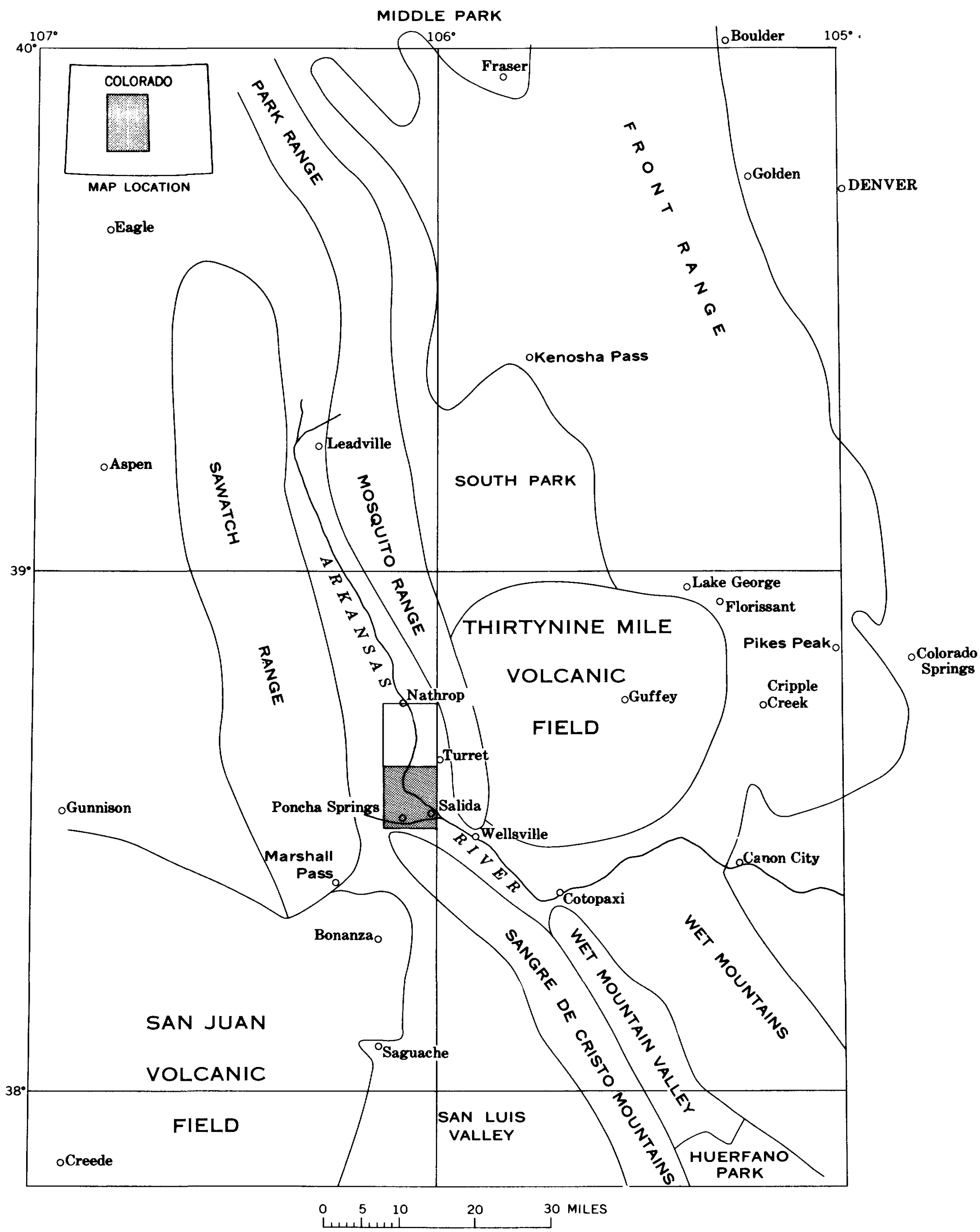

FIGURE 1.—Index map of south-central Colorado showing locations of Poncha Springs SE quadrangle and quadrangle to north (Van Alstine, 1969).

is reported on by Penfield and Sperry (1886), Penfield (1894), Lindgren (1908; 1933, p. 803), Pearl (1958, p. 82–86), and Heyl (1964, p. C31–C32, C42–C44, C83). Powers (1935) described terraces that extend into the quadrangle. According to the geologic map of Colorado (Burbank and others, 1935), the area is underlain by Precambrian hornblende gneiss and undivided Tertiary volcanic rocks.

Published reports on adjacent areas include those by Adams (1953); Behre, Osborn, and Rainwater (1936); Crawford (1913); DeVoto (1964); Dings and Robinson (1957); Hanley, Heinrich, and Page (1950, p. 23–27); Tweto (1960); and Van Alstine (1969).

ACKNOWLEDGMENTS

The Colorado State Mining Industrial Development Board participated in the financial support of the geological work done in the Poncha Springs SE quadrangle. Peter W. and David R. Van Alstine ably provided volunteer assistance during the fieldwork.

I am indebted to professional colleagues in the U.S. Geological Survey for chemical and spectrographic analyses and for X-ray identification of some minerals. Vertebrate fossil studies by G. E. Lewis were especially helpful in determining the stratigraphy and age of the upper Tertiary Dry Union Formation; his review of the description of this formation is greatly appreciated. The thorough critical reading of this manuscript by Glenn R. Scott and Richard B. Taylor led to improvements of the report.

SETTLEMENT AND CLIMATE

In 1779, Juan Bautista de Anza and a small force of Spaniards were the first white men to enter this area, which was then inhabited by Ute Indians (Waters, 1958, p. 714). Zebulon M. Pike and his army expedition spent Christmas of 1806 in the Arkansas Valley west of Salida, but it was not until about 1860, when placer gold was found nearby in Chaffee County, that mining, irrigation, and farming began. In 1880, the Denver & Rio Grande Western Railroad extended tracks westward through Salida, which became the starting point for several narrow-gage branch lines used for many years.

Salida, at the southeast corner of the quadrangle, is the seat of Chaffee County and has about 5,000 inhabitants. Poncha Springs, which has about 200 inhabitants, is at the junction of two major highways. Temperatures at Salida since 1902 have ranged from −35° to 100°F, and the annual mean is 45.7°F (Waters, 1958, p. 410–412). The mean annual precipitation is 11 inches, most of the precipitation falling in July and August. The average frost-free growing season is 111 days; irrigated, fertile benchlands along the Arkansas and South Arkansas Rivers yield agricultural, dairy, and livestock products.

TERRAIN

Maximum relief in the quadrangle is about 1,800 feet. Altitudes range from about 7,000 feet, where the Arkansas River leaves the area at Salida, to about 8,800 feet near the northeast and southwest corners of the quadrangle. West of the Arkansas River, dissected surfaces on Pleistocene outwash and alluvial deposits rise westward to an altitude of about 8,400 feet.

GEOLOGIC UNITS

Bedrock exposed in the northeast and southwest parts of the Poncha Springs SE quadrangle includes Precambrian igneous, metaigneous, and metasedimentary rocks and Tertiary volcanic rocks; however, most of the map area is covered by semiconsolidated or loose alluvial, mudflow, and landslide deposits of late Tertiary and Quaternary ages, found chiefly in the downdropped Arkansas Valley (fig. 2). Paleozoic rocks crop out just beyond the east and west borders of the quadrangle; Mesozoic rocks have been mapped about 20 miles to the southwest and northeast (Burbank and others, 1935).

PRECAMBRIAN ROCKS

Precambrian metamorphic and igneous rocks occupy about 6 square miles in the northeastern corner of the quadrangle and a fraction of a square mile

FIGURE 2.—Sawatch Range viewed west from Cleveland Mountain, 1 mile south of map area and southwest of Poncha Springs, showing Precambrian, Paleozoic, and Tertiary volcanic rocks of the range and Dry Union Formation of late Tertiary age in foreground.

near the southwestern corner. The predominant rock unit is banded gneiss—a layered quartz-feldspar-biotite gneiss; rocks of this unit are of unknown thickness and are interlayered with hornblende gneiss. Both gneisses are cut by metagabbro intrusive rocks; these in turn are cut by granitic pegmatite.

METAMORPHIC ROCKS

The map units of plate 1 portray the predominant rock types at any given locality and divide the interlayered gneissic rocks into the banded gneiss unit, which is typically biotitic gneiss, and the hornblende gneiss unit, which is characteristically made up of amphibolite. The gneissic rocks are commonly interlayered so thinly that finer divisions cannot be mapped at the present scale.

BANDED GNEISS

The characteristic lithologic type of the banded gneiss unit is a fine- to medium-grained foliated gneiss that consists chiefly of quartz, plagioclase (albite to andesine), potassic feldspar (microcline or orthoclase), and biotite, and lesser amounts of muscovite and magnetite. Sphene, zircon, garnet, and apatite are typical accessory minerals. Leucocratic varieties are most abundant near the north border of the quadrangle; at least locally the rock is not distinctly banded and might be called a granofels. In some layers, the feldspar content is very low or zero, and the rock is clearly a quartzite.

Foliation in banded gneisses of granitic aspect is defined by the arrangement of flakes, grain clusters, and lenses of micaceous minerals, as well as by the compositional layering. Lineation is formed by the elongation of grain clusters of quartz and mica and by the orientation of elongated crystals, such as hornblende, within the surface of foliation.

North of Salida, in the area near the old Sedalia copper-zinc mine, the banded gneiss unit is made up chiefly of schist and phyllite. The micaceous varieties are composed mainly of biotite, quartz, and plagioclase (albite to andesine) and contain lesser amounts of muscovite, potassic feldspar (microcline or orthoclase), magnetite, and apatite. Some specimens contain chlorite, hornblende, cordierite, sphene, and zircon; garnet, sillimanite, tourmaline, andalusite, corundum, gahnite, rutile, and calcite were also noted. Hornblendic rocks are interlayered and intergraded with the micaceous varieties; fine-grained hornblende schist is composed chiefly of blue-green hornblende, plagioclase (albite to labradorite), quartz, and magnetite, with small amounts of muscovite, biotite, chlorite, epidote, clinozoisite, microcline, sphene, and apatite.

Carbonate rocks were not found in the banded gneiss unit except as represented by skarn, discussed later with the economic geology of the Sedalia base-metal (copper-zinc) mine.

HORNBLENDE GNEISS

The hornblende gneiss unit is made up dominantly of concordant bodies of amphibolite that lack obvious compositional banding; north of Salida the amphibolites range in thickness from about 2 to 350 feet, strike N. 50°–60° E., and dip about 70° SE. This gneiss unit also contains layered gneisses characterized by hornblende and plagioclase. The mineralogy is typical of the almandite-amphibolite facies of regional metamorphism.

The amphibolite is fine to medium grained and black to dark greenish gray. It is composed of almost equal amounts of dark-green hornblende and plagioclase near An_{50} in composition. Small quantities of sphene, magnetite, apatite, epidote, clinozoisite, and chlorite are present in most specimens. About half of the specimens examined contain small rounded masses of quartz or other minerals interpreted as amygdule fillings in original metabasalts. Nearly all the amphibolite is well foliated and lineated, as defined by oriented grains and grain aggregates of hornblende and plagioclase.

The layered rocks of the hornblende gneiss unit include hornblende-quartz-plagioclase gneisses and schists intergradational with the hornblende-biotite gneisses characteristic of the banded gneiss unit. The shapes of quartz grains in some of these amphibolites suggest preservation of an original clastic texture.

METAGABBRO

In secs. 7, 8, and 18, T. 50 N., R. 9 E., north of Salida (pl. 1), several metagabbro bodies intrude the banded gneiss. Most of these bodies are narrow and short, but one, as much as 175 feet thick, was traced along strike for about ¾ mile. The metagabbro bodies have concordant contacts with adjacent gneisses except for small dikelike extensions from some of them.

Most of the metagabbro masses are made up of fine-grained amphibolite. One mass is formed of medium-grained metagabbro having plagioclase crystals as long as 7 millimeters. The rock is black to dark greenish gray and well foliated, but it lacks gneissic layering. Although original igneous textures were largely obliterated during recrystallization, ophitic texture is locally preserved, and some hornblende crystals contain remnants of diopsidic pyroxene. Dark-green hornblende forms 45 to 65 percent of the metagabbro; the remainder is plagioclase, An_{50} to An_{85}. Other minerals found in small quantities include biotite, quartz, magnetite, sphene, apatite, epidote group minerals, and chlorite.

ORIGIN OF THE METAMORPHIC ROCKS

The local preponderance of quartz over other minerals, the persistence of thin layers along strike for hundreds of feet, and the compositional differences between layers suggest that parts of the banded gneiss unit were formed by metamorphism of sedimentary rocks. The composition of the layers indicates that the sedimentary progenitors were beds of sandstone, graywacke, shale, and rare carbonate rocks. The leucocratic varieties lacking compositional banding probably had a different origin. Outside this quadrangle, to the south and east, rocks that seem to belong with this light-colored assemblage of metamorphic rocks locally show very little recrystallization or deformation compared with those nearer a large intrusive body of gneissic quartz monzonite to the north (Van Alstine, 1969, pl. 1). Preservation in some of relict euhedral crystals, flattened porphyritic pumice clots, and shardlike features suggests welded tuffs. Other rocks with bedding were probably formed by sedimentary reworking of silicic volcanic materials. Similarly, breccias of metabasalt or meta-andesite and amphibolitic graywackes indicate reworking of basaltic volcanic materials.

Cross (1895, p. 292) regarded the Precambrian rocks of the Salida area as metamorphosed volcanic and intrusive rocks, even though he mentioned that some resembled quartzites and other metasedimentary rocks. He recorded metadiorite with ophitic texture, rhyolite porphyry, micaceous and amphibolitic schist, and gneissic rocks. Lindgren (1908, p. 160–161) considered the amphibolitic schists to be masses of gabbro or diabase intrusive into micaceous metasedimentary rocks. A chemical and mineralogical study of several concordant ortho-amphibolites of the Salida area (Van Alstine, 1971) showed that some were amygdaloidal basalt flows and others were gabbro sills. A metabasalt here has higher values in SiO_2, K_2O, Be, Nb, Pb, Sr, V, Y, Yb, and Zr and lower values in MgO and CaO than the metagabbros.

The total aspect of this metamorphic terrane implies formation from a mixed section consisting largely of basalt flows, silicic tuffs, and sedimentary rocks derived from these volcanic materials.

PEGMATITE

Dikes and sills of coarse granitic pegmatite, some containing commercially valuable minerals, cut the metamorphic complex and a few of the metagabbro sills. A swarm of steeply dipping northeast-trending pegmatites transects the metamorphic rocks north of Salida (pl. 1). The dikes are especially abundant northeast of the old Sedalia copper-zinc mine, where some are about 50 feet thick. Only the larger bodies are shown on the geologic map. Most of the pegmatites have a pronounced topographic expression and are readily located on aerial photographs.

The pegmatite swarm is localized along a strong regional structure, the southeast limb of an antiform (pl. 1). Apparently it is genetically related to the large mass of gneissic quartz monzonite exposed about 2½ miles to the north in the adjacent quadrangle (Van Alstine, 1969, pl. 1). The dikes and sills are regarded as the external pegmatites that formed in the wallrocks 1–3 miles from the large intrusive body, whereas previously described (Van Alstine, 1969, p. 8) pegmatites are chiefly within the intrusive mass. Heinrich (1953, p. 68) suggested that external pegmatites owe their more distant position from batholiths to a relatively late withdrawal from the pegmatite hearth, which resulted in increased fluidity, greater rare-element content, and greater permeability of the surrounding rocks.

The pegmatites are composed chiefly of quartz, microcline, plagioclase, biotite, and muscovite but also contain beryl, columbite-tantalite, magnetite, hematite, fluorite, and garnet. Locally, the quartz and microcline have graphic texture. As few of the pegmatites have been opened by prospecting, little is known about their continuity and internal structure. Some are zoned, however, and contain concentrations of beryl, columbite-tantalite, muscovite, or feldspar. The pegmatite minerals are described later, under the section on economic geology.

A shallow pit dug on an east-trending pegmatite near the northeast edge of sec. 12, T. 50 N., R. 8 E., exposes a dike 8–10 feet thick in which graphic granite composed of feldspar, quartz, biotite, and magnetite was brecciated and mineralized with a later generation of cleavelandite, purple and colorless fluorite, green muscovite, and quartz. The hand specimens are radioactive, probably from uranium, when tested with a scintillometer.

TERTIARY ROCKS

VOLCANIC ROCKS

In the map area, Tertiary volcanic rocks rest directly on the Precambrian rocks. The Tertiary volcanic rocks of the adjoining quadrangle to the north (Van Alstine, 1969, p. 9–18) consist of rhyodacite ash, volcanic mudflow deposit, and flow; a rhyolitic ash-flow tuff (ash-flow 1 of Epis and Chapin, 1968) dated by the potassium-argon method as early Oligocene or approximately 35–37 million years; and a late Oligocene sequence of pyroclastic and flow rhyolite (Nathrop Volcanics). The rhyolitic ash-flow tuff is the only one of these volcanic units found in the northeast part of the Poncha Springs SE quadrangle; it is also present near the southwest corner of the quadrangle as a small remnant of lower rhyolitic ash-flow tuff. At the latter locality it is overlain by rhyodacite flow and tuff and an upper rhyolitic ash-flow tuff, all of Oligocene age. This sequence is overlain by semiconsolidated sediments of the Dry Union Formation (late Miocene and Pliocene).

The lower and upper ash-flow tuffs may have come from the Bonanza volcanic center, 11 miles south of the quadrangle and in the northeast part of the San Juan field (Burbank, 1932; Lipman, Steven, and Mehnert, 1970); a source west of the Salida area recently has been proposed (Chapin, Epis, and Lowell, 1970). The ash-flow tuff in the northeast part of the quadrangle evidently was preserved in the downfaulted western end of an east-trending paleovalley that localized these and other ash flows (Epis and Chapin, 1968, p. 69). A slightly younger Oligocene ash-flow tuff in this paleovalley was mapped in Railroad Gulch by Lowell (1971, pl. 1) about 1 mile northeast of outcrops of the lower ash-flow tuff at the north edge of the Poncha Springs SE quadrangle.

LOWER RHYOLITIC ASH-FLOW TUFF

The lower rhyolitic ash-flow tuff locally is several hundred feet thick and covers nearly 2 square miles in the northeastern and southwestern parts of the quadrangle. The two main areas of tuff to the north (pl. 1) may be different cooling sheets of the lower ash flow, as previously suggested (Van Alstine, 1969, p. 12). This lower ash flow formerly was regarded as the equivalent of ash-flow 4 of the units in the Thirtynine Mile volcanic field (Chapin and Epis, 1964, p. 148–151) to the northeast, but these authors now consider it to belong in their ash-flow 1, a multiple-flow simple-cooling unit (Chapin, C. E., written commun., 1970). Chemical analyses of vitrophyric and devitrified ash-flow tuffs indicate that they are rhyolitic to quartz latitic in composition.

The largest patch of lower ash-flow tuff to the northeast consistently contains a basal black vitrophyric densely welded tuff which ranges from less than a foot to more than 20 feet thick. This vitrophyre is 60–70 percent brown isotropic glass having an index of refraction slightly less than 1.51. It shows fluidal layering, perlitic structure, and shard structure and contains abundant crystal fragments of commonly zoned sanidine, zoned oligoclase-andesine, biotite, magnetite, apatite, zircon, and very rare augite. Pollen and spores from a carbonized unwelded zone at the base of the black vitrophyre indicate an Oligocene age (Van Alstine, 1969, p. 14–15).

In the lower ash flow, pinkish-gray to reddish-brown porphyritic and devitrified welded tuff, which overlies the black vitrophyre, is composed of abundant sanidine, oligoclase-andesine, and biotite and of rare quartz, cristobalite, tridymite, magnetite, apatite, zircon, fluorite, sphene, and topaz in a microcrystalline and locally glassy groundmass that is white, gray, yellow, red, or brown in reflected light. Sanidine crystals, some zoned, are as much as 8 mm long. Fairly abundant inclusions of volcanic and Precambrian rocks generally are less than an inch in diameter. The devitrified welded tuff commonly is silicified and near faults may also be argillized, sericitized, chloritized, carbonatized, pyritized, or fluoritized.

RHYODACITE FLOW AND TUFF

Near the southwest corner of the quadrangle, a small patch of lower rhyolitic ash-flow tuff is overlain by an estimated 150 feet of rhyodacite flow and interbedded tuff and by an unknown thickness of upper rhyolitic ash-flow tuff. The rhyodacite flow contains vitrophyric layers, locally perlitic or columnar. Closely spaced joints in places give the rhyodacite flow a pronounced platy structure. Near the top of the flow, a brown lithic tuff is composed of small angular fragments of rhyodacite in a similar matrix, and a white vitric tuff consists of rare phenocrysts of biotite, andesine, quartz, hornblende, and unzoned sanidine in a matrix of nearly isotropic glass having abundant pumice fragments and shard structures.

The gray-brown rhyodacite porphyritic lava flow, which makes up most of this unit, consists of phenocrysts of abundant plagioclase and bronze-brown to black biotite; rare sanidine, augite, hypersthene, and hornblende; and accessory magnetite-ilmenite, apatite, zircon, and fluorite. In most thin sections the apatite is cloudy gray or pleochroic in shades of pink and yellow. The plagioclase commonly is andesine-labradorite and is strongly zoned; some is as calcic as An_{55} and is rimmed by albite. The groundmass generally is a hematite-stained microcrystalline aggregate of feldspar, quartz, and biotite; locally it is vesicular, spherulitic, or perlitic glass. Cristobalite, tridymite, quartz, opal, calcite, and clay occupy vesicles. The rhyodacite flow was dated by the potassium-argon method (R. F. Marvin, written commun., 1967) as Oligocene (33.2±1.3 m.y. on biotite and 33.7±2.1 m.y. on plagioclase); specimens for dating were collected about 3 miles to the south along U.S. Highway 285 in the adjoining quadrangle. The rhyodacite probably was erupted from the Bonanza volcanic center about 11 miles south of the Poncha Springs SE quadrangle (Burbank, 1932; Karig, 1965).

UPPER RHYOLITIC ASH-FLOW TUFF

An upper rhyolitic ash-flow tuff exposed west of Poncha Springs ranges from gray and pinkish-brown to black and is characterized by yellow sphene and unzoned chatoyant sanidine crystals in most of the thin sections examined. Biotite is common; zoned plagioclase, An_{25-40}, is largely altered. Augite and quartz phenocrysts are rare. Zircon, apatite, and magnetite are common accessory minerals. A glassy base is not well exposed but probably is represented by remnants of black perlitic and porphyritic obsidian found near the crest of the hill in the east half of sec. 17, T. 49 N., R. 8 E., and by greenish bentonitic ash containing chatoyant sanidine, exposed in a pit on the north end of the hill. This ash-flow tuff most commonly appears as a porphyritic devitrified gray-brown rock and shows eutaxitic, spherulitic, axiolitic, and perlitic structures. Abundant lithic fragments consist chiefly of the underlying rhyodacite and various types of Precambrian rock. Examination of this unit in the field and in thin section led Charles E. Chapin (written commun., 1967) to correlate it with ash-flow 7 cooling unit in the Thirtynine Mile volcanic field; that unit has yielded potassium-argon dates of 34.8±1.4 m.y. (Epis and Chapin, 1968, p. 72–73) and 33.6±1.1 m.y. (L. I. Briggs, Jr., in Steven and Epis, 1968, p. 246).

DRY UNION FORMATION

White, gray, tan, and pink clay, silt, sand, and gravel of the Dry Union Formation of late Miocene and Pliocene age unconformably overlie deformed and eroded Oligocene volcanic rocks and Precambrian rocks and are unconformably overlain by Pleistocene pediment gravels or glacial outwash. These Tertiary flood-plain, alluvial-fan, pond, mudflow and volcanic ash deposits were first regarded as Pliocene Lake deposits by Hayden (1869, p. 77; 1874, p. 48), who called them the Arkansas marls. The type locality of the Dry Union Formation is in the Leadville area, about 45 miles north of the Poncha Springs SE quadrangle (Tweto, 1961).

The poorly consolidated Dry Union Formation occupies much of the quadrangle and crops out at altitudes ranging from 7,100 to 8,800 feet in a trough bounded by faults. Locally the beds are tilted and cut by steep faults. Areas underlain by this formation commonly have badland topography (fig. 3). Individual beds generally have little sorting and internal stratification. Some sand and gravel layers are finely bedded, however, and locally crossbedded; bedding dips gently in various directions. The finer sediments are slightly calcareous and locally gypsiferous; in places the beds are cemented by porous caliche or coarse calcite. The sand and silt contain nodules of calcite and black manganese oxide. Sand consists chiefly of quartz, sanidine, orthoclase, microcline, plagioclase, biotite, muscovite, hornblende, epidote, magnetite, sphene, zircon, and garnet. The gravel contains angular and subrounded pebbles and cobbles of predominantly Precambrian and Tertiary rocks like those exposed nearby. About 20 large detached blocks of Paleozoic rocks (pl. 1) were reported (Van Alstine, 1970) in the Dry Union Formation west of Poncha Springs; 10 are in the map area.

Some of the clay and silt is bentonite or altered volcanic ash in which shard structures are readily recognizable. In other volcanic ash beds the shards consist of bubble walls and cellular tubes of isotropic colorless to brown glass having an index of refraction ranging from 1.490 to 1.510. Beds of gray to white volcanic ash are about 6 inches to 2 feet thick.

FIGURE 3.—Badland topography on Dry Union Formation southeast of Salida; view west to quadrangle.

Best exposures of Pliocene volcanic ash are southwest of Salida, near SW¼NW¼ sec. 7, T. 49 N., R. 9 E., where Glenn R. Scott (written commun., 1970) found four different ash layers, and north of Salida, in NW¼SW¼ sec. 20, T. 50 N., R. 9 E. Ash beds interlayered with fossiliferous upper Miocene strata are exposed just outside the boundaries of the quarrangle in SW¼NW¼ sec. 7, T. 49 N., R. 8 E. and in SW¼NE¼ sec. 16, T. 49. N., R. 9 E. Some of this clay and bentonite swells when wet and would be hazardous as a foundation under roads and buildings and unsuitable as fill material directly beneath the bearing course of a highway.

Lack of continuous section and horizon markers, variable direction of dip, and faulting of unknown displacement prevent estimation of the thickness of the Dry Union Formation. More than 500 feet is exposed west of the Arkansas River, however, where the beds extend to an unknown depth in a fault trough. In the quadrangle to the south, this trough may contain more than 10,000 feet of Dry Union sediments (Van Alstine, 1970, p. B45).

G. Edward Lewis (written commun., 1968, 1971, 1972) made the following report on the age and stratigraphic paleontology of the Dry Union Formation of the Poncha Springs SE quadrangle:

Hayden [1869, p. 77] reported that "on the west side of the Arkansas Valley" [in the present Poncha Springs–Salida–Centerville area] the "Tertiary beds * * * are very nearly the same as the Santa Fe Marls, and were doubtless contemporaneous * * * I have called this group the Arkansas marls." In his report for 1873 [1874, p. 49], Hayden again wrote of "the Arkansas marls * * * of Pliocene age * * *," and in his report for 1875 [1876, p. 51], writing of the fill in the old valley, "from the source of the Arkansas * * * to the cañon above Cañon City * * * [these deposits] are undoubtedly of comparatively modern origin, not extending back farther than the Pliocene * * *."

Powers [1935, p. 189] reported Romer's identification of the Pliocene equid *Pliohippus leidyanus* from this area. Between the years 1958 and 1969 Harold Krasomil, a very helpful local resident, G. A. Izett, G. E. Lewis, R. W. O'Donnell, G. R. Scott, R. B. Taylor, and R. E. Van Alstine of the U.S. Geological Survey collected a number of fossil vertebrates from localities in the Poncha Springs SE quadrangle area. Study of these fossil vertebrates demonstrates that Hayden's correlation almost a century ago was remarkably accurate. Lewis [in Van Alstine and Lewis, 1960; and Van Alstine, 1969, p. 21–22] has shown that, in addition to the Pliocene rocks, Miocene rocks are present, as attested by characteristic fossil vertebrates. Mapped localities have been given USGS (Denver) fossil vertebrate locality numbers, and the faunal elements listed below were identified. When research work is completed, the fossil vertebrates found in this quadrangle will be reported on more fully by the following numbered localities which are also shown on plate 1 [in this report].

D590 (SE¼NW¼ sec. 35, T. 50 N., R. 8 E.).
- ?*Megatylopus* sp., fragments of hind leg.
- ?*Pliohippus* sp., fragments of tibia.
- ?*Yumaceras figginsi* Frick, right ramal fragment with P_4M_{1-3}. Found and collected by R. E. Van Alstine; it is an important discovery because it is the second known specimen of this taxon to be reported.

D591 (NW¼SW¼ sec. 7, T. 49 N., R. 9 E.) Van Alstine [1969, p. 21] suggests that this is the locality reported by Powers (1935, p. 189).
- *Neohipparion* sp., fragments of upper cheek tooth.
- mastodont, gen. and sp. indet., tusk fragments.

D750 (NE¼SW¼ sec. 7, T. 49 N., R. 8 E.); about 100 feet west of map area.
- *Merychippus calamarius* (Cope), fragments of upper and lower cheek teeth.
- merycodont, gen. and sp. indet., proximal phalanx.

D752 (NE¼SE¼ sec. 12, T. 49 N., R. 8 E.).
- *Neohipparion* sp., fragments of upper cheek tooth.

D753 (SW¼NW¼ sec. 7, T. 49 N., R. 9 E.).
- ?*Neohipparion* sp., lower cheek tooth fragment.
- ?*Megatylopus* sp., fragments of calcaneum and metapodial.
- mastodont, gen. and sp. indet., tusk fragments.

Although the rocks that yielded these fossils have now been described as the Dry Union Formation in the Leadville area about 45 miles north of Poncha Springs [Tweto, 1961, p. B133], Van Alstine [1968, p. C158–C159] has shown that "The Arkansas and San Luis Valleys of south-central Colorado are connected by a structural trough containing volcanic rocks and sediments of late Tertiary age, rather than being separated by a barrier of Precambrian rocks as previously believed. The existence of this trough indicates that the Rio Grande depression extends continuously northward * * * into the upper Arkansas Valley * * *." Therefore, it is possible that Miocene and Pliocene rocks in the San Luis Valley, stratigraphically equivalent to at least part of the Miocene to Pleistocene Santa Fe Group [Spiegel and Baldwin, 1963, p. 38–63], once extended continuously into the upper Arkansas Valley in central Colorado. The vertebrate fossils from these rocks in the Poncha Springs–Salida–Centerville area show that these sediments were deposited at the same time as some rocks of the Santa Fe Group.

Merychippus calamarius (locality D750) is a characteristic upper Miocene fossil of part of the Tesuque Formation of the Santa Fe Group [Galusha and Blick, 1971, p. 32, 108]. Closely related taxa of the Equidae (horse family) are characteristic of other rock units of the same stratigraphic position in the western United States.

Pliohippus (loc. D590), *Neohipparion* (locs. D591, D752, and D753), *Megatylopus* (locs. D590 and D753), and *Yumaceras* (loc. D590) are characteristic faunal elements of the Pliocene of the western United States. The fortunate association of *Pliohippus*, *Megatylopus*, and *Yumaceras* at locality D590 shows that some of the Pliocene rocks are properly referable to the upper Pliocene (if a twofold division of the Pliocene be used). This association can only be duplicated in the so-called "Wray fauna," from the upper Ogallala Formation near Beecher Island in Yuma County, eastern Colorado, which is correlated with the upper part of the "Ash Hollow Formation of the Ogallala Group" [Nebraska Geological Survey terminology; cf. Wood and others, 1941, p. 14, 37, pl. 1].

It is my belief that the fossil vertebrates found to date do not come from either the lowest or the highest parts, stratigraphically, of this rock unit, so in the future we should not be surprised to find either still older, or still younger, or both older and younger faunal elements than any of those recorded here.

Other types of fossils found in the Dry Union Formation include *Typha lesquereuxi* Cockerell and *Robinia* sp., respectively a cattail and a locust, not helpful in indicating the age of the beds within the Tertiary (J. A. Wolfe, written commun., 1962). These plant fossils were found about 2 miles southeast of Salida in SW¼NE¼ sec. 16, T. 49 N., R. 9 E., Cameron Mountain quadrangle, in rocks that overlie those containing late Miocene vertebrates (USGS fossil vertebrate loc. D747). Invertebrate fossils collected from thinly bedded silicified tuffaceous limestone at this locality consist of undiagnostic fresh-water gastropods, pelecypods, and ostracodes. In specimens from here, D. W. Taylor (written commun., 1966) found a snail, a small species of Planorbidae, genus uncertain, and the clam *Sphaerium*, which suggest no precise age. The ostracodes are smooth-shelled types common in Tertiary rocks; at least three genera are present, but they are too poorly preserved for identification (I. G. Sohn, written commun., 1962, 1965). The silicified limestone was disintegrated, concentrated, and examined for diatoms, but none was found after careful systematic search (G. W. Andrews, written commun., 1962).

West of Poncha Springs from similar pond-type limy deposits immediately underlying beds with upper Miocene vertebrate fossils (USGS fossil vertebrate loc. D750) just beyond the west edge of the quadrangle, the writer collected gastropods, pelecypods, and ostracodes that are mainly indeterminate smooth-shelled types. A crushed ostracode probably is *Candona*, according to I. G. Sohn (written commun., 1968), who also recognized ?*Darwinula* sp. and a large, smooth ostracode. Sohn reported that a snail in these rocks was examined by J. P. E. Morrison of the U.S. National Museum, who stated that it belongs to the group of *Galba parva* (Lea). After study of two slides of this limestone, R. E. Peck (written commun., 1967) reported 18 gyrogonites of the alga *Chara*, a worldwide charophyte that is common in fresh water and ranges in age through late Tertiary to Holocene. The limestone was examined for diatoms, but none was found (G. W. Andrews, written commun., 1964).

QUATERNARY DEPOSITS

PLEISTOCENE DEPOSITS

GRAVEL

In the Poncha Springs NE quadrangle the sequence of nine gravel deposits shown in table 1 was

TABLE 1.—*Pleistocene deposits, Poncha Springs quadrangle, Chaffee County, Colo.*

Gravel unit (Qg)	*Height*[1] (*feet*)	*Probable age*
		Wisconsin:
9	<10	Pinedale III.
8	30	Pinedale II.
7	20	Pinedale I.
6	50	Bull Lake II.
5	40	Bull Lake I.
4	70	Illinoian.
3	80	Kansan.
2	70	Nebraskan.
1	100	Nebraskan.

[1] Approximate height of upper surface of gravel above surface on next younger gravel. Pinedale III gravel is about 10 feet above modern major streams.

established (Van Alstine, 1969, p. 22), five of Bull Lake and Pinedale Ages and four older, but the geologic map of Poncha Springs SE quadrangle (pl. 1) shows only gravels 2–7. Gravel 1 was not found in this quadrangle, and small areas of gravels 8 and 9 were mapped as Qal. Details on the lithology and thickness of the various gravels and their characteristic soils are given elsewhere (Van Alstine, 1969, p. 23–25). These alluvial deposits locally cover the Dry Union Formation (fig. 4); four are on pediment surfaces, and five form lower terraces. The deposits originated chiefly as outwash from multiple-stage mountain glaciers in the Sawatch Range to the west. Earlier descriptions of the glacial deposits were given by Hayden (1869, p. 77; 1874, p. 48), Powers (1935, p. 188, 197), and Ray (1940, p. 1902–1903). As mentioned later in the present report, some of the gravel deposits are worked intermittently as

FIGURE 4.—Coarse Pleistocene gravel (Qg_4) unconformably overlying tilted gravel of Dry Union Formation (Td) of late Tertiary age. West side of U.S. Highway 285, east of cemetery at Poncha Springs.

sources of construction material by private companies and by State and County Highway Departments. The Salida airport is built on gravel 6.

This sequence of the Pleistocene deposits was based chiefly upon: (1) the topographic positions of three older units on high-level erosion surfaces regarded as pediments and of six units in lower outwash plains and terraces graded to former levels of the Arkansas River, (2) the tracing of nearly all units upslope into terminal moraines of former glaciers, (3) the field determination of the youngest outwash gravels as deposits of various stades of the Wisconsin Glaciation (G. M. Richmond, written commun., 1964), (4) the discovery by R. G. Dickinson and me of a Pearlette-like (type O of Izett and others, 1971) volcanic ash within the third oldest gravel unit, and (5) the presence of more strongly developed soils on the older gravels, which also commonly contain more deeply weathered rock fragments.

Recent study (Izett and others, 1970a, b) shows that gravel 2 may be Kansan instead of Nebraskan, for ash that R. G. Dickinson found in silt above the gravel from a roadcut at Centerville Cemetery, Poncha Springs NE quadrangle (Van Alstine, 1969, p. 23–24), has been correlated with ash of the Bishop Tuff of California, which the potassium-argon method on sanidine (Dalrymple and others, 1965) dated at about 700,000 years ago. This old Pleistocene ash is not highly altered, as it was well preserved on an upland surface. The correlation of this rhyolitic ash and other widely separated ashes at localities scattered from California to Nebraska with ash of the Bishop Tuff is based on similar petrography and on chemistry as determined by electron microprobe, atomic absorption, and emission spectrographic analysis (Izett and others, 1970a, b); Bishop ash was distinguished by them from the Pearlette-like ash (type O) found nearby in the younger gravel 3 (Van Alstine, 1969, p. 24), as follows:

	Bishop ash	*Pearlette-like ash*
Color	Chalky white	Silver gray.
Predominant shard shape.	Pumiceous	Bubble wall and junction.
Refractive index of glass.	Average 1.495–1.496.	Average 1.499.
Diagnostic phenocrysts.	Biotite	Ferroaugite, hornblende.
Total iron (as FeO).	0.6–0.7 percent	1.2–1.5 percent.
TiO_2	0.06–0.08 percent	0.10–0.12 percent.
Zn	30–40 ppm	70–90 ppm.

The Pearlette-like volcanic ash (type O) is best exposed in silt near the top of a bench of Pleistocene gravel 3 (fig. 5) in SE¼NE¼ sec. 17, T.50 N., R.8 E.

FIGURE 5.—Pearlette-like volcanic ash (type O) locality (×) west of U.S. Highway 285 about 5 miles northwest of Poncha Springs. Ash is near top of bench of Pleistocene gravel 3.

(pl. 1). It is as much as 3 feet thick (fig. 6) in an east-facing cliff at an altitude of about 7,820 feet. The ash dips gently northeast within silt which underlies gravel and overlies gravel that rests unconformably on the Dry Union Formation (Miocene and Pliocene). This type of ash probably came from eruptions in Yellowstone National Park, which were dated at 600,000 years by the potassium-argon method on sanidine (Izett and others, 1971, p. 266).

Evidence for an arid climate in this area during part of Pleistocene or possibly Pliocene time (Heyl, 1964, p. C43–C44) is based upon the presence of supergene willemite, smithsonite, hydrozincite, and aurichalcite at the old Sedalia mine near Salida. Heyl also suggested that during later more humid periods of oxidation of the deposit, hemimorphite and malachite were deposited.

HOLOCENE DEPOSITS

Holocene deposits shown on plate 1 consist of alluvium, fan alluvium, and landslide debris.

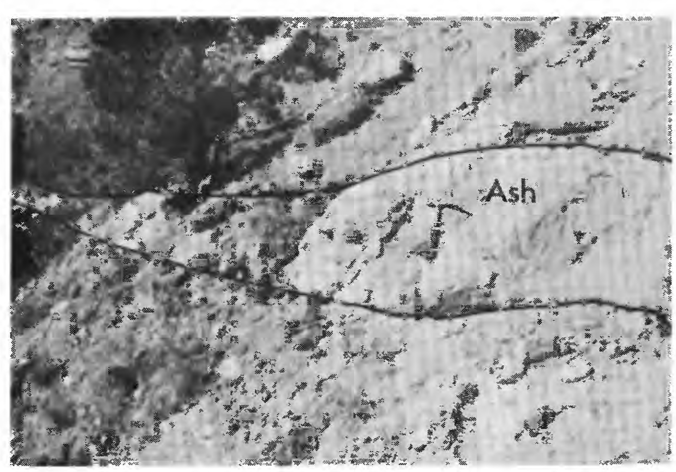

FIGURE 6.—White layer of Pearlette-like volcanic ash (type O) in Pleistocene gravel 3. Same locality as Figure 5.

ALLUVIUM

Deposits mapped as Holocene alluvium include silt, sand, and gravel along major and minor streams and colluvium on adjoining gentle slopes. In addition, unmapped fine-grained alluvium underlies most small draws to a depth of 5–10 feet, and unmapped colluvium covers most slopes.

Along major streams the alluvium is largely coarse stratified gravel composed of fresh hard boulders, cobbles, and pebbles. The upper part generally consists of humus-rich sand, silt, and clay that are arable. Along small draws the alluvium is stratified humic sand and silt but contains sparse layers of angular gravel. Modern arroyos have dissected the deposits along the draws. Along the Arkansas and South Arkansas Rivers some small unmappable deposits of Pinedale alluvium were mapped with the Holocene alluvium.

The colluvium is a heterogeneous nearly unstratified deposit of coarse angular fragments generally in a fine-grained matrix; the material moved downward by slopewash and gravity. The texture of the colluvium depends on the texture of parent bedrock; it is coarse grained downslope from Precambrian rocks and fine grained downslope from the Dry Union Formation.

FAN ALLUVIUM

Alluvial fans cover the slopes east and west of the Arkansas River and south of the South Arkansas River. The fan alluvium is much coarser downslope from hard blocky rocks, such as the Precambrian gneisses, than below the Dry Union beds. Also, it is coarser at the head of a fan than at the toe. The coarse particles are angular, poorly sorted, and only fairly well stratified. Because of the coarseness and permeability of the fan alluvium, streams generally sink out of sight when they reach the heads of the fans. East of the Arkansas River the large compound fan, called Sand Park on the map, is partly overlain by a blanket of eolian sand. The sand is more than 5 feet thick locally but is not mapped.

LANDSLIDE DEBRIS

Three large landslides, here classified as rockslides, are in the northern part of the quadrangle. Their debris consists of large masses of Tertiary lower welded ash-flow tuff that slid from a cliff when the nonwelded parts beneath the cliff were weakened or undercut. These landslides apparently are now stable, but similar cliffs of lower ash-flow tuff possibly are still unstable.

STRUCTURAL GEOLOGY

The Poncha Springs SE quadrangle encompasses the south end of a broad valley downdropped between high mountain ranges (fig. 1). The Sawatch Range on the west, the Mosquito Range on the east, and the Sangre de Cristo Mountains on the south are uplifted blocks flanking the graben of the Arkansas Valley, one of several units of the north-trending Rio Grande rift system. The faults bounding this graben on the west are largely concealed beneath Tertiary and Quaternary valley fill. On the south, the graben is disrupted by a major east-trending fault zone bringing Precambrian rocks of the Sangre de Cristo Mountains up against Miocene and Pliocene rocks of the valley block. The eastern fault zone bounding the graben is well exposed; the eastern valley wall is faulted up on subparallel northwest- and north-trending breaks, like the treads and risers of stairs. The blocks between the faults here are tilted variously, but most slope westward toward the graben.

The major structural features within the quadrangle are Precambrian folds and Tertiary faults. Precambrian folding accompanied metamorphism and emplacement of a syntectonic body of gneissic quartz monzonite in the quadrangle to the north (Van Alstine, 1969); this body has been dated at 1.65–1.70 billion years (Wetherill and Bickford, 1965; Hutchinson and Hedge, 1967). Foliation and lithologic layering strike northeast and dip steeply northwest or southeast. In the area north of Salida, this layering is folded into two antiforms and a synform (pl. 1); small drag folds plunge gently northeast.

The region was deformed again during the Laramide orogeny of Late Cretaceous to early Tertiary age; the quadrangle is on the east flank of the north-trending Sawatch anticline. Thousands of feet of once-overlying Paleozoic and Mesozoic sedimentary rocks have been eroded from the area, and east-dipping lower Paleozoic rocks crop out a few thousand feet east of the quadrangle. The quadrangle is between two areas of early Tertiary intrusive bodies (Dings and Robinson, 1957; Behre and others, 1936) —on the west, the Mount Princeton batholith and related intrusive bodies and on the east, the Calumet or Whitehorn stock.

Dips in the Tertiary rocks demonstrate the local intensity of Tertiary deformation. In the southwest part of the quadrangle Oligocene volcanic rocks resting on the Precambrian rocks dip 30°–40° W. into the Tertiary trough. To the northeast, the attitude of the ash-flow tuffs is variable; dips locally are fairly steep, especially near faults bounding jostled blocks. Near the margins of the largest area of ash-flow tuff, however, compaction layering dips gently inward toward the center of the mass. In the Dry Union Formation of late Miocene and Pliocene age, dips also are highly variable, and many are believed to reflect tilting of beds near faults.

Most of the faults that cut the Dry Union Formation, but not the overlying Pleistocene gravels, are poorly exposed, and their positions on plate 1 are based chiefly upon lineaments on aerial photographs. Locally these faults are mineralized with coarse calcite or chalcedony; at no place was the amount of displacement measured. These late Tertiary faults are related to the graben that forms the northward extension of the Rio Grande trough. Pegmatite dikes and some quartz veins containing magnetite, specularite, and sulfide minerals may occupy faults of Precambrian age. Many of the bedrock faults traced on aerial photographs as lineaments follow breccia zones (fig. 7), strike valleys, alined saddles or sags, and scarps or other topographic breaks (fig. 8).

The two long north-trending faults near the east and west margins of the quadrangle are normal faults related to the borders of the Rio Grande trough. These faults bound a downdropped graben in which an unknown depth of Dry Union sediments accumulated, and the faults extend south to the San Luis Valley (Van Alstine, 1968). The north end of the Sangre de Cristo Mountains is terminated by an east-trending system of faults that cut the Dry Union Formation near the south margin of the quadrangle. Most branches of this system are steep normal faults, downthrown on the north. North of Salida, the south end of the Mosquito Range similarly is marked by a complex system of north-trending and east-trending faults (pl. 1) that give a very irregular distribution to the Precambrian rocks, the Oligocene ash-flow tuffs, and the Dry Union Formation in this area. The main northwest-trending fault system through the old Sedalia mine extends more than 4 miles northwest, where it is strongly mineralized with fluorspar in the Browns Canyon district (Van Alstine, 1969, p. 30–43).

FIGURE 7.—Angular blocks of Precambrian gneiss in fault breccia zone ½ mile northwest of Sedalia copper-zinc mine.

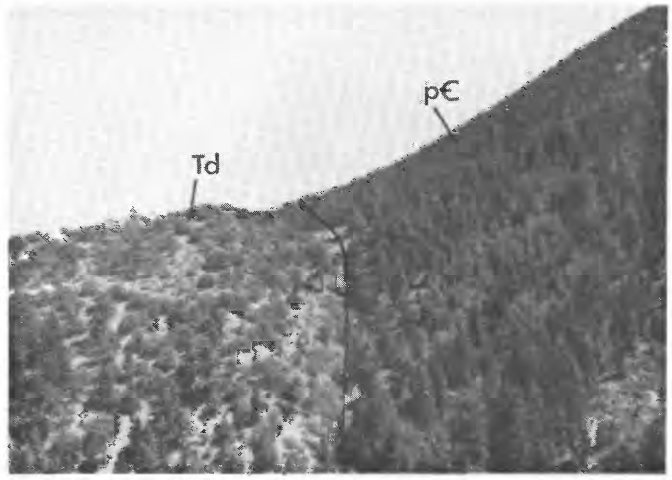

FIGURE 8.—View east along fault between Dry Union Formation of late Tertiary age (Td) and Precambrian gneiss (p€). South of U.S. Highway 50, east of King Gulch, and just south of the quadrangle.

GEOMORPHOLOGY

As in the adjoining quadrangle to the north (Van Alstine, 1969, p. 28–29), the landscape of this part of the Arkansas Valley is characterized by gently sloping surfaces at 10 levels. A late Tertiary pediment was cut on Oligocene volcanic and Precambrian rocks, and three intermediate pediments of early Pleistocene age formed chiefly on Dry Union sediments between the Arkansas River and the Sawatch Range to the west. Six lower later Pleistocene terraces locally border the Arkansas River, the South Arkansas River, and their main tributaries.

The topography on the Oligocene volcanic and Precambrian rocks north of Salida is quite different from that on the soft sediments of the Dry Union Formation. Streams cutting hard bedrock north of Salida produced the west-sloping pediment of late Tertiary age, narrow canyons and fault-controlled valleys, and spires and cliffs of welded tuff, and they contributed to the formation of landslides. West of the river, the terrain consists of badlands formed on the Dry Union Formation; three east-sloping pediments beneath Pleistocene gravels; broad, straight, east-trending valleys with gravel-capped interfluves; and terraces. The higher levels furnish good grazing land, and the lower terraces yield most of the crops. Streams of the quadrangle are intermittent, except the Arkansas River, South Arkansas River, and their main tributaries, Poncha Creek, Little Cochetopa Creek, and Squaw Creek. The Arkansas Valley is well supplied with water from surface flow and ground water largely from Pleistocene gravels.

A truncated valley was formed by piracy in sec. 29, T. 50 N., R. 8 E. at an altitude of 8,000 feet (fig. 9). The valley is cut in the Dry Union Formation and is occupied by Pleistocene outwash gravel 3; gravel 2 is on the higher benches to the south and north. The southeast-trending valley was beheaded by headward erosion of gullies extending south from an area of badland topography.

Extensive areas of alluvial fans are found along the fronts of the ranges and east of the area of badland topography formed on the Dry Union Formation. Locally the fans are surfaced with eolian sand blown from loose deposits along the valley.

ECONOMIC GEOLOGY

Deposits that were studied include base metals (copper-zinc), fluorspar, gravel and sand, manganese, and pegmatite minerals (beryl, columbite-tantalite, feldspar, and muscovite).

FIGURE 9.—View northeast across flat truncated valley (arrow points to upper end of valley) cut in Dry Union Formation and occupied by Pleistocene gravel 3. The smooth-surfaced southeast-trending valley, which opens to the right, was beheaded by gullies extending south from the area of badland topography. Located 3½ miles northwest of Poncha Springs in SE¼NW¼ sec. 29, T. 50 N., R. 8 E.

BASE METALS

The Sedalia copper-zinc deposit is on the northeast side of the Arkansas Valley in NW¼ sec. 18, T. 50 N., R. 9 E., about 3½ miles northwest of Salida, Chaffee County. It is reached by about 2 miles of mine access road extending north from Colorado State Highway 291 at Belleview at the west edge of section 24 (pl. 1). Workings range in altitude from an adit at about 7,475 feet to a pit at about 8,200 feet near the ridge crest. The deposit was located in October 1881 and was worked intermittently until 1923. The Sedalia mine was the largest copper mine in the State and also yielded significant quantities of zinc ore and a little silver and gold. By 1907, from 60,000 to 75,000 tons of copper-zinc ore, mostly oxidized, had been shipped from this mine; it contained at least 5 percent copper, nearly twice as much zinc, and $1 to $2.50 worth of gold and silver per ton (Lindgren, 1908, p. 161–162). Total production of the mine probably was about 100,000 tons (Heyl, 1964, p. C83) of partly oxidized ore and sulfide ore. A small quantity of rich native silver ore was found in a pocket on a lower level. A leaching plant near the mine in 1906 was replaced by a 50-tons-per-day concentrating mill. As Heyl (1964, p. C83) pointed out, the partly oxidized copper-zinc ore containing some gold, silver, and lead from the Sedalia mine is difficult to market because the abundant zinc is detrimental to copper smelting, and the abundant copper and incomplete oxidation of the zinc minerals are detrimental to zinc smelting. The ore was shipped mainly to a Canon City zinc-lead paint plant and to smelters at Leadville; some was treated locally at Salida.

A detailed description of the Sedalia deposit is given because of its past production, remaining substantial resources, great variety of minerals, and similarity to deposits to the north near Railroad Gulch in the adjacent quadrangle (Van Alstine, 1969, p. 43–44) and to the east at Cotopaxi (Lindgren, 1908, p. 166–167). As many of the mine workings were caved and several others were regarded as too dangerous for examination, they were not mapped. The old workings are extensive, however; Lindgren (1908, p. 162) reported underground workings aggregating about 5,000 feet, and examination of unpublished company maps made in 1917 and at some later date showed about 8,100 feet of drifts and crosscuts and many stopes and raises extending through an altitude of about 420 feet between the first and third levels. The main workings shown on these old maps are:

Adit	*Approx. altitude (feet)*	*Approx. extent (feet)*
No. 1	7,896	1,000
No. 2	7,796	2,800
Dewey	7,796	300
Jack Pot	7,696	800
No. 3	7,475	3,200

Until recently the mine was owned by Anne A. Preston and Allison P. C. Goodheart of Denver, and six patented claims were recorded at the County Clerk and Recorder's office in Salida. A sign posted at the mine in 1969 showed that J. V. Dodge and A. A. Hanson, Colorado Springs, then had an interest in the property.

The sulfide deposit at the Sedalia mine was first described as a thick bed of actinolite schist richly impregnated with copper minerals (Cross, 1895, p. 289). According to Lindgren (1908, 1933), the deposit is a contact and regionally metamorphosed magmatic segregate in a diabase or gabbro dike and adjacent chlorite and mica schists. Heinrich and Salotti (1959), however, considered it to be a pyrometasomatic skarn replacing an amphibolite layer in gneiss. Heyl (1964, p. C3) regarded the deposit as a massive replacement of noncarbonate schists. The following information on the Sedalia deposit is based mainly upon the present geologic study of the quadrangle and on reports of Lindgren (1908) and Heyl (1964).

The geologic map (pl. 1) shows that the Sedalia deposit is localized in and near a metagabbro sill intruded into gneiss, schist, and phyllite. Layering and foliation strike northeast and commonly dip 40°–70° SE. The area is on the southeast limb of an antiform, and younger rocks apparently are to the east. Northwest of the mine, the gneiss is predominantly a light-colored quartz-feldspar-biotite variety, but southeast of the mine, dark phyllites and amphibolites prevail. Field and microscope studies and chemical analyses of the amphibolites show that metagabbro sills and metabasalt flows are both present in this area (Van Alstine, 1971). A pegmatite dike about 50 feet thick and dipping 70° N. cuts the deposit in two (Lindgren, 1908, p. 163, 166). As a result of contact metamorphism, regional metamorphism to the almandite-amphibolite facies, sulfide mineralization, wallrock alteration, and later oxidation of the deposit, the mineralized metamorphosed sedimentary and igneous rocks contain a great variety of minerals.

The presence of idocrase, diopside, garnet, cordierite, gahnite, and other high-temperature minerals suggests that the deposit may have formed by pyrometasomatism and regional metamorphism. The garnet is the almandite variety (Penfield and Sperry, 1886, p. 310), having a specific gravity of 4.163 and high ferrous iron and aluminum contents. At the Sedalia mine, unusually large garnets, as much as 6 inches in diameter, have weathered from outcrops of the chlorite schist, especially near a pegmatite that cuts the ore body; large specimens also have been collected from underground workings between the No. 2 and No. 3 adits. Cordierite is present in footwall and hanging-wall biotite schists next to the amphibole schist that locally was replaced by sulfide minerals. Gahnite, zinc spinel, occurs as small dark-green octahedra.

Although the Sedalia deposit has been regarded as a replaced skarn (Heinrich and Salotti, 1959), the usual genetic connection with limestone or dolomite has not been clearly demonstrated at this deposit. Carbonate rocks are almost totally absent from the terrain northwest of Salida. Adjacent to an area of sandhills southeast of the Sedalia mine, however, a layered amphibolitized skarn consists of about 70 percent hornblende and 20 percent calcite; the rest of the rock is composed of diopside, andesine, clinozoisite, biotite, sphene, and magnetite. In the footwall of the Sedalia mine, a similar layered skarn rock is made up of dolomitic calcite, quartz, tremolite, anthophyllite, diopside, chlorite, magnetite, chalcocite, and malachite; an adjacent layer of white, dense fine-grained material consists of bytownite, largely untwinned, locally with quartz, clinozoisite, talc, chlorite, hornblende, sphene, apatite, and magnetite. Amphibolitic schist containing actinolite, tremolite, or anthophyllite, probably derived from skarn or basic igneous rock, also was found at the Sedalia mine. Possibly some of the skarn was formed by regional metamorphism of impure calcareous and siliceous beds and not, as it usually does, near the contacts between limestone or dolomite with granitic intrusive rocks.

The following minerals, listed alphabetically, were found in the wallrock at the Sedalia mine: actinolite, andalusite, anthophyllite, apatite, asbestos, beryl, biotite, bytownite, calcite, chlorite, clinozoisite, cordierite, corundum, cummingtonite, diopside, epidote, gahnite, garnet, hornblende, idocrase, kyanite, labradorite, microcline, muscovite, phlogopite, quartz, rutile, serpentine, sillimanite, sphene, talc, tourmaline, tremolite, and zircon. In addition, Cross (1893,

p. 424) reported the occurrence of staurolite. The glaucophane(?) reported by Lindgren (1908, p. 165) probably is one of the actinolite, anthophyllite, or tremolite varieties of fibrous amphibole in the wallrocks.

The following ore and gangue minerals, listed alphabetically, are present on the dump or in the workings at the Sedalia mine: anglesite, aurichalcite, azurite, barite, calcite, cerussite, chalcanthite, chalcocite, chrysocolla, cuprite, gahnite, galena, gold, gypsum, hematite, hemimorphite, hydrozincite, limonite, magnetite, malachite, marcasite, melanterite, opal, psilomelane, pyrite, pyrrhotite, quartz, rosasite(?), silver, smithsonite, sphalerite, tenorite, willemite, and an unnamed yellow sulfate of lead and copper that was reported by Lindgren (1908, p. 164).

Polished-section study of the sulfide ore shows chiefly sphalerite, chalcopyrite, and anisotropic marcasite replacing and marginal to muscovite and fibrous silicate minerals. The presence of marcasite was confirmed by X-ray. The sphalerite contains remnants of unreplaced earlier marcasite and chalcopyrite and exsolved lamellae of chalcopyrite. Locally, chalcopyrite is altered to chalcocite.

The ore body is a flat lens 800 feet long and at most 150 feet thick striking east and dipping 50°–70° S. (Lindgren, 1908, p. 163). The amphibolitic rocks are intruded by granitic pegmatites; the largest pegmatite dike cuts the main southward-dipping ore body, and ore was mined beneath the dike. In the sequence of layered metamorphic rocks, some amphibolitic layers were more susceptible to attack and were massively replaced by sulfide minerals. A fault system at the Sedalia mine (pl. 1) extends northwest, where it is strongly mineralized with fluorspar in the Browns Canyon district (Van Alstine, 1969, p. 30–43). Other faults, also later than the mineralization, strike about N. 20° W. and dip 40°–70° W.

The deposit is completely oxidized at the surface and partly oxidized to about 300 feet below the present outcrop (Heyl, 1964, p. C31). The upper 100 feet has been leached to a gossan consisting mostly of limonite, quartz, malachite, and a little yellow earthy sulfate of lead and copper. The secondary zinc and copper minerals formed an ore body in the second hundred feet, from which much of the 60,000 to 75,000 tons of ore was produced before 1908 (Lindgren, 1908, p. 161). Heyl (1964, p. C31, C42–C44, C83) described this oxidized ore, gave an analysis of sulfate-bearing material from the dump, and discussed the derivation of the supergene zinc and copper minerals from the sulfides.

Wallrock alteration at the Sedalia mine consists largely of the formation of epidote, clinozoisite, serpentine, biotite, phlogopite, chlorite, talc, and sericite. These hydrous silicates formed by retrograde metamorphism of earlier formed silicates in the metamorphic rocks. Phlogopite and talc veinlets locally cut bladed prisms of tremolite. Some of the late retrograde clinozoisite, pink in hand specimen but colorless in thin section, resembles thulite, the manganiferous variety. Study of the light-green chlorite coating almandite garnet at this mine revealed a nearly uniaxial aphrosiderite or ripidolite variety high in aluminum, iron, and magnesium (Penfield and Sperry, 1886, p. 310).

FLUORSPAR

Although the Poncha Springs SE quadrangle is immediately south of the Browns Canyon district, a former major center of fluorspar production (Van Alstine, 1969), no fluorspar has been mined in the quadrangle. Late Tertiary faults, like those mineralized with fluorite in the adjoining quadrangle, are common in the area, however, and along a few, fluorite has been observed. Possibly additional exploration would be successful in finding ore bodies.

Pink fluorite, barite, calcite, chalcedony, and pyrolusite (X-ray identification by Edward Chao, U.S. Geol. Survey) are exposed in a 15-foot prospect trench across a fault zone between rhyolitic welded tuff of Oligocene age and Precambrian leucocratic gneiss in SE¼ sec. 2, T. 50 N., R. 8 E. (pl. 1). The fluorite was introduced into the northwest-trending fault late in the sequence of mineralization, for fluorite veinlets cut the other minerals; fluorite crystals are as large as one-fourth of an inch on an edge. As other faults nearby also contain some fluorite, and chalcedony float is abundant, this area adjoining the fluorspar district on the south may warrant further prospecting.

At a prospect along a gulch in NE¼ sec. 6, T. 50 N., R. 9 E., Precambrian gneiss was brecciated along a north-south fault zone, altered to chloritic schist, and mineralized with veinlets of white and purplish fluorite. The fluorite is massive and in cubes, and is accompanied by quartz, manganese oxides, and limonite. The thickest fluorite veinlet is only about 1½ inches thick, and the mineralized fault zone is estimated to contain 10–15 percent CaF_2.

Fluorite was seen at two other localities in Precambrian rocks. Purple and colorless fluorite was the last mineral to form in a steeply dipping pegmatite dike striking east-west in gneiss at the northeast edge of sec. 12, T. 50 N., R. 8 E. The dike, 8–10 feet thick, is composed largely of quartz, feldspar, magnetite, and green muscovite. The hand specimens are radioactive when tested with a scintillometer, probably because of uranium content. In a gulch southwest of Poncha Springs at the east edge of sec. 17, T. 49 N., R. 8 E., and at an altitude of about 8,000 feet, float specimens of chloritized gneiss are coated with purple fluorite. The material was not found in place, but similar chloritized rock was seen in east-trending faults mapped here, and possibly late fluorite was introduced into some of them.

GRAVEL AND SAND

Extensive deposits of gravel and sand in this quadrangle are worked intermittently, chiefly as sources of construction material. Any of the Pleistocene gravel units is potentially a substantial source of gravel, but generally the older ones have more clay and calcium carbonate and are less suitable for concrete aggregate than the younger Bull Lake, Pinedale, and Holocene deposits. Gravel 6 is worked most (table 2) and from several pits (pl. 1); a small pit was started in gravel 3.

TABLE 2.—*Gravel pits in the Poncha Springs SE quadrangle, Chaffee County, Colo.*

Location	*Pleistocene gravel unit represented* [1]
NW¼ sec. 22, T. 50 N., R. 8 E	7
Border secs. 7–8, T. 49 N., R. 9 E	6
SE¼ sec. 23, T. 50 N., R. 8 E	6
NW¼ sec. 32, T. 50 N., R. 8 E	3

[1] Stratigraphic position and correlation given in table 1.

The Pleistocene gravels consist of boulders, cobbles, and pebbles of Precambrian and Tertiary granitic rocks, fine-grained and porphyritic Tertiary intrusive and volcanic rocks, Precambrian metamorphic rocks, and Paleozoic sedimentary rocks—all in a sandy and silty matrix. In working the deposits, excessively large and hard boulders are to be avoided, such as the huge angular blocks of Precambrian debris in gravel 7 at the mouth of Browns Canyon. These boulders are as much as 25 feet across and probably were derived from a landslide about 2 miles to the north (Van Alstine, 1969, p. 25).

Recorded production of sand and gravel from Chaffee County in 1964 was 282,000 tons (U.S. Bur. Mines, 1965, v. 3, p. 242). Nearly all output was made by crews of the State and County Highway Departments and by a contractor for the U.S. Forest Service. The remainder was production from pits south of Salida by the Redi Mixt Concrete Co., which has been the largest private local producer since 1950. In 1964, the Shavano Sand and Gravel Co. began operating a plant to supply all types of aggregate; maximum daily production was about 150 cubic yards from the open pit in gravel 6 in SE¼ sec. 23, T.50 N., R. 8 E., northwest of Salida.

On the Holocene alluvial fans along the Arkansas and South Arkansas valleys, yellowish-gray to brown eolian sand locally is more than 25 feet thick. The engineering and other physical properties of similar windblown sand along the Arkansas River near Pueblo are given by Scott (1969, p. 102–106). Eolian sand has a potential use as plaster sand.

MANGANESE

Black manganese oxide, largely hard psilomelane, formed in several places in Precambrian metamorphic rocks. X-ray spectrometer analysis using copper radiation showed major peaks representing *d*-spacings characteristic of psilomelane. Manganese oxides were found at the following four localities northwest of Salida:

NE¼ sec. 12, T. 50 N., R. 8 E.
NE¼ sec. 7, T. 50 N., R. 9 E.
SE¼ sec. 7, T. 50 N., R. 9 E.
SW¼ sec. 8, T. 50 N., R. 9 E.

The first site overlooks Longs Gulch and is undoubtedly the locality 4½ miles northwest of Salida described by Muilenburg (1919, p. 29–31), who reported pyrolusite, wad, and psilomelane 3 inches to 5 feet thick and analyzing 27–43 percent manganese; the vein was said to have been traced 10–12 miles, to pass near the old Sedalia copper-zinc mine, and to extend west to similar deposits along the Arkansas River. The present investigation does not confirm the suggested continuity of this manganese mineralization and finds that all these deposits are small and isolated.

The wallrock at all four manganese deposits is similar but not identical; leucocratic fine-grained gneiss predominates, containing chiefly quartz, microcline, and plagioclase. The rocks are well layered, and some layers are quartzite. Locally, the rock is green and contains chlorite, sericite, or actinolite. Foliation and layering strike about N. 50° E. in this area and dip 40°–60° SE. The white gneiss was brecciated and cemented by botryoidal black manganese oxides and by a later generation of botryoidal and stalactitic calcite that is especially observable on the upper sides of cracks. All deposits are near strong late Tertiary faults.

Little prospecting work has been done at the deposits, which seem small and spotty. Most consist of 1–2 feet of breccia that is cemented with manganese oxide and may contain 25–45 percent manganese. The largest excavation is a pit about 10 feet in diameter at the westernmost deposit. Similar veinlets, nodules, and replacement masses elsewhere in Colorado have been prospected but have yielded little ore (Crittenden, 1964, p. 101–102). They may become the source of small quantities of high-grade manganese ore under emergency conditions, when the price is high.

Pyrolusite, manganite, and psilomelane are found in the fluorite veins nearby (Van Alstine, 1969, p. 33) cutting Oligocene volcanic rocks and Precambrian rocks. The Leadville Limestone of Mississippian age contains manganese deposits north of Salida near Turret and also east of Salida near Wellsville (Muilenburg, 1919, p. 28–32; Jones, 1920, p. 63–67).

PEGMATITE MINERALS

Precambrian pegmatites within the Poncha Springs SE quadrangle have had a small production of beryl, columbite-tantalite, feldspar, and muscovite. The pegmatite area extends southwest of the Turret pegmatite district (Hanley and others, 1950), which was productive chiefly during World War II and at intervals thereafter. For several years the Turret district was the State's largest feldspar producer (Baillie, 1962, p. 9) and until 1963 also had produced 25,487 pounds of beryl, 135 tons of muscovite, and a small quantity of columbite-tantalite (Meeves and others, 1966, p. 7). Every pegmatite in the quadrangle is potentially beryl-bearing, and the area is near the center of a large beryllium-rich province of Colorado (Siems, 1963, fig. 3). No pegmatite was seen, however, having sufficient tonnage and grade for the profitable extraction of beryl alone, under present conditions. Beryl may be recovered from some pegmatites as a byproduct of mining feldspar and scrap mica.

Several pegmatites have been prospected by excavating shallow pits or by stripping adjacent to the outcrops. The Bonus Extension deposit, the most extensively explored pegmatite in the quadrangle, probably is typical of others in the area. The group of claims, which was held by John Kostelc of Salida, and associates, is in SW¼NW¼ sec. 8, T. 50 N., R. 9 E., at an altitude of about 8,640 feet (pl. 1). The deposit is on the crest of a ridge overlooking Salida and is reached by driving north from Salida over Chaffee County 180 (Ute Trail) for about 8 miles to the Longs Gulch trail road; west on this road for about 3 miles to a turnoff to the southwest; and then about 2 miles along a mine access road. The workings consist chiefly of an opencut quarry site 15–25 feet wide, 15 feet deep, and more than 150 feet long. The deposit was explored in the early 1950's and 1960's, when a small quantity of feldspar, mica, beryl, and columbite-tantalite was produced.

The Bonus Extension pegmatite strikes about N. 50°–70° E., essentially parallel to the strike of the foliation of the adjacent quartz-feldspar-biotite gneiss, and dips steeply northward and southward. It consists chiefly of an intermediate zone of microcline, albite, quartz, muscovite, biotite, and garnet, and a core of feldspar and quartz. Beryl and columbite-tantalite are distributed erratically in both of these zones. Garnet crystals as much as 5 inches in diameter have weathered out of the pegmatite and adjacent metamorphic rock northeast of the pegmatite; similarly occurring large crystals of almandite garnet were reported (Van Alstine, 1969, p. 8) in adjacent areas.

The beryl forms blue-green euhedral, subhedral, and anhedral crystals, some tapered, less than one-fourth of an inch to a foot in diameter and as much as 4 feet long. The index of refraction of the ordinary ray, which varies inversely with the BeO content, is about 1.575. A study (W. T. Schaller, written commun., 1948) suggests that beryl having this index contains about 13.5 percent BeO. The coarser material in the intermediate zone, where the beryl content is visually estimated to be about 1 percent, is best suited for hand sorting. About 20 tons of beryl have been recovered from this pegmatite.

The presence of columbite-tantalite, a hard, black, nonmagnetic, metallic mineral with a brownish-black streak, was confirmed by X-ray. The mineral occurs in thin plates, equant crystals, and lumps as much as 3 inches in diameter; however, it probably forms less than 0.01 percent of the pegmatite. The specific gravity was determined to be about 6. Comparison with published analyses (Palache, Berman, and Frondel, 1944, p. 783) suggests that columbite-tantalite having such a specific gravity contains about 35 percent Ta_2O_5. A columbite-tantalite close to this composition from a pegmatite near Canon City, Colo., contains 22 percent Ta_2O_5 (Headden, 1905). The columbite-tantalite from the Bonus Extension pegmatite was tested with a discriminating scintillometer and found to be strongly radioactive because of contained uranium. Other black metallic minerals of the pegmatite that might be confused with columbite-tantalite are magnetite and its nonmagnetic pseudomorph, martite, which is a hematite with a red-brown streak and a specific gravity ot about 4.9.

The pegmatites may be of greatest value as potential sources of potassium feldspar (microcline) and scrap mica. Soda feldspar (albite) is less conspicuous than the potassium variety in the pegmatites, and it is not the fine-grained type that was produced in large quantity from the nearby Homestake feldspar mine (Hanley and others, 1950, p. 23–24). The muscovite of the pegmatites generally is of poor quality or too scarce to be of commercial importance. Much muscovite occurs as small irregular warped books; some is fine grained and green.

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