Geologic Map of the
Golden Quadrangle,
Santa Fe County, New Mexico

By

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June, 2002

New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 036

Scale 1:24,000

New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place, Socorro, New Mexico, 87801-4796

GEOLOGIC MAP OF THE
GOLDEN 7.5-MINUTE QUADRANGLE
SANTA FE AND SANDOVAL COUNTIES, CENTRAL NEW MEXICO

by

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INTRODUCTION

Location, land status, and terrain

The Golden 7.5-minute quadrangle comprises an area of about 158 km^2 (61 mi^2) east of the Rio Grande Valley in Santa Fe County and a narrow strip of Sandoval County, New Mexico. The majority of the land is privately owned; most of the private land lies within the Ortiz Mine Grant. The study area also covers lands administered by the Bureau of Land Management, on the western and southern margins of the quadrangle. The village of Golden lies in the quadrangle and is the only settlement apart from a few ranch houses. NM-14 (the Turquoise Trail) is the major highway on the quadrangle, crossing it from the southern to the northern boundary. County road 22 crosses northwest corner of the quadrangle, linking NM-14 with Interstate 25. County road 55 (Gold Mine Road) enters the northeastern part of the quadrangle and connects the inactive Cunningham Hill Mine to NM-14 near Cerrillos. Private ranch roads allow access to the rest of the quadrangle.

Elevations range from 1,630 m (5,380 ft), on Tuerto Arroyo, in the southwestern edge of the quadrangle; to 2,688 m (8,897 ft), on Placer Mountain in the Ortiz Mountains. The Ortiz Mountains occupy the northwest quarter of the quadrangle. The northern part of the west to east trending San Pedro Mountains (Tuerto Mountains), with elevations up to 2,500 m (8,000 f,) lies on the southern margin of the quadrangle. West of the village of Golden, the northern part of the Little Tuerto Hills lies in the southwestern corner of the Golden quadrangle. A gently sloping, locally incised, Tuerto Gravel-covered peneplain, the Ortiz Surface, occupies the remainder of the quadrangle.

Drainages on the Golden quadrangle are ephemeral. A few springs are located along Tuerto Arroyo, and on Cañon del Agua, south and west of Golden. Most drainages flow to Tuerto Arroyo, which in turn flows west to Tonque Arroyo and the Rio Grande. In the northern and northwestern parts of the quadrangle, drainages flow to the northwest, toward Galisteo Creek. Canyons of the south and southeastern parts of the Ortiz Mountains flow towards Cañamo Arroyo and Arroyo de la Joya, and then to Galisteo Creek. Cunningham Gulch is an important drainage in the eastern part of the Ortiz Mountains; it flows northeast to Galisteo Creek.

Note to Users

A geologic map displays information on the distribution, nature, orientation and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map are based on reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist. Cross sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other structures. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. The topographic base for the geologic map is the Golden 7.5-minute topographic quadrangle, published by the United

States Geological Survey at a scale of 1:24,000 (one inch equals 2000 feet). Topographic and cultural changes associated with recent development may not be shown.

PRINCIPAL GEOLOGIC AND PHYSIOGRAPHIC FEATURES

Santo Domingo Sub-Basin of the Albuquerque Basin

The Santo Domingo sub-basin is the northern-most sub-basin of the Albuquerque Basin of the Rio Grande Rift (Kelly, 1997). The eastern part of the sub basin occupies the northwestern part of the Golden quadrangle and is bounded by the La Bajada Fault.

Galisteo Creek Monocline

An east-dipping monocline exposes tilted Triassic through Tertiary sedimentary rocks in the footwall (eastern side) of the La Bajada Fault on the Madrid quadrangle (Maynard and others, 2001). On the Golden quadrangle the east tilt of the sedimentary section persists as far as the Tijeras-Cañoncito Fault System along the southeastern margin of the Ortiz Mountains. Strata exposed in the San Pedro Mountains, south of the Tijeras-Cañoncito Fault System, are similarly tilted to the east. Tilting post-dates the 30-34 Ma intrusions of the Ortiz Porphyry Belt.

Ortiz and San Pedro Mountains Intrusive Complexes

The Ortiz Mountains and the San Pedro Mountains are composed of andesite-porphyry laccoliths, a quartz monzodiorite stock, augite-hornblende (+/-biotite) monzonite stocks, and subordinate feldspar-porphyry latite dikes and plugs that have been dated between 34 Ma and 30 Ma. In addition, sills and irregular stock-like masses of felsite and quartz porphyry occur in the San Pedro Mountains. These intrusive rocks intruded and inflated Pennsylvanian through Eocene sedimentary rocks. Volcanic breccia at Dolores Gulch, in the eastern part of the Ortiz Mountains, is intruded by a feldspar-porphyry latite stock, which is interpreted as a subvolcanic intrusive. The volcanic breccia is believed to be a remnant of one of the volcanic source vents of the Espinaso Formation. Aphanitic and porphyritic dikes radiate from the Cerrillos Hills. Gold and gold-tungsten breccia-hosted, porphyry copper-gold, and gold-copper and gold-iron skarn mineralization, represent the last stages of magmatic activity in the Ortiz and San Pedro Mountains.

Laccoliths

Laccoliths composed of hornblende-andesite porphyry occur throughout the Ortiz Porphyry Belt. Four principal laccolithic bodies are identified in the Golden quadrangle. The San Pedro Laccolith intrudes Pennsylvanian Madera Formation limestone in the San Pedro Mountains, forming a single thick concordant body. The Lomas de la Bolsa laccolith, in the northwestern part of the Ortiz Mountains, appears to be a "Christmas-Tree" type laccolith (Corry, 1983), with multiple concordant bodies emanating from a central mass. The Lomas de la Bolsa laccolith intrudes mainly the Cretaceous section, including the sills that host mineralization at Carache Canyon. The Cedar Mountain laccolith, on the north side of the Ortiz Mountains, intrudes the Menefee Formation of the Upper Cretaceous Mesa Verde Group and the lower part of the Paleocene Diamond Tail Formation. The fourth laccolithic mass intrudes Triassic rocks south of the Ortiz Mountains.

Tijeras-Cañoncito Fault System.

Tijeras-Cañoncito Fault System is perhaps the most obvious and important geologic structure on the Golden quadrangle. The fault system can be divided into three distinct segments, from southwest to northeast: 1) The Little Tuerto horst, in the south western part of the quadrangle, is cored by Precambrian rocks (quartzite and amphibole schist), with a cover of Mississippian(?) and Pennsylvanian sedimentary rocks. 2) A transition zone characterized by a right-stepping jog, to 3) the Ortiz Graben, which contains Upper Cretaceous Mesa Verde Group and Paleocene Diamond Tail Formation sedimentary rocks. The Ortiz Graben terminates in the volcanic vent of Dolores Gulch. The southern bounding structure of the Ortiz Graben, the Buckeye Hill Fault, continues onto the Captain Davis Mountain quadrangle, to the east of the Golden quad. The Buckeye Hill Fault is the principal trace of the Tijeras-Cañoncito Fault System on the Golden quadrangle.

About 5 km (3 mi) of left-lateral strike-slip separation is recorded by outcrops of the Dakota Sandstone across the Tijeras-Cañoncito Fault System in the Ortiz Mountains. Some of the apparent offset may be accounted for by overall down-to-the-north movement across the fault system. In any case, major mid-Tertiary movement is constrained by Ar-Ar isotopic dating of cross-cutting igneous rocks to the period 30-34 Ma.

Several studies document the Tijeras-Cañoncito Fault System as the controlling structure of the Laramide Galisteo Basin, controlling deposition of the Diamond Tail and Galisteo Formations in a fault-parallel northeasterly trough during the early Tertiary (Abbott and others, 1995; Gorham and Ingersoll, 1979).

La Bajada fault system

The study area includes the southern exposures of the, in the western part of the quadrangle, which juxtaposes the Eocene Galisteo Formation sandstone and mudstone, Oligocene Espinaso volcanics, and unconsolidated sediments of the Santa Fe Group with Triassic and Jurassic sedimentary rocks. It forms the eastern boundary of the Santo Domingo sub-basin of the Albuquerque Basin. The La Bajada Fault strikes from 350 to 010 azimuth and appears to dip steeply to the west. Jurassic strata are sharply folded into the fault, forming a tight, faulted anticline adjacent to the La Bajada Fault. Movement on

the La Bajada Fault probably began in the early Miocene. Pleistocene movement on the La Bajada Fault is indicated by Tuerto Gravel capping small mesas on the fault's east side lying about 12 m (40 ft) higher than the gravel-capped mesa on the west side in the southwestern part of the quadrangle. This displacement is less apparent to the south, but may be expressed as a subtle change in the slope of the constructional surface of the Tuerto Gravel.

Ortiz Surface
The Plio-Pleistocene Tuerto Gravel caps the extensive mesas that slope away from the Ortiz and San Pedro Mountains (the "conoplain" of Ogilvie, 1905). The constructional top of the Tuerto Gravel forms the Ortiz Surface as defined by Ogilvie (1905) and Kelley (1977).

MINERAL PRODUCTION AND RESOURCES

Base- and precious-metal mineralization
The Golden quadrangle covers parts of the Old Placers (also known as the Dolores or Ortiz) District and New Placers (a.k.a. Golden, Tuerto, or San Pedro) Mining District as defined by Elston (1967). The New Placers District comprises gold placer deposits southeast of the village of Golden and lode copper and gold deposits in the San Pedro Mountains. The Old Placers District includes gold placer deposits and lode gold, copper, and tungsten deposits in and around the Ortiz Mountains. The Ortiz Mine Grant refers to a tract of land originally measuring about 100 square miles and centered on a gold-bearing vein in the eastern part of the Ortiz Mountains. The original surveyed boundaries of the Ortiz Mine Grant are indicated on the Golden, Madrid, Captain Davis Mountain, and Picture Rock 7.5-minute quadrangle topographic maps. The Grant was deeded to Francisco Ortiz in 1832 by the Mexican government for the purpose of mining gold.

Placer Gold
In the placer deposits southeast of Golden, gold is found in the Tuerto Gravel, commonly concentrated at its contact with bedrock. Similar placer deposits in the Tuerto Gravel occur along the southern and eastern flanks of the Ortiz Mountains, notably on Cunningham Mesa, on the Captain Davis Mountain 7.5-minute quadrangle. Gold production from the numerous placer pits in both districts prior to 1904 is unrecorded. Placer production for the period 1904 – 1960 is less than 4,500 ounces. Gold production in the period 1960 – 2000 is probably less than 2,000 ounces. Placer gold is also found in Quaternary alluvium washing from canyons draining the Ortiz and San Pedro Mountains.

Skarns
Contact metasomatic deposits consisting mainly of tactite, or garnet skarn, occur in the San Pedro Mountains, where the Pennsylvanian Madera Formation limestone was altered to massive garnet in proximity to latite-porphyry stocks. Important copper deposits were exploited at the Old Timer Mine, in the northwestern part of the San Pedro Mountains, and at the San Pedro Mine (on the San Pedro 7.5-minute quadrangle). The San Pedro Mine produced 26.5 million pounds of copper; 26,300 troy ounces of gold; and

365,000 troy ounces of silver from 470,000 short tons of Cu-Au-Ag-bearing material in the period 1889-1992. Total production including the period prior to 1889 may exceed 600,000 short tons of material.   Production from the Old Timer Mine is unknown. The Carnahan Mine (San Pedro 7.5-minute quadrangle) exploited lead-zinc-silver ore and produced 3.5 million pounds of lead, 4 million pounds of zinc, and 96,000 troy ounces of silver from 27,377 short tons of material during the period 1925-1928. Including the production during the 1880s, total material mined at the Carnahan Mine may have exceeded 100,000 short tons (A. Sanders, personal communication, 2000).

A resource of 6 million short tons grading 0.25% copper and 0.03 ounces per short ton gold has been outlined at Lukas Canyon, in the southwestern part of the Ortiz Mountains (Maynard, 1995). The Lukas Canyon garnet skarn is developed in the Greenhorn Limestone Member of the Mancos Shale. Magnetite-pyroxene skarn is locally developed in limestone of the Todilto Formation at the Iron Vein prospect on the southeast flank of the Ortiz Mountains.

The Iron "Vein" prospect, on the southern flank of the Ortiz Mountains, is, in part, a gold-bearing hematite-garnet replacement of the Luciano Mesa limestone member of the Todilto Formation. Surrounding units are variably altered to quartzite and hornfels.

Breccias

At the Cunningham Hill Mine, gold and tungsten mineralization occurs in a breccia body formed in quartzite formed by contact metasomatism of sandstone of the Paleocene Diamond Tail Formation along latite-porphyry dikes, adjacent to a volcanic vent. Consolidated Gold Fields recovered 250,000 troy ounces of gold from 6 million short tons grading 0.055 troy ounces per short ton during the period 1979 – 1986.

The un-mined Carache Canyon deposit is hosted by open-space breccia formed in andesite-porphyry sills and Point Lookout Sandstone around the margin of a collapse breccia pipe. A resource of 6.7 million short tons grading 0.070 ounces of gold per short ton has been estimated at Carache Canyon. Gold-bearing quartzite breccias have also been identified at the Florencio and Benton prospects in the Ortiz Mountains.

Veins

Auriferous magnetite veining along a northeast-trending fissure was exploited during the 19th century at the Ortiz Mine. Total production of gold from the Ortiz Mine was about 50,000 troy ounces.

Coal

Coal, hosted by the Menefee Formation, occurs on the Golden quadrangle, in the Carache Canyon area, and in fragmentary exposures along the southern margin of the Ortiz Graben, near the Iron Vein prospect. Coal seams intersected in drilling in Carache Canyon rarely exceed 1 ft in thickness and do not appear to be laterally continuous.

Construction Aggregate

The volumetrically abundant andesite porphyry sills in the Ortiz represent a considerable resource of aggregate for construction use. The Tuerto Gravel also constitutes potentially economic aggregate resources.

PREVIOUS WORK

Descriptions of the geology of the region began with Marcou's expedition in 1853 (Marcou, 1858). Subsequently, Hayden (1869) described the red beds of the Galisteo "sands" and the Santa Fe Marl. Johnson (1903) was the first to describe laccoliths as being characteristic of the Ortiz Porphyry Belt. Ogilvie (1905, 1908) and Keyes (1909, 1918, and 1922) advanced the laccolith idea, though they did not distinguish between different intrusive rock types in the region. Ogilvie described the high-altitude conoplain (1905) and nepheline-bearing intrusive rocks (1908).

Stearns (1943, 1953a, 1953b, 1953c) formally described the Tertiary Galisteo and Espinaso Formations, and Tuerto Gravels; and the Upper Cretaceous rocks of the Galisteo-Tonque area surrounding the Ortiz Mine Grant. Though Stearns' work did not specifically included the area of the Golden quadrangle, his stratigraphic and structural framework of the area laid much of the foundation for the present-day understanding of the geology of the area.

Griswold, in an unpublished report to Ortiz Mines, Inc., made the first systematic inventory of the mineral prospects of the Ortiz Mine Grant and placed them in a geologic framework (Griswold, 1950). C.T. Griswold and his son, G.R.Griswold, prepared the first geologic map of the Grant and described the occurrence of Paleozoic and Mesozoic rocks. They considered all the sandstone of the southern margin the of Ortiz Mountains to belong the Mesaverde Group. The Griswolds' work represented the first accurate resource estimates at Lukas Canyon and Cunningham Hill, and recognized the potential for gold mineralization at Carache Canyon.

Bachman's (1975) map of the 1:62,500 Madrid quadrangle, the southwestern quarter of which is covered by the Golden quadrangle. Bachman's map grouped all the intrusive rocks of the Ortiz Porphyry Belt together as a laccolithic complex. Bachman indicated approximately 5 kilometers (3 miles) of left-lateral stratigraphic separation on the Tijeras-Cañoncito fault system in the Ortiz Mountains and showed outcrops of Mesaverde Group Galisteo Formation sedimentary rocks in a graben bounded by two principal strands of the fault system. Bachman and Mehnert (1978) presented the first published K-Ar dates on rocks of the region, establishing an Oligocene age for intrusive activity in the Ortiz Porphyry Belt.

Master's theses conducted in and near the Golden quadrangle include Emerick's (1950) study of the Golden area, and Peterson's (1958) and McCrae's (1958) studies of the Ortiz Mountains. Kay (1986) studied gold mineralization in the area of the then-operating Cunningham Hill Mine. Kay's work included fluid-inclusion studies, and K-Ar age dating of the host rocks and mineralization and alteration. Coles (1990) examined the alteration and mineralization at Carache Canyon, and documented the petrologic distinctions of the calc-alkaline and alkaline intrusive rocks of the Ortiz Mine Grant. Schroer (1994) reported on the copper-gold skarn mineralization at Lukas Canyon. The latter three masters' theses benefited from sponsorship by the mining companies exploring the Grant and access to these companies' exploration data.

Picha's (1982) descriptions of Phanerozoic stratigraphy of the Hagan Basin were used as a basis for correlations in the Ortiz Mountains. Gorham's (1979) and Lucas' (1982) work on the Galisteo Formation in the Hagan Basin and Cerrillos area led to recognition of the wide distribution of Tertiary sedimentary rocks in the Ortiz Mountains.

The Tijeras-Cañoncito fault system has been studied by many workers. Woodward (1984) illustrated the relationship of the Tijeras-Cañoncito fault system to mid-Tertiary mineralization. Abbott (1995) studied exposures of the Tijeras-Cañoncito Fault System to the southwest and northeast of the Ortiz Mine Grant and documented its Laramide and Quaternary activity. Kelson and others (1998 and 1999) and Koehler and Kelson (2000) assessed seismic risk along the Tijeras-Cañoncito fault system.

Water supply and mine-working dewatering problems on the Ortiz Mine Grant have been addressed by Summers (1977) and Shomaker (1995).

Lindgren and Graton (1906) and Lindgren and others (1910) described mineral deposits in the Ortiz Mountains. Elston (1967) summarized mineral resources and production in the area.

The author of this map of the Golden quadrangle was an employee of LAC Minerals, USA, Inc. during the years 1986 – 1990. During that time, LAC Minerals conducted a mineral exploration program on the Ortiz Mine Grant. The present work is in part an outgrowth of that investigation.

DESCRIPTION OF MAP UNITS

CENOZOIC ERATHEM

Neogene and Quaternary System

Colluvial, eolian, and anthropogenic deposits

Thin surficial deposits derived from wind and mass-movement processes, or extensive areas disturbed by gypsum or coal mining, or construction operations.

af   **artificial fill (Historic)** – Dumped fill and areas affected by human disturbances. Locally mapped where areally extensive or geologic contacts are obscured. Includes mine dumps around the Cunningham Hill Mine.

Qca – undivided colluvium and alluvium, including colluvium consisting of fluvial gravel from adjacent, higher terraces.

Qf – Alluvial fan deposits not covered by Qa and Qca.

Alluvium and terrace deposits

Qa – Alluvium. Modern channel, floodplain terraces deposits, mainly in Tuerto Arroyo, some alluvial fans and colluvium at valley margins. May include terraces and colluvium in tributary drainages.

Basin-fill deposits

Santa Fe Group (upper Oligocene-lower Pleistocene) - The Santa Fe Group comprises the syntectonic sedimentary fill and associated volcanic rocks of basins within the Rio Grande Rift of central Colorado, New Mexico, and northern Chihuahua (Bryan, 1938; Chapin and Cather, 1994). In the Golden quadrangle, the Santa Fe Group consists of lower piedmont-slope deposits **(Tsf)** on the eastern part of the Santo Domingo sub-basin and unconformably overlying piedmont-slope deposits that were laid down on erosion surfaces outside the structural boundaries of the sub-basin. The piedmont-slope deposits are correlative with the Blackshare Formation of Connell (2001). The upper group is known as the Tuerto Gravel (**QTt)** which caps a well-defined erosion surface flanking and sloping away from the Ortiz Mountains and the San Pedro Mountains.

Spiegel and Baldwin (1963) suggested a correlation between the Ancha Formation and the Tuerto Gravel. The age of the Tuerto Gravel is deduced from field relations and isotopic dating techniques of the Ancha Formation. Age dating of interfingering Cerros del Rio basalts (Bachman and Mehnert, 1978) and overlying lower Bandelier pumice (J. Winick, 1999, unpublished NM Geochronological Laboratory Internal Report, IR-78) indicates that the upper part of the Ancha Formation is between 2.8 and 1.6 Ma old. Both units rest unconformably on older tilted Santa Fe Group (Stearns, 1979). These are constraints are believed to be true for the Tuerto Gravel.

Upper Santa Fe Group (Pliocene (?) – lower Pleistocene)

QTt – Tuerto Gravels of Stearns (1953b) and Koning and others (2001) (lower Pleistocene to upper Pliocene) – Yellowish to reddish-brown and yellowish-red moderately consolidated and caliche cemented, moderately to well stratified pebble to cobble conglomerate and pebbly to cobbly sandstone with scattered boulders and muddy sandstone interbeds. Matrix is fine- to very coarse-grained, very poorly sorted sandstone, and gravel clasts contain abundant subrounded to subangular clasts derived from the Ortiz Mountains and San Pedro Mountains (andesite porphyry and augite monzonite; black, reddish-brown, and banded hornfels; and lesser quartzite, chert, and petrified wood. The Tuerto Gravel contains no material derived from the Sangre de Cristo Mountains in its exposures on the flanks of the Ortiz Mountains. Bedding in the Tuerto Gravel is subhorizontal. The unit is locally faulted by the La Bajada Fault and the Tano Fault on the Madrid quadrangle, north of the Golden quadrangle; no offset of the Tuerto Gravel by the La Bajada Fault has been observed on the Golden quadrangle.

Oligocene Epoch

Ortiz Intrusive-Extrusive Complex

Intrusive rocks on the Golden quadrangle can be divided into an early group, consisting of quartz-bearing laccoliths and related sills and dikes, and a later group, consisting of quartz-poor and generally nepheline-normative stocks and dikes. These

groupings are typical of the entire Ortiz Porphyry Belt (Stearns, 1953; Disbrow and Stoll, 1957; Atkinson, 1961).   Isotopic dating shows that the first group ranges from 33.3 to 36.2 million years old (Ma). The second group cuts the laccolithic rocks; its oldest age is therefore constrained by the ages given for the laccoliths.   Volcanics and a subvolcanic stock of the second group yield dates of 31.3 to 31.9 Ma. Base- and precious-metal mineralization occurs with the latest stages of the second group of intrusive rocks, at approximately 31 Ma.

The following descriptions of intrusive rocks of the Golden quadrangle are taken from Coles (1991). Classification of the rocks is based on a QAPF modal classification scheme for phaneritic rocks and on alkali-silica plots of whole-rock analytical samples including phaneritic and aphanitic to micro-phaneritic intrusives, and those containing very fine-grained isotropic material in the groundmass. Using the criteria of MacDonald and Katsura (1965), the early group of intrusives falls into the subalkaline field and the later group mostly lies in the alkaline field.

Early Intrusives – Calc-alkaline Group

Tap - Quartz andesite porphyry
Andesite porphyry laccoliths, sills, and dikes constitute the oldest igneous rocks in the Ortiz Mountains area (Peterson, 1958; McRae, 1958; Kay, 1986, and Coles, 1991). Isotopic age determinations (K-Ar and $^{40}Ar/^{39}Ar$) cluster in the range from 33.3 +/- 0.09 to 36.2 +/- 0.8 Ma (Mehnert and Bachman, 1979; Sauer, 1999; this study).   Andesite porphyry forms laccoliths throughout the Ortiz Porphyry Belt. Andesite also occurs as dikes parallel to the Golden Fault, a part of the Tijeras-Cañoncito Fault System.

Phenocrysts make up 40%-50% of the andesite with plagioclase dominating. Subhedral plagioclase phenocrysts (32%) are medium grained (1.4 mm average), and range in An content from 35 to 50%. Hornblende (12%) phenocrysts are euhedral, range from fine to medium grained (0.6-1.1 mm), and are black in fresh specimens. Quartz phenocrysts\ microphenocrysts average only 2% of the rock, and occur as groundmass to fine-grained (0.1-1.0 mm), clear, highly resorbed crystals. Augite, generally the least abundant phenocrystic phase, constitutes from 0 to 2% of the rock. It occurs as both distinct euhedral to subhedral, black phenocrysts\micro-phenocrysts (0.1-1.5 mm) and locally as cores to hornblende phenocrysts.

Andesite porphyry ranges from greenish gray to grayish green on fresh surfaces. Weathering produces surfaces that are olive drab to brownish green. Fractures in weathered rock locally contain coatings of iron and manganese oxide.

Andesite porphyry forms the following laccolithic masses: Lomas de la Bolsa Laccolith in the northwestern part of the Golden quadrangle, Cedar Mountain and Cerro Chato laccoliths along the northern border of the quad, Tuerto laccolith, in the south-central part of the quad, San Pedro, in the eponymous range along the southern border of the quad, and Captain Davis Mountain along the quadrangle's eastern border.

Tqmd - Quartz-hornblende monzodiorite
Quartz-hornblende monzodiorite crops out at Candelaria Mountain, in the southwestern part of the Ortiz Mountains. This rock is weather-resistant and forms steep

slopes and cliffs with 0.2 to 5.0 meter diameter blocks at the base. The rock generally is medium to light gray, and hornblende crystals impart a black speckled appearance on fresh surfaces. Weathered surfaces are usually chalky gray to tannish brown, depending on the intensity of iron oxide staining. A similar intrusion is mapped on the eastern side of Captain Davis Mountain (Lisenbee and Maynard, 2001). K-feldspar from a single sample from Candelaria Mountain yielded a $^{40}Ar/^{39}Ar$ age of 31.1 +/- --- Ma (this study).

       The quartz hornblende monzodiorite forms roughly cylindrical stocks at both Candelaria Mountain and Captain Davis Mountain. Cross-cutting relations indicate that the quartz hornblende monzodiorite is younger than the andesite-porphyry laccoliths. However its relationship to the Tijeras Cañoncito Fault System and to the augite monzonite stock is not known. Late trachyte dikes cut it, however.

Late Intrusives – Alkaline Group

Tam – Augite- and hornblende-monzonite; and hornblende-augite monzodiorite

       Augite monzonite, hornblende-augite monzodiorite, and hornblende monzonite form the the core of the Ortiz Mountains and underlie its highest peaks. These rock types are grouped together for the sake of mapping as augite monzonite. K-Ar and $^{40}Ar/^{39}Ar$ age determinations range from 29.6 +/- 1.5 to 35.36 Ma. The age of the augite monzonite may be more tightly constrained by its cutting 33.3 +/- 0.09 to 36.2 +/- 0.8 34 Ma quartz andesite porphyry laccoliths and its being cut by the 31.1 to 31.91 Ma latite porphyry subvolcanic stock in Cunningham Gulch.

       On fresh surfaces the rock ranges from light gray to deep gray or black. Locally, potassium feldspar imparts a pinkish tint to the rock. Weathered surfaces appear chalky gray white to tannish brown, depending on the presence and thickness of iron oxide stains.

       Plagioclase (An_{32}-An_{48}) is usually the dominant phase in the augite monzonite, making up 43% of the rock. It occurs as subhedral crystals that average 0.6 mm in length. Orthoclase (37%) is found in subequal amounts to plagioclase and locally exceeds plagioclase in abundance. Orthoclase occurs as anhedral to subhedral, 0.6 mm, crystals that locally enclose plagioclase, augite, and hornblende giving the rock a poikilitic fabric. Quartz was observed in two samples as a trace mineral.

       Augite and hornblende are present in the Coles' (1991) study sample in variable amounts, their relative abundance determining their names. Magnetite is the most abundant accessory mineral making up 3% of the rock on average and ranging from 2 to 4%. The 0.15 mm average diameter magnetite crystals are usually subhedral and in part appear to replace ferromagnesian minerals and sphene. Apatite, sphene, zircon, rutile, and allanite occur as accessory minerals that make up less than 1% of the rock.

       Hornblende-augite monzodiorite is very resistant and tends to form steep slopes and cliffs, locally with large boulders strewn at the base. On fresh surfaces, the rock is generally gray to pale pink, with conspicuous black spots imparted by hornblende and augite. Weathering tends to produce a tannish brown to pinkish color caused by iron oxide stains. Texturally, the hornblende-augite monzodiorite is hypidiomorphic granular.

       Hornblende monzonite apparently is a phase of the augite monzonite (Maynard et al., 1989). It occurs southeast of a latite stock (Kay, 1986) and within the Ortiz graben

(Maynard et al., 1989). Plagioclase and hornblende make up 40% and 15% of the hornblende monzonite, respectively. These early phases are enclosed by later interstitial cloudy orthoclase that makes up 30 % of the rock.

      Kay (1986) reported K-Ar dates of 29.6 +/- 1.5 Ma for the hornblende monzonite and 30.3 +/- 1.2 Ma for the quartz latite/latite stock, which intrudes the hornblende monzonite. The overlapping data suggest that the intrusions are closely related temporally, as well as spatially.

Tlp - Quartz latite and latite porphyry

      The quartz latite and younger latite porphyries occur in the upper part of Cunningham Gulch in an elongate stock to the southwest of the Ortiz volcanic vent breccia. They intrude the main augite monzonite stock (McRae, 1958; Kay, 1986). The rock types are grouped together on the geologic map. Isotopic dates range for the Quartz latite and latite porphyry range from 29.9 +/- 1.2 to 35.1 +/- 1.4 Ma (Kay, 1986; this study). $^{40}Ar/^{39}Ar$ ages cluster in the range from 31.56 to 31.91 Ma (this study). Quartz latite is restricted to the southwestern end of the stock and forms the summit of Porphyry Hill. A small plug of latite porphyry also is present immediately to the northwest of Carache Canyon at Rattlesnake Hill. Weathering produces light gray to tannic brown iron oxide coatings on outcrops of both latites. Orthoclase phenocrysts are resistant to weathering relative to the groundmass and other phenocrysts, and stand out in relief on weathered surfaces.

      The quartz latite samples studied from the Porphyry Hill-Cunningham Gulch area contain 38% sodic-andesine, subhedral to euhedral plagioclase (An_{30} to An_{44}) phenocrysts. Orthoclase phenocrysts make up 10% of the rock on average, are subhedral, and average 3.0 mm in size. Ferromagnesian minerals make up approximately 6% of the rock and include hornblende, pyroxene, and biotite. Hornblende occurs as subhedral to euhedral, 0.8 mm phenocrysts

      The latite usually has smaller phenocrysts than the quartz latite; otherwise, they appear identical in hand specimen. Plagioclase phenocrysts (36%) are euhedral to subhedral and average 0.8 mm along their c-axes. Euhedral to subhedral orthoclase phenocrysts (12%) average 1/0 mm on their long axis. Augite, at Porphyry Hill, and aegirine-augite, at Rattlesnake Hill, are the only ferromagnesian phases in the latite. They occur as euhedral to subhedral phenocrysts that make up 6% of the rock and average 0.5 mm along the c-axis.

      The aphanitic microgranular groundmass consists of orthoclase, which is estimated, to make up 39% of the rock and quartz that makes up about 7%. The groundmass phases average 0.02 mm in size and are anhedral. Apatite and sphene occur as accessory minerals that make up less than 1% of the rock. Both minerals occur as euhedral crystals and average 0.08 mm on their longest axis.

Post-volcanic Intrusives

      Dikes of latitic to trachytic composition cut the volcanic vent breccia of Dolores Gulch and are therefore considered post-volcanic. Similar dikes cutting the Carache Canyon collapse breccia and the quartz monzodiorite stock at Candelaria Mountain are

grouped with the post-volcanic intrusives on the basis of their similarity of chemistry and appearance.

Thltp - Hornblende latite/trachyte porphyry

Hornblende latite/trachyte porphyry occurs as dikes parallel to the Tijeras-Cañoncito fault system within the Carache Canyon area, and to the southwest in upper Buckeye Canyon. This unit is more altered and more susceptible to weathering than other dike rocks at Carache Canyon and does not form extensive outcrops. Weathered samples of the latite/trachyte are grayish green and characterized by distinct light gray plagioclase phenocrysts and brown to brownish green altered hornblende phenocrysts.

Phenocrysts make up 45% of the average latite/trachyte with plagioclase dominating at 29%. Plagioclase phenocrysts are sericitized, subhedral and average 1.3 mm along the c-axis. Ferromagnesian mineral phenocrysts are the second most abundant phenocrystic phase constituting 16% of the rock. Pseudomorphic evidence indicates that both amphibole and pyroxene were present, the amphibole having been dominant. These replaced phenocrysts average 1.3 mm and consist entirely of secondary minerals. Biotite phenocrysts are present in several specimens (OC-40, 314.5' and OC-53, 465.5') and may have been ubiquitous before alteration. The biotite averages 0.4 mm on its long axis and is subhedral to euhedral.

Ttlp - Porphyritic alkali feldspar trachyte and trachyte/latite porphyry

Porphyritic alkali feldspar trachyte occurs as dikes that crosscut hornblende latite/trachyte and the Carache Canyon breccia pipe. Like the hornblende latite/trachyte porphyry, the trachyte dikes lie parallel to the Tijeras-Cañoncito fault system. The trachyte dikes weather to conspicuous positive relief relative to host sediments and andesitic porphyry sills. The trachyte is light tannish brown on weathered surfaces due to iron staining. Liesegang bands are prominent at some locations on the surface and in near-surface drill core, and apparently reflect a weathering phenomenon.

Plagioclase phenocrysts make up 7% of the trachyte on average, although many samples contain no phenocrysts. Groundmass sanidine constitutes approximately 87% of the rock.

Tqt - Porphyritic quartz-bearing trachyte

Porphyritic quartz-bearing trachyte crops out as dikes in the southwest and western Ortiz Mountains (geologic map). Outcrops commonly have strong positive relief, are brownish-tan and locally display liesegang iron oxide banding due to weathering. Although crosscutting relationships are not clear, this unit is considered to be temporally close to the other latite and trachyte dikes in the Ortiz Mountains.

Plagioclase and sanidine phenocrysts make up 8% of the rock on average, and range from 3 to 14%. Sanidine is the most abundant groundmass phase.

Ttp - Tephriphonolite porphyry

Tephriphonolite porphyry occurs as a dike on the hillside northeast of Buckeye Canyon. Light gray, medium grained (1.2 mm), subhedral plagioclase phenocrysts make up 25% of the rock. Euhedral nepheline phenocrysts (2%) average 0.4 mm in diameter.

The nepheline is completely altered, leaving only pseudohexagonal outlines filled with gieseckite and traces of analcime. Black, medium grained (1.1 mm), euhedral augite phenocrysts make up 15% of the rock.

Thpm - Hornblende-porphyry monzonite
Hornblende-porphyry monzonite occurs as dikes in the southeastern part of the Ortiz Mine Grant. In hand specimen it is dark purple-brown and aphanitic, with phenocrysts of pyroxene and feldspar. Dikes to 7 m (23 ft) width stand as bold walls along much of their lengths.

Extrusive Rocks

Tv - Volcanic vent of Dolores Gulch
Vent-facies volcanic rocks are preserved at Dolores Gulch, attesting to volcanic activity associated with the latter part of the second group of intrusive rocks. Various investigators (Stearns, 1953a, Disbrow and Stoll, 1957, Kautz and others, 1981, and Erskine and Smith, 1993) have noted compositional variations in the Espinaso volcanics suggesting that earlier intrusives may have contributed to the volcanic pile.
Volcanic rocks underlie a roughly elliptical area 1900 x 900 m (6200 x 3000 ft) in Dolores Gulch, in the eastern part of the Ortiz Mountains, immediately north of the Cunningham Hill Mine. Most exposures of the volcanic rocks, such as in the upper pit walls of the Cunningham Hill Mine, are a matrix-supported breccia composed of clasts of igneous and sedimentary rock in a tuffaceous matrix. Lithic clasts vary in size and composition. In some exposures the vent breccia may be described as a lithic tuff. Fine-grained, water-lain sediments occur in the southeastern part of the vent breccia, suggesting a subsiding basin. Along the northwestern margin of the vent breccia, clasts are predominantly augite monzonite. Along the southeastern margin, quartzite and other clasts of sedimentary origin dominate.
Core drilling shows that the volcanic rocks are at least 330 m (1000 ft) thick and that the body's contacts with the surrounding rocks are near vertical. This observation, coupled with the unsorted nature of much of the volcanic breccia, the intrusive contacts with sandstone of the Diamond Tail, and the subvolcanic latite stock, lead to the interpretation of the Dolores Gulch volcanics being a vent facies.
Kay (1986) reports a K-Ar date on hornblende from the Dolores Gulch volcanic vent of 34.2 +/- 1.4 Ma. This date seems too old, given that the volcanic vent clearly is younger than the andesite porphyry and the augite monzonite. Two ^{40}Ar/^{39}Ar isochron dates on K feldspar from the volcanic vent (this study) yielded ages of 31.31 and 31.48 Ma. These dates are consistent with ages reported above for the subvolcanic quartz latite and latite porphyry stock.

Tdtbx - Quartzite breccia derived from Diamond Tail Formation. Tight- to open-spaced breccia in Dolores Gulch area of Ortiz Mountains. Host to gold and tungsten mineralization at Cunningham Gulch Mine, Benton Mine, and Florencio prospect.

Sedimentary Rocks

Eocene Epoch

Tg - Galisteo Formation.   Tan to whitish fine- to coarse-grained sandstone with cross bedding and red, gray and green mudstone. Isolated outcrops in Arroyo Coyote (T13N, R6E, sec. 24; T13N, R7E, sec. 19) and T13N, R7E, sec. 18.

Paleocene Epoch

Tdt - Diamond Tail Formation of Lucas and others (1997). Fine to coarse, pebbly sandstone. Subordinate mudstone beds. Silicified petrified wood fragments. Thickness of the Diamond Tail Formation in the Ortiz Mountains is estimated at 1500 ft (457 m), comparable to the thickness reported by Lucas and others at its type locality in the Hagan Basin (442 m (1459 ft)), by Lisenbee and Maynard (2001) east of the Ortiz Mountains (90 m (300 ft) or by Lucas (1982) in the southeastern part of the Cerrillos Hills (353 m (1,158 ft)).   In the Ortiz Mountains, sandstone and mudstone of the Diamond Tail Formation is metamorphosed to quartzite and black hornfels, respectively. The Diamond Tail Formation was divided out of the Galisteo Formation of Stearns (1943) and Lucas (1982) by Lucas and others (1997). The Diamond Tail Formation's upper contact with the Galisteo Formation is not exposed on the Madrid quadrangle.

MESOZOIC ERATHEM

CRETACEOUS

Upper Cretaceous

Mesa Verde Group
Mesa Verde Group sediments are divided into the Point Lookout Sandstone and Menefee Formation. Extensive core drilling in the Carache Canyon area has shown the indicated ranges in thickness.

> **Kmf – Menefee Formation undivided** Above the Harmon sandstone in Carache Canyon, up to 230 m (755 ft) of shale, carbonaceous shale, sandstone, and coal has been cut by drilling.

>> **Kmfu – upper Menefee member** – gray, tan to orange-tan, cross-bedded, and laminated to thick-bedded siltstone and sandstone; dark-gray to olive-gray and black shale; dull, dark-brown to shiny black coal; and maroon to dark-brown iron concretions.

>> **Kmh – Harmon sandstone member** – A prominent, trough-crossbedded, laterally persistent sandstone in Carache Canyon corresponds to the "Harmon sandstone" in the Hagan Basin (Black, 1979; Picha, 1982) and in the Madrid coal field (Bachman, 1975; Maynard and

others, 2001). At Carache Canyon, the Harmon sandstone is 22.7 m (75 ft) thick, on average.

Kmfl – lower Menefee member – At Carache Canyon, the lower Menefee member is composed of 52.7 to 91.5 m (173 to 300 ft) of shale, carbonaceous shale, sandstone, and coal. Detailed drilling shows that sandstone beds are not continuous over short distances.

Kpl – Point Lookout Sandstone - White to tan, fine-grained, medium-bedded sandstone overlying the upper Mancos Shale member and underlying non-marine shale, sandstone, and coal of the Menefee Formation forms the ridge dividing Carache Canyon and the unnamed canyon to the west in the southern part of the Ortiz Mountains. The Point Lookout Sandstone can be traced northward in the Ortiz Mountains to the upper reaches of Crooked Canyon, where its trace is interrupted by the large augite-monzonite stock. The Point Lookout Sandstone resumes on the northwestern side of the augite-monzonite stock and can be traced along the west flank of Cerro Chato and into the southern reaches of Miller Gulch, west of the village of Madrid.

The Point Lookout Sandstone on the Ortiz Mine Grant is best known at Carache Canyon, where it serves as both a convenient stratigraphic marker for evaluation of, and a host for, gold mineralization. At Carache Canyon, the Point Lookout Sandstone ranges from 25 to 31.4 m (82 to 103 ft) thick, as determined by core drilling.

Km - Mancos Shale, undivided - The Mancos Shale on the Golden quadrangle has been subdivided into seven members with an aggregate thickness of 552.7 m (1,813 ft). A complete section of the Mancos Shale is preserved in the Ortiz Mountains though it has been extensively intruded by laccoliths and sills of andesite porphyry. Contact metamorphism and metasomatism have strongly affected the Mancos Shale, in many places obscuring original sedimentary textures and structures.

Kmu - upper Mancos Shale Member - Marine shales ranging from 104 to 113 m (340 to 371 ft) thick overlie the Hosta-Dalton sandstone and underlie the Point Lookout Sandstone in the Ortiz Mountains. The upper 15 m (50 ft) contain beds of bioturbated sandstone. These strata are probably equivalent to the Satan Tongue (Molenaar, 1983).

Khd - Hosta-Dalton Sandstone (Mesa Verde Group) - The Hosta-Dalton sandstone is the turnaround of the Cretaceous shoreline during and after Crevasse Canyon Formation deposition and therefore represents a regressive-transgressive cycle (R-3 – T-4 of Molenaar, 1983). It corresponds to the Cano Sandstone Member of Stearns (1953). In the Ortiz Mountains, the Hosta-Dalton is shown by drilling to be 46 to 64 m (150 to 210 ft) thick. Exposures in the Ortiz Mountains on the ridge east

of Monte del Largo Canyon are poor, but considerable float of fine-grained sandstone covers the surface in this area. In the Cedar Crest area, the Hosta and Dalton sandstones are separated by the coal-bearing Crevasse Canyon Formation (Molenaar, 1983). The Hosta-Dalton sandstone overlies the Niobrara Shale Member and underlies marine shales of the Upper Mancos Shale Member. It may include part of the El Vado Sandstone in its basal part.

Kmn - Niobrara Member - The Niobrara Member measures 245 m (804 ft) thick by drilling in the southern Ortiz Mountains. It is composed of interbedded calcareous sandstone, siltstone, and shale. In the Ortiz Mountains the lower part of the Niobrara likely includes strata equivalent to the D-Cross Shale Member.

Kmj - Juana López Member - In the southwestern part of the Ortiz Mountains, east of Lukas Canyon, the Juana López Member is strongly metamorphosed to a garnet porphyroblast-bearing hornfels. In core drilling in the southwestern Ortiz Mountains, 16.7 m (55 ft) of hornfels of the underlying Carlile member is included in the Juana López Member.

Kmc - Carlile Shale Member - The Carlile Shale crops out in the southwestern part of the Ortiz Mountains, where it is 88 m (288 ft) thick, as measured by drilling. In outcrop in the southwestern Ortiz Mountains, the Carlile is commonly metamorphosed to a variegated brown, red, cream, and green hornfels. In the lower part of the Carlile section, near the skarn bed in Lukas Canyon, the Carlile hornfels commonly contains porphyroblasts of reddish brown garnet.

Kmg - Greenhorn Limestone Member - The Greenhorn Limestone Member of the Mancos Shale serves as an important stratigraphic marker horizon regionally and locally (Molenaar, 1983). In the Ortiz Mine Grant, the Greenhorn is metamorphosed to a gold- and copper-bearing garnet-pyroxene-scapolite skarn in Lukas and Monte del Largo Canyons, in the southwestern part of the Ortiz Mountains. Extensive drilling of the Lukas Canyon deposit shows the metamorphosed Greenhorn beds to be 15 to 18 m (50 to 60 ft) thick. The skarn beds grade laterally into poorly exposed fresh limestone and shale. The Greenhorn Limestone can be traced from the region of the Galisteo Dam southward into the northwestern portion of the Ortiz Mine Grant.

Kmgr - Graneros Shale Member - Black shale underlying the Greenhorn Limestone Member and overlying sandstone of the Dakota Formation is assigned to the Graneros Shale Member. Drilling in the southwestern part of the Ortiz Mountains penetrated 38 m (126 ft) of marine shale below the Greenhorn Limestone Member and above sandstone of the Dakota Formation.

Middle Cretaceous

Kd - Dakota Formation - The Dakota Formation crops out on the top of El Punto Hill, on the southwest end of the Ortiz Mountains, and can be traced 1370 m (4500 ft) to the south and 600 m (2000 ft) to the north. Other smaller exposures of the Dakota Formation occur in the southeastern foothills of the Ortiz Mountains. The Dakota Formation has not been subdivided into members as it has been in the Hagan Basin (Picha, 1982), or at Galisteo Dam (Lucas and others, 1999). Coarse to conglomeratic sandstone with common worm burrows mark the Dakota. Holes ORT-116 and ORT-126 drilled 32.8 m (108 ft) of Dakota sandstone and shale in the southwestern part of the Ortiz Mountains.

JURASSIC

Jurassic rocks are exposed on the Ortiz Mine Grant on the western margin of the Ortiz Mountains and along the southern side (footwall) of the Buckeye Hill Fault.

Upper Jurassic

Jm - Morrison Formation. Undivided – On the Golden quadrangle, the Summerville Formation and the Salt Wash, Brushy Basin, and Jackpile members of the Morrison Formation were not distinguished in surface mapping. All sandstone and mudstone (and quartzite and hornfels derived from them) above the Tonque Arroyo gypsum member of the Todilto Formation and below the conglomeratic sandstone of the Dakota Formation were grouped together in the Morrison Formation. The lower part of the Morrison Formation is poorly exposed. Most of the Morrison Formation from the Ortiz Mountains is known from the 191 m (628 ft) thickness drilled in the southwestern part of the Ortiz Mountains. The kaolinitic sandstone exposed below the Dakota Formation on the west side of the hill known as El Punto, on the southwestern end of the Ortiz Mountains, is probably correlative with the Jackpile Member of the Morrison Formation, as described by Picha (1982) and Lucas and others (1999).

Middle Jurassic

San Rafael Group

> **Js - Summerville Formation** - The Summerville Formation is not mapped separately on the surface on the Ortiz Mine Grant, but instead is mapped with the Morrison Formation. In core drilling, sandstone and mudstone assigned to the Summerville Formation measures 21.2 m (86 ft) thick.

> **Jt - Todilto Formation -** Thin-bedded limestone of the Luciano Mesa Member of the Todilto Formation crops out in Arroyo del Tuerto approximately 45 m (150 ft) east of NM-14, and along the southwestern and southern flanks of the Ortiz Mountains. Hole ORT-126 intersected 3.4 m (11 ft) of the

Todilto limestone. The gypsum (Tonque Arroyo) member of the Todilto is poorly exposed on the Ortiz Mine Grant and is considerably altered and brecciated in all known exposures. The limestone member is altered to magnetite-garnet skarn at the Iron Vein prospect. At the Iron Vein, and in one exposure in Arroyo del Tuerto, the gypsum member is replaced by a carbonate-matrix breccia with clasts of sandstone and andesite porphyry.

Je - Entrada Sandstone - Sandstone overlying mudstone of the Chinle Group and overlain by the limestone member of the Todilto Formation is exposed in Arroyo del Tuerto 90 m (300 ft) east of NM-14, in several exposures along the southeastern and southwestern flanks of the Ortiz Mountains, and in Arroyo de la Joya about 1,800 m (6,000 ft) east of the Lone Mountain Ranch headquarters. Thickness of the Entrada sandstone was measured at 8.8 m (29 ft) in hole ORT-126. In the vicinity of the Iron Vein prospect, on the southern flank of the Ortiz Mountains, the Entrada sandstone is metamorphosed to quartzite. The Slick Rock Dewey Bridge Members are not distinguished on the Golden quadrangle.

TRIASSIC

Upper Triassic

Triassic rocks underlie much of the Tuerto Gravel-covered pediment west and south of the Ortiz Mountains. The best exposures of Triassic strata on the Grant are in the north-trending ridge northeast of the village of Golden and in the northeastern part of the San Pedro Mountains.

TRc - Chinle Group, undivided - No attempt has been made on the Golden quadrangle to differentiate the Salitral Formation, Petrified Forest Formation, and Correo Sandstone of the Chinle Group. The Chinle Group is exposed in several isolated areas in the southwestern part of the Ortiz Mine Grant. Reddish brown mudstone and lesser sandstone exposed in Arroyo del Tuerto west of NM-14 and in Arroyo de la Joya east of the Lone Mountain Ranch headquarters probably correlate to the Petrified Forest Formation. Along the southern foothills of the Ortiz Mountains, in the low hills about 1,500 m (5,000 ft) northwest of the Lone Mountain Ranch headquarters and in the eastern part of the San Pedro Mountains, mudstone and sandstone of the Chinle Group has been metamorphosed to a mottled green to black and white hornfels and quartzite. Lucas and Heckert (1995) measured 390 m of Chinle Group rocks above the Agua Zarca Formation in the Hagan Basin. Chinle Group sedimentary rocks are extensively intruded by andesite porphyry laccoliths and sills in the south-central part of the Ortiz Mine Grant.

TRca - Agua Zarca Formation - Coarse to locally conglomeratic sandstone of the Agua Zarca Formation forms prominent ridges northeast of the village

of Golden; and on the north flank of the San Pedro Mountains, about 2,100 m (7,000 ft) south-southwest of the Lone Mountain Ranch headquarters. The minimum thickness of Agua Zarca Formation sandstone is estimated at 15 m (50 ft).

TRm - Moenkopi Formation - Red siltstone and sandstone form a recessive bench on the western slope of a north-trending ridge northeast of the village of Golden; and on the north flank of the San Pedro Mountains, about 2,100 m (7,000 ft) south-southwest of the Lone Mountain Ranch headquarters. The unit overlies San Andres Formation limestone and underlies the Agua Zarca Formation sandstone. The unit appears to be approximately 6 m (20 ft) thick. On the basis of lithology, thickness, and stratigraphic and geographic position, the unit is assigned to the Moenkopi Formation as defined by Lucas and Heckert (1995).

PALEOZOIC ERATHEM

PERMIAN

Permian rocks crop out in the southern part of the Ortiz Mine Grant. The lowermost formations, the Abo and Yeso formations, are undifferentiated in the northern foothills of the San Pedro Mountains. In the San Pedro Mountains these formations are commonly metamorphosed to a black to green hornfels.

P – Permian, undivided (cross sections only) – Includes San Andres Formation, Glorieta Sandstone, Yeso, and Abo Formations

Psa - San Andres Formation - Gray to yellowish limestone of the San Andres Formation crops out on the western slope of a north-trending ridge northeast of the village of Golden, and on the north flank of the San Pedro Mountains, about 2,100 m (7,000 ft) south-southwest of the Lone Mountain Ranch headquarters, and in a small exposure along Arroyo del Tuerto about 1,500 m (5,000 ft) east of NM 14. The San Andres Formation has not been measured but is estimated to be about 6 m (20 ft) thick on the ridge northeast of Golden.

Pg - Glorieta Sandstone - The Glorieta Sandstone is a quartzose, white, medium-grained sandstone that crops out on the western slope of a north-trending ridge northeast of the village of Golden, and on the north flank of the San Pedro Mountains, about 2,100 m (7,000 ft) south-southwest of the Lone Mountain Ranch headquarters, and in a small exposure along Arroyo del Tuerto about 1,500 m (5,000 ft) east of NM 14. The Glorieta's thickness appears to be about 15 m (50 ft) on the ridge northeast of Golden and closer to 30 m (100 ft) in the San Pedro Mountains. Glorieta sandstone has been mined for silica sand from an open cut in the San Pedro Mountains about 1,200 m (4,000 ft) south of the south boundary of the Ortiz Mine Grant.

Py - Yeso Formation - The Yeso Formation crops out as brownish red sandstone and mudstone in isolated exposures northeast of the village of Golden and south of Arroyo del Tuerto. Atkinson (1961) estimated a thickness of about 120 m (400 ft) for the Yeso Formation in the San Pedro Mountains.

Pa - Abo Formation - The Abo Formation is poorly exposed in isolated outcrops of reddish mudstone on the west side of the Little Tuerto Hills, along NM 14 about 1,200 m (4,000 ft) north of the village of Golden, and along Arroyo del Tuerto about 1,700 m (5,500 ft) east of NM 14. Atkinson (1961) estimated about 275 m (900 ft) of Abo Formation in the San Pedro Mountains.

CARBONIFEROUS

lPM– Pennsylvanian and Mississippian, undivided (cross sections only) – Includes Madera Formation, Sandia Formation (?), and Mississippian Arroyo Peñasco Group (?).

PENNSYLVANIAN

lPm - Madera Formation - Gray, thick-bedded limestone of the Madera Formation crops out on the north end of the Little Tuerto Hills, in isolated overturned beds in an arroyo about 0.5 km (0.3 mi) south of the village of Golden, and in the northwestern foothills of the San Pedro Mountains. No thickness was measured, but there appears to be in excess of 60 m (200 ft) exposed thickness of limestone in the Little Tuerto Hills. Emerick (1950) estimated the thickness of the Madera Formation in the Golden area at 300 m (1000 ft). In the San Pedro Mountains, Madera Formation limestone beds have been variously metamorphosed to garnet skarn and marble, and mineralized, in proximity to latite-porphyry intrusive rocks. Shales have been converted to hornfels.

lPs - Sandia Formation - Shale and limestone overlies sandstone and conglomerate of the Del Padre Sandstone and underlies thick-bedded limestone of the Madera Formation in the Little Tuerto Hills. The unit is approximately 15 m (50 ft) thick and is assigned to the Sandia Formation.

MISSISSIPPIAN

Md - Del Padre (?) Sandstone (Arroyo Peñasco Group) - White quartzite-pebble conglomerate nonconformably overlies metamorphic rocks and is overlain by shale and limestone of the Sandia Formation in the Little Tuerto Hills. The unit is approximately 15 m (50 ft) thick and is composed of medium to coarse sandstone and pebbles to cobbles of quartzite. The quartzite pebbles bear strong resemblance to the underlying quartzite, suggesting local provenance. This unit was assigned to the Sandia Formation by Emerick (1950). Read and others

(1999a and b) describe similar sandstone and pebble conglomerate in the Sandia Mountains and assign it to the Mississippian Del Padre Sandstone.

PRECAMBRIAN ERATHEM

Metamorphic Rocks

Precambrian rocks exposed on the Ortiz Mine Grant are limited to exposures in the Little Tuerto Hills southwest of the village of Golden. The rock types present, quartzite and amphibolite schist, are similar to rocks exposed in the Monte Largo Hills, about 6 km (4 mi) to the southwest and described by Huzarski (1971), Timmons and others (1995), and Ferguson and others (1999). The Precambrian outcrop in the Little Tuerto Hills forms the core of a notheast-trending horst block 760 m (2500 ft) and 3,600 m (12,000 ft) long. The northern part of the horst block is expressed as a northeast-plunging anticline formed by the Madera Formation.

pC – Precambrian, undivided (cross sections only) – Includes metamorphic and granitic rocks.

pCa - Amphibolite schist - Black, strongly lineated amphibolite schist crops out on the west flank of the Little Tuerto Hills near the south border of the Ortiz Mine Grant. Foliation strikes uniformly to the northeast and dips steeply northwest.

pCq – Quartzite - White to tan, rarely micaceous quartzite with occasional iron-oxide-rich bands marking compositional layering is exposed in the southern part of the Little Tuerto Hills. The compositional layering indicated by iron-oxide bands strikes northeast and dips steeply to the northwest.

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