GEOLOGY OF THE CERRO DEL VIBORO AREA

SOCORRO COUNTY, NEW MEXICO

by

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ABSTRACT

The Cerro del Viboro area is characterized by a gentle, southerly plunging anticlinorium of Pennsylvanian to Recent rocks. Low-angle faulting, north-south and northwest-southeast graben faulting and folding have complicated the anticlinal structure. The oldest rock unit exposed is the Madera Limestone (192-feet) (Pennsylvanian). The Madera is overlain by the Bursum (193.6-feet), Abo (370-feet), Yeso (944.0-feet), San Andres (355-feet), and Bernal (99-feet) formations of Permian age. The Upper Triassic Dockum Group (777-feet) overlies the Permian rocks in the southern and eastern parts of the study area. Upper Cretaceous strata unconformably overlie the Upper Triassic layers. The Dakota Sandstone (67-feet) is overlain by the Mancos Shale (1007.6-feet), in turn overlain by the strata of the Mesaverde Group (61-feet). In the southeast map area, the Mesaverde Group lies beneath an angular unconformity with Tertiary strata. The Baca (127-feet) and Santa Fe (70.5-feet) formations are Tertiary in age and are located along the western margin and southeast corner of the map area. A few isolated dikes, andesitic in composition and Tertiary in age, occur in the map area.

Field mapping, a measured section and petrographic studies conducted during the summer and fall of 1981, indicate oscillating marine and terrestrial environments have occupied the Cerro del Viboro area since the Upper Paleozoic. Periods of erosion and nondeposition occurred at the end of the Pennsylvanian, Permian, Triassic, and late Cretaceous. In the late Cretaceous to middle Eocene, folding, uplift of strata and low-angle faulting associated with the Laramide orogeny occurred. Rocks uplifted by compressive forces during the Laramide were eroded and deposited in adjacent, low-lying depressions during the Eocene. In early to late Miocene through Pliocene, north-south, northwest-southeast normal faulting and related drag folds associated with the Basin and Range orogeny occurred. Intrusion of Tertiary dikes occurred following expansion and prior to closure of the extensional, graben fault systems. From Pleistocene to Recent deposits of alluvium have been filling local depressions and the present stream and tributary systems were developed.

INTRODUCTION

Purpose of Investigation

The objectives of this thesis are to construct a geologic map of the Cerro del Viboro (Darton, 1929) area near Carthage, New Mexico, correlate the stratigraphy with the accepted stratigraphic terminology, and determine the geologic history of the area.

Location and Accessibility

The center of the Cerro del Viboro area lies 8 miles east of San Antonio, New Mexico (figure 1). The area is approximately 4 to 5 miles square and is approximately bounded to the south by U.S. Highway 380 between secs. 8 and 11, T.5S. R.2E., and to the north by Socorro County road A129 between secs. 15 and 17, T.4S., R.2E.. Access to the area is by unimproved Socorro County roads A137 and A129, and the American Telephone and Telegraph longlines service road 2E, all of which turn north from U.S. Highway 380. Most of the area lies within a 2 mile proximity of an access road.

Previous Work

The first work concerning geology of the Cerro del Viboro area was published by J.H. Gardner in 1910. Gardner (1910) described the Carboniferous to Recent strata and constructed a geologic map of the area giving special emphasis to the Carthage coal field.

In 1928, N.H. Darton measured and described

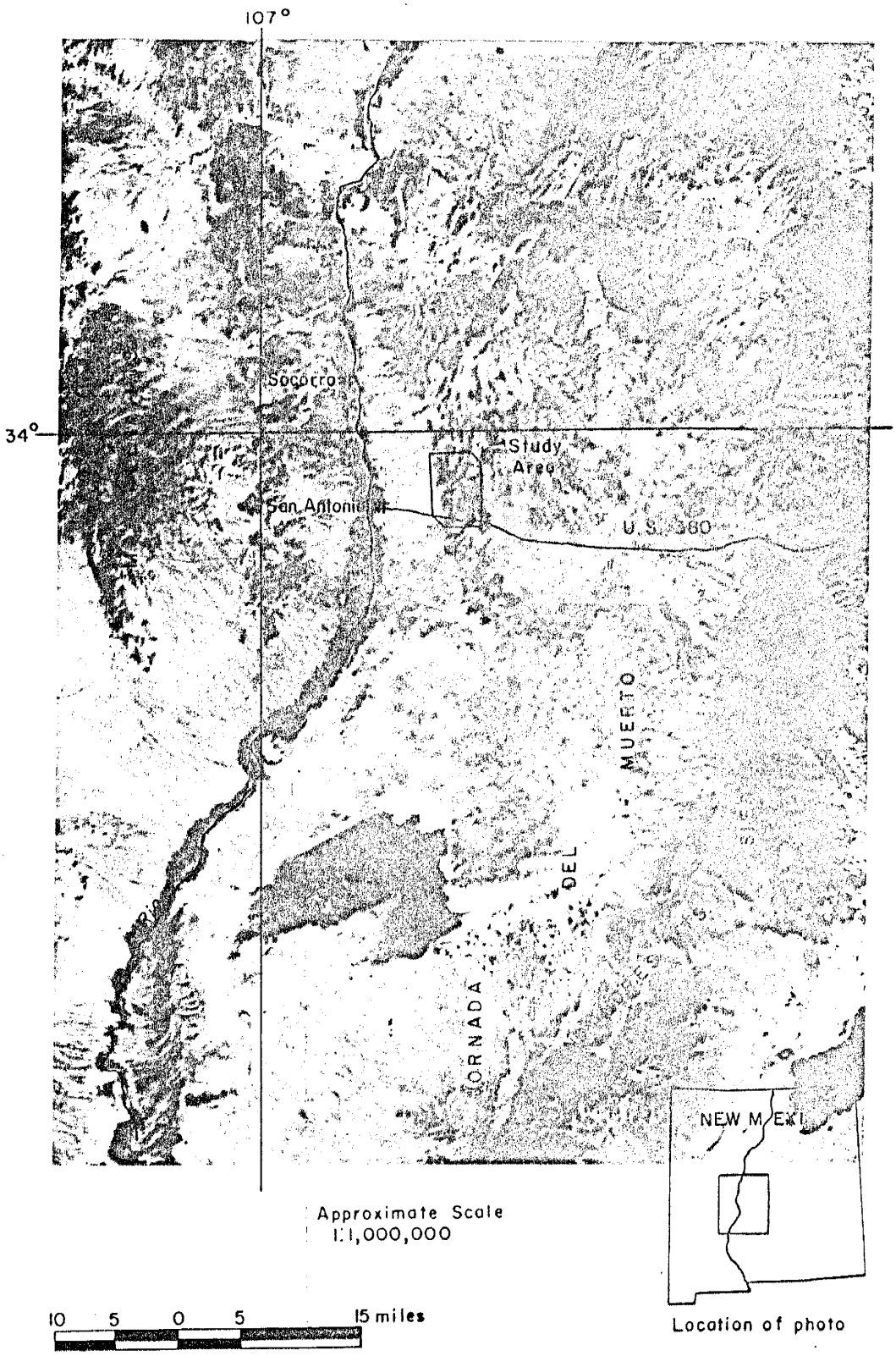

Figure 1. Index map and photo showing general location of study area. Photo, courtesy of Landsat imagery; print reproduction by B. DeMarco, R. & D.D. photo lab.

Pennsylvanian through Quaternary strata east of Socorro, New Mexico. In his report, Darton (1928) named the Cerro del Viboro (located in the S./2 of T.4S., R.2E.) and published a reconnaissance geologic map of central New Mexico.

In 1951, R.H. Wilpolt and A.A. Wanek published a report on the regional geology from Socorro and San Antonio east to Chupadera Mesa, Socorro County, New Mexico. Wilpolt and Wanek (1951) presented a reconnaissance map and several cross-sections in their report, and are responsible for extending much of the stratigraphic nomenclature that is currently used in the Cerro del Viboro area from other areas.

In 1963, R.W. Foster published a road log of the area adjacent to U.S. Highway 380 east of San Antonio, New Mexico, and A.J. Budding published a field trip and geologic map of the Carthage area.

The first work involving paleontologic studies in the Cerro del Viboro area was published by E.C. Case in 1916, and revealed evidence of vertebrate fauna from red beds near the old lime kiln (S.E. 1/4 S.E. 1/4 sec. 5, T.5S., R.2E.). Darton (1922) correlated the beds with exposures of the Dockum Group.

In 1979, W.A. Cobban and S.C. Hook published a report on ammonite fauna located in the Mancos Shale. Based on their studies, Cobban and Hook (1979) subdivided the Mancos Shale into a lower Shale Tongue, the middle Tres Hermanos Sandstone Member, and an upper D-Cross Shale Tongue.

Most recently S. Lucas and others (In Press), discovered

Titanothere teeth in red beds of the Baca Formation. Their study (Lucas and others, In Press) shows that the Baca outcrops near Carthage, were deposited from Bridgerian to Chadronian time.

Method of Investigation

A composite stratigraphic section was measured and surface mapping of the Cerro del Viboro area was completed during the summer and fall of 1981 (Plate 1, Plate 2 and Plate 4). Mapping was recorded on a topographic base constructed from the Canyon Agua Buena and San Antonio preliminary 7.5 minute quadrangle maps, using a scale of 1:24,000.

Classification of sedimentary rocks was based on earlier work by Wilpolt and Wanek (1951), Cobban and Hook (1979), and Smith and Budding (1959). Sorting, size, type, and angularity of constituent grains was estimated in the field and in thin-sections. Twenty four thin-sections were studied to determine composition and textures of the rocks.

Acknowledgements

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Geographic Setting

The Cerro del Viboro area consists of high north-trending ridges capped by the San Andres Formation to the north and lower ridges capped by the Dakota Sandstone to the south. The area is bordered on the east by the Jornada del Muerto basin, the south by the Carthage coal field, and on the west by the Rio Grande Valley. Elevations range from 5,760 feet above sea level at the highest point to 4,845

feet above sea level at the lowest point. Present topography is controlled by various structural patterns and weathering resistance of the formational units.

GEOLOGY

Geologic Setting

The Cerro del Viboro area lies on the east flank of the Rio Grande rift and is located north of the Carthage coal field; it is separated from Chupadera Mesa to the southeast by the Jornada del Muerto basin, and from the Chupadera Mountains to the west by the Rio Grande Valley. The Cerro del Viboro area includes a gentle southerly plunging anticlinorium with Triassic and Cretaceous sandstone and shale in the south and Permian sandstone, siltstone, and limestone in the north. Local folding, low-angle faulting, north-south and northwest-southeast graben faulting, complicate the anticlinal structure.

Pennsylvanian Rocks

Madera Limestone

The Madera Limestone of the Magdalena Group, first described by Keyes (1903) for exposures on the eastern slope of the Sandia Mountains in Bernalillo County, is the oldest rock unit exposed in the map area. Previous workers (Thompson (1942), Kottlowski and others (1956), and Pray (1961)) have subdivided the Magdalena Group on the basis of fusulinid zones. Recently, Siemers (1978) subdivided the Magdalena Group on the basis of rock-stratigraphic units.

Siemers (1978) recognized a lower terrigenous unit, a medial limestone unit, and an upper mixed limestone-terrigenous unit in the Pennsylvanian System throughout the Socorro region. The lower terrigenous unit is named the Sandia Formation and the overlying lower gray limestone unit and arkosic limestone unit are referred to as the Madera Limestone of Desmoinesian to Virgilian age (Plate 5). In the Cerro del Viboro area only outcrops of the upper arkosic limestone unit are exposed; these exposures are located in the northwest corner of the area and form a narrow (1/4-mile wide) north-trending ridge bordered by younger Tertiary sediments to the west and Permian rocks to the east (fig. 2). An incomplete section comprising 192-feet of thinly bedded calcareous shale and moderately bedded limestone and arkose was measured in sec. 17, T.4S., R.2E..

The oldest outcrops of Madera Limestone measured consist of green-gray shale and limestone. The shale and limestone are thinly interbedded and form a slope capped by a massive gray limestone. Overlying the massive limestone, thin, medium-bedded limestone with a few interbedded calcareous arkoses, buff to brown in color, dominate the section. The limestones are commonly gray to black, medium-and massive-bedded, hard, brittle, arkosic and contain abundant and diversified fossil material (brachiopods, rugosids, crinoid columnals, fusulinids, ostracods, oolites, gastropods and coralline algae). Nodules and lenses of chert, ripple marks and mudcracks are common features along some

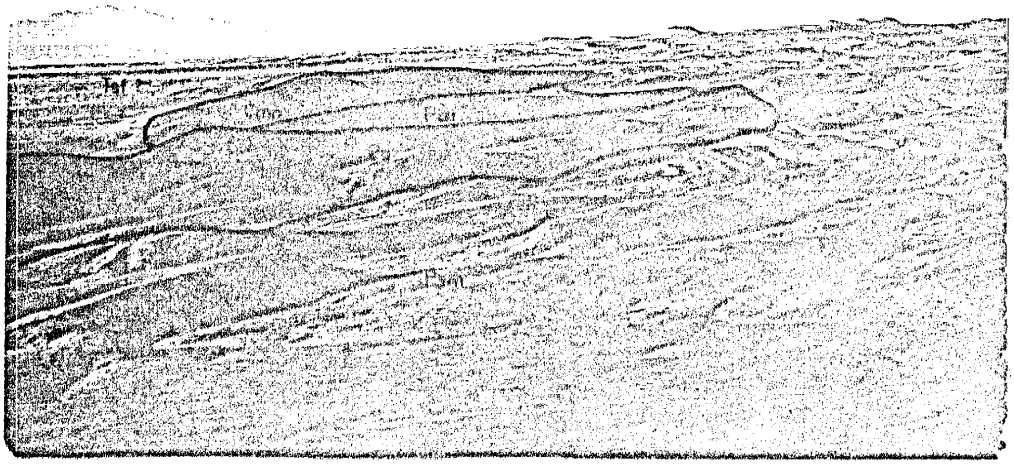

Figure 2. View looking northwest of Santa Fe, Madera, Bursum, Abo and Meseta Blanca outcrops, Socorro Peak on left horizon. Location of photo; sec. 17, T.4S., R.2E..

bedding planes.

The contact between the Madera Limestone and overlying Bursum Formation is picked at the top of a gray arkosic limestone containing chert nodules, crinoid columnals replaced by jasper, brachiopods and a few rugosids; the immediately overlying unit is a gray to purple arkosic limestone containing mudcracks, clusters of pink feldspar grains and very few brachiopods. The contact appears to be conformable within the map area; however, over a much larger area, Wilpolt and Wanek (1951) have shown that the contact is disconformable.

Permian Rocks

Bursum Formation

The Bursum Formation was first defined by Wilpolt and others (1946) from exposures in sec. 1, T.6S., R.4E., and later redefined by Bates and others (1947) and Lloyd (1949) from exposures in sec. 14, T.2N., R.4E., Socorro County. Earlier fusulinid studies by Thompson (1942) indicate the Bursum Formation is Wolfcamp in age.

In the map area, outcrops of the Bursum Formation are located in the northwest and form a narrow (1/4-mile wide), north-trending slope on a ridge of the Madera Limestone. A complete section, comprising 193.6 feet of interbedded sandy shale, arkose and limestone, was measured in sec. 17, T.4S., R.2E..

The Bursum Formation consists of thick-beds of purple and maroon siltstone and shale interbedded with thinner-beds

of gray limestone and arkose. The siltstone and shales are commonly sandy, poorly sorted, calcareous, contain calcareous concretions and occur as slope-forming units capped by more resistant thin-bedded limestone and arkose. The limestone ledges are commonly arkosic, fossiliferous (gastropods, crinoid columnals, algae and brachiopods), and contain mudcracks. The arkoses are varicolored and range from maroon to brown to pink in color. They are calcareous and poorly sorted with large, subrounded cobbles of white quartz and pink feldspar floating in finer, coarse-sand to pebble-size quartz, chert and feldspar grains.

The contact between the Bursum Formation and overlying Abo Formation is picked at the top of a green-gray calcareous arkose with low-angle crossbeds which contains coarse-sand to pebble-size subangular smoky quartz, chert, feldspar, and mica grains; it is overlain by an unconsolidated, calcareous, maroon shale. The contact is obscured by deposits of younger sandwash material; however, it has been shown by Wilpolt and others (1946) to be a conformable and transitional boundary.

Abo Formation

The Abo Formation was first defined by Lee (1909) then redescribed by Needham and Bates (1943) from outcrops in Abo Canyon at the south end of the Manzano Mountains, Socorro County. Fossil plants from the upper Abo Formation have been interpreted by King (1945) to be Leonardian in age.

Outcrops of the Abo Formation occur as a north-trending

(1/3-mile wide) slope-and mesa-forming unit overlying the Bursum Formation in the northwest and as an uplifted block bounded by normal faults in the northcentral region of the map area. An incomplete section composed of 370 feet of dark red to purple shale, conglomerate and siltstone was measured in sec. 17, T.4S., R.2E..

The basal unit of the Abo Formation is a slope-forming maroon shale. The shale is 48 feet thick, poorly indurated and calcareous. A true thickness of this shale was unavailable due to the overlapping of younger sandwash material at the base. Above the basal shale, thick maroon and brick-red shales, interbedded with thinner siltstone and conglomerate beds, occur. The shales are calcareous, poorly indurated, slope-forming units which are capped by more resistant siltstone and conglomerate beds. The siltstones are thickly laminated (1/4-1/2 inches thick), calcareous, well-indurated, hard, brittle and contain ripple marks, burrows, leaf prints, circular white to light gray bleach spots and manganese stain on weathered surfaces. The conglomerates are dark brown to maroon, brick-red and pink. They occur as thin, continuous beds and as laterally discontinuous thin-lenses, and are composed of poorly sorted pebble-size clasts of gray limestone, brick-red siltstone and shale, and a few medium to coarse, subround and frosted quartz grains. The conglomerates are commonly well-indurated, hard, brittle, slightly calcareous and contain vuggy porosity.

The contact with the Abo Formation and overlying Yeso Formation is picked at the top of a dark red-brown to maroon siltstone and at the base of a maroon and green-gray shale. The siltstone is thickly laminated (1/8 inch), well-indurated, very hard, brittle and calcareous; whereas, the overlying shale is thinly laminated (1/16 inch), soft, brittle, has platy cleavage and is noncalcareous. The contact is well-exposed in the map area and considered to be conformable and transitional in nature.

Yeso Formation

The Yeso Formation was first described by Lee (1909) from exposures in secs. 4 and 5, T.2S., R.2E., and sec. 33, T.1S., R.2E., Socorro County. Needham and Bates (1943) redefined the type section and subdivided the Yeso Formation into a lower clastic, limestone and evaporite unit, a middle Canas Gypsum Member and an upper Joyita Sandstone Member. Subsequent work by Wilpolt and others (1946) named the lower unit of the Yeso Formation the Torres Limestone Member, then extended the base of the Yeso Formation to include 190-355 feet of rock formerly included in the upper part of the Abo Formation by Needham and Bates (1943) and correlated it with the Meseta Blanca Sandstone Member of Wood and Northrup (1946). The Yeso Formation lacks good age diagnostic fossils; however, on the basis of regional correlations Pray (1961) indicates the Yeso is Leonardian in age.

Outcrops of the Yeso Formation trend northeast from the west-central part of the map area and represent an irregular

1/2 to 2 mile wide, valley-, slope-and cliff-forming unit that has been disrupted by periods of folding and faulting. Three incomplete sections comprising 940 feet of sandstone, interbedded limestone, sandstone and shale, interbedded thin limestone, shale and gypsum, and medium-bedded sandstone were measured in secs. 20 and 21, T.4S., R.2E..

Meseta Blanca Sandstone Member- The Meseta Blanca Sandstone Member is the lowermost clastic unit in the Yeso Formation and is composed of 294 feet of uniformly bedded red-brown, maroon and gray, sandstone, siltstone and shale. The sandstones are fine-to very fine-grained at the base of the section and range up to medium-grain size at the top, moderately to poorly sorted, poorly indurated, soft and brittle. The siltstones are thickly laminated (1/8-1/2 inch), well-sorted, poorly to well-indurated, soft to hard and brittle, and the shales are soft, crumbly and poorly exposed. Fossil material was not located in the Meseta Blanca Sandstone; numerous ripple marks, mudcracks and salt casts occur on bedding surfaces.

The contact between the Meseta Blanca Sandstone and overlying Torres Limestone Member was chosen at the top of a thinly bedded, tan to brown sandstone composed of medium, subangular, moderately sorted, translucent and frosted quartz grains, and at the base of a calcareous, crossbedded, tan sandstone composed of coarse, poorly sorted, subangular, frosted and translucent quartz grains. The contact is well-exposed in the map area, is transitional, and represents a

conformable boundary.

Torres Limestone Member-An incomplete section of the Torres Limestone Member composed of 455 feet of dominantly sandstone (63%) and limestone (18%) with lesser amounts of siltstone (6%), mudstone (3%) and breccia (4%) was measured (fig. 3). The basal 85 feet of the Torres is composed of thick-bedded, tan and red-brown, calcareous sandstone that contains very fine to coarse, subround, moderately to poorly sorted, translucent and frosted quartz grains and in a few cases is crossbedded and has ripple marks and few salt casts on bedding surfaces. A green and tan shale interbedded with thin sandstone stringers separates the basal clastic unit from the lowermost limestone of the Torres Member. Above this shale alternating thick-bedded limestone, sandstone, mudstone and breccia occur. The sandstone beds are thickest and dominate the section, their lithology is similar to the clastic units in the basal Torres. The limestones are gray to black, sandy, medium-bedded and contain vuggy porosity. Few fossils were found in the Torres limestone layers; the lowermost limestone bed contains a few brachiopods and gastropods, and the uppermost limestone contains abundant fossil material (brachiopods, gastropods, pelecypods, crinoid columnals, algae and oolites). The breccias that occur in the Torres are varicolored, laterally discontinuous and contain up to boulder-size, randomly oriented, angular fragments of limestone floating in a silt-to medium sand-size material. The breccias are commonly well-silicified,

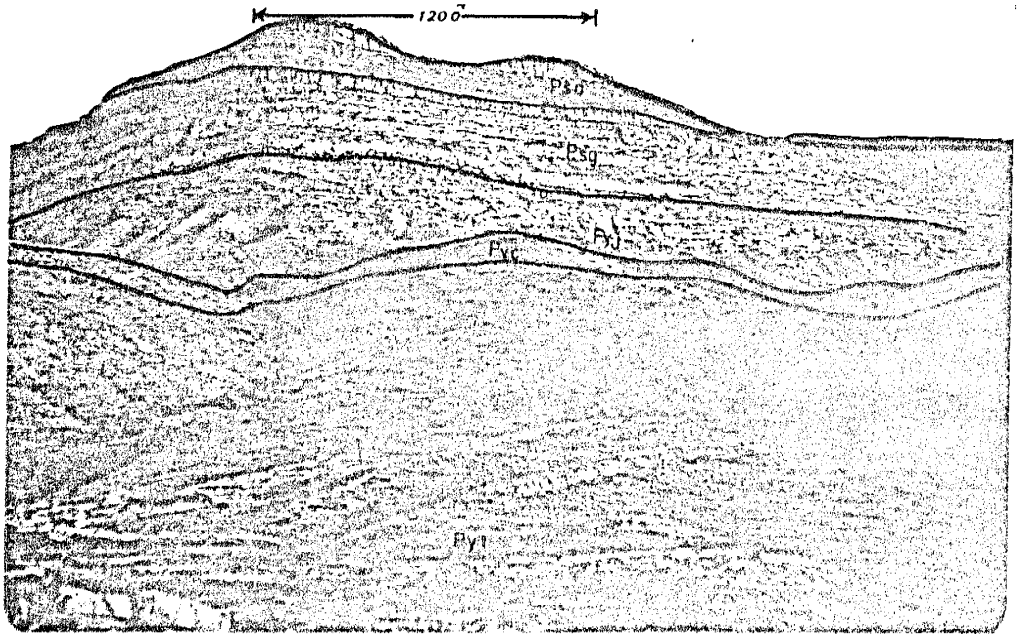

Figure 3. View looking east of Torres, Joyita, Canas, Glorieta, and San Andres outcrops. Location of photo; N.W. 1/4, Sec. 28, T.4S., R.2E..

very hard, brittle and well-indurated; localized vugs and cavities filled with precipitated carbonate with a radial axial texture occur.

The contact between the Torres Member and overlying Canas Gypsum Member is picked at the top of a light gray sandstone when it exists, or at the top of a gray, thinly bedded fossiliferous limestone and at the base of a breccia. The breccia is varicolored with hematite stain and desert varnish, intensely silicified, laterally discontinuous and contains up to boulder-size, angular, randomly oriented limestone fragments of the Canas Member and sandstone fragments of the underlying Torres Member. The breccia may rest on the uppermost Torres sandstone, or incorporate large blocks of the same sandstone and lie directly on the underlying limestone. The contact is a low-angle fault zone and changes laterally; however, in sec. 7, T.4S., R.2E., the contact is conformable and thick gypsum beds occur. The thick gypsum beds in the study area were removed by low-angle faulting; subsequent leaching of the remaining gypsum layers altered the fault zone.

Canas Gypsum Member-An incomplete section of the Canas Gypsum Member comprising 35.2 feet of thin-bedded breccia, limestone, mudstone, siltstone, sandstone and gypsum was measured. The basal breccia of the Canas Member is overlain by thin-bedded dark-gray to black limestone. The limestone is gradational with the underlying breccia, sandy at the top, fetid, contains few fossils (gastropods) and evidence

of soft sediment deformation. Overlying the basal limestone thinly interbedded buff to yellow mudstone, gray limestone, pink to maroon siltstone and gray sandstone occur. These units are poorly sorted, crumbly, soft, poorly preserved and calcareous. The mudstone and siltstone beds may be gypsiferous, the siltstone beds may contain pebble-to cobble-size clasts of mudstone, and the limestone bed contains a trace of algae. The uppermost unit in the Canas is a gypsum bed, the gypsum is laterally discontinuous and pure white lacking any noticeable impurities.

The contact between the Canas Gypsum Member and overlying Joyita Sandstone Member is picked at the top of the uppermost gypsum bed of the Canas when it exists and at the base of a red to tan, calcareous, sandstone. The sandstone is composed of fine to medium, subround, poorly sorted, frosted quartz grains and a few pebble-size clasts of red-brown siltstone. Where the gypsum is absent, traces of gypsum are disseminated in pores and fill small fractures in the sandstone. In this case, the contact is picked at the top of the uppermost mudstone bed in the Canas. The contact is conformable, its appearance and associated rocks having been altered by post-depositional phenomena.

Joyita Sandstone Member-The Joyita Sandstone Member is the uppermost clastic unit of the Yeso Formation. A complete section comprising 155.7 feet of dominantly sandstone (93%) with lesser amounts of interbedded siltstone (3%), mudstone (2%), shale (2%) and a trace of conglomerate was measured.

The sandstones are red-brown, gray, buff, pink and tan in color, calcareous and are commonly composed of fine to medium, subround, moderately to poorly sorted, frosted quartz grains with a trace of chert and feldspar grains and contain abundant hematite stain and concretions (fig. 4). The beds are thin-to medium-bedded, slightly convolute and may have very low-angle crossbedding. Mudcracks are the only recognizable feature on bedding surfaces. The rocks form a soft, crumbly, poorly indurated slope-unit capped by cliffs of the San Andres Formation.

The contact between the Joyita Sandstone Member and the overlying San Andres Formation is picked at the top of a buff to pink, calcareous sandstone containing medium, subround, moderately sorted, frosted quartz grains; it is overlain by a light-gray to white, calcareous sandstone with massive, low-angle crossbedding which contains medium, subround, well-sorted, translucent quartz grains (fig. 5). The contact is transitional and conformable.

San Andres Formation

The San Andres Formation was named by Lee (1909) and redescribed by Needham and Bates (1943) and also Kottlowski and others (1956). The San Andres Formation is subdivided into a lower clastic member, a limestone member and an upper gypsum member. At the base of the San Andres Formation the Glorieta Sandstone, given formational status by Keyes (1915) and Hager and Robitaille (1919) occurs. Subsequent work by Wilmarth (1938) and Needham and Bates (1943) further

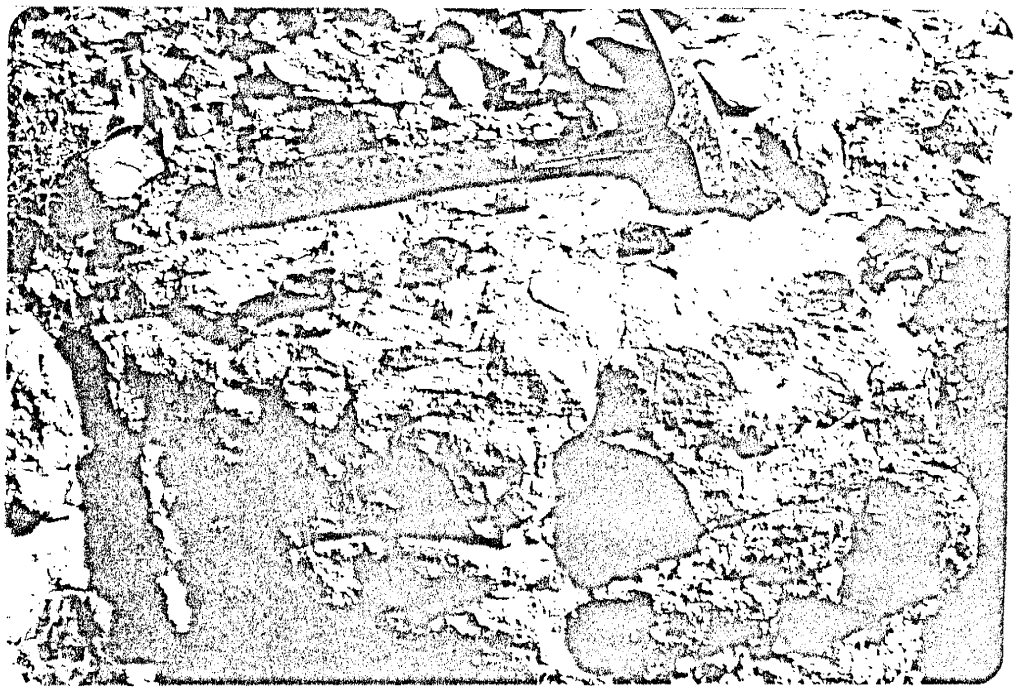

Figure 4. Hematite stain and concretions in the Joyita Sandstone Member of the Yeso Formation. Location of photo; N.W. 1/4, Sec. 28, T.4S., R.2E..

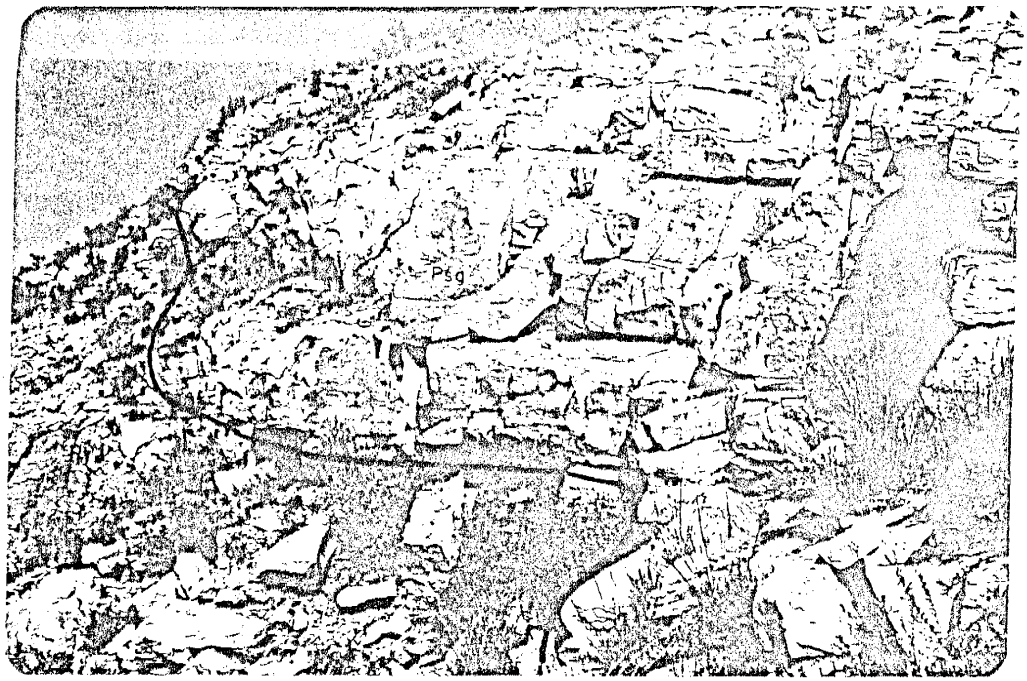

Figure 5. View northeast along contact between the Joyita Sandstone and Glorieta Sandstone. Location of photo; N.W. 1/4, Sec. 28, T.4S., R.2E..

supported the formational status of the Glorieta Sandstone; however, Read and Andrews (1944) followed by King (1945) began the current usage of the Glorieta Sandstone as a basal member of the San Andres Formation. Using diagnostic ammonoids found in the upper San Andres Formation Kottlowski and others (1956) interpret a Leonardian age for the San Andres Formation.

Outcrops of the San Andres Formation are widespread throughout the map area. The Cerro del Viboro, a belt (1 to 2 miles wide) of mesas and escarpments trending northeast across the central portion of the map area is capped by layers of the limestone member; outcrops of the Glorieta Sandstone Member form steep cliffs underlying the limestone beds. An isolated outcrop of the upper gypsum member occurs on the northeast end of the Cerro del Viboro. The upper gypsum member forms a valley and slope unit above the underlying limestone beds and is overlain by younger rocks of the Bernal Formation. Three separated and incomplete sections comprising 404 feet of thick-bedded sandstone, limestone, mudstone and gypsum were measured in secs. 21, 22 and 28, T.4S., R.2E., and in sec. 4, T.5S., R.2E..

Glorieta Sandstone Member-The Glorieta Sandstone Member comprises 133 feet of white to tan and pink, calcareous sandstone. The sandstones contain medium, subround to round, well-sorted, dominantly translucent quartz grains with few frosted, along with a minor amount of hematite stain and concretion material. The beds are medium-to

thick-bedded, commonly crossbedded, laterally discontinuous and may have ripple marks or mudcracks on bedding surfaces. The rocks form a poorly indurated, hard and crumbly, blocky weathering cliff unit capped by the resistant limestone member of the San Andres Formation.

The contact between the Glorieta Sandstone Member and the overlying limestone member of the San Andres Formation is conformable and located at the top of a white to pink, calcareous, crossbedded and massive sandstone containing fine to medium, moderate-sorted, translucent quartz grains. A gray limestone overlain by a black, fossiliferous (brachiopods, gastropods, algae) and fetid limestone marks the base of the overlying San Andres Limestone Member. Irregular and laterally discontinuous, silicified and hematite stained regions are common along the contact. Randomly oriented nodules and masses, and thin-interlayers of silica parallel bedding occur in the overlying limestone. Areas of stained and silicified material extending into the uppermost sandstone beds of the Glorieta are found near areas of moderate and intense structural deformation.
San Andres Limestone Member-Two incomplete sections of the San Andres Limestone Member, the first a thick limestone interval overlying the Glorieta Sandstone in the west-central map area and the second, a thick limestone interval underlying the Bernal Formation in the southwest part of the map area were measured. The incomplete section is composed of 222 feet of dominantly limestone (66%) and breccia (22%)

with lesser amounts of interbedded mudstone (6%) and sandstone (5%). Chert nodules and silicified zones are common in the basal limestone beds. Breccia and interbedded sandstone occur with the middle limestones, and mudstone and siltstone are interbedded with the upper limestone beds. The limestones are massive, very thick to thin-bedded, cavernous, gray to black, rarely tan in color. Most are fossiliferous (algae, gastropods, brachiopods, crinoid columnals, and a minor amount of oolites and rugosids were observed); few are fetid and mudcracks or ripple marks are common features on some bedding planes. The limestone breccias are commonly gray but may range from tan to black in color and are composed of pebble-to boulder-size, randomly oriented, angular fragments of gray limestone and occasional intergranular silt and fine to medium, subround, frosted quartz grains. The breccias are discontinuous and grade both vertically and laterally into the overlying and adjacent beds. In the middle of the limestone a white to gray, calcareous sandstone with medium, rounded, very well-sorted, translucent quartz grains underlies a black, thinly bedded, fossiliferous limestone; this sandstone is laterally discontinuous and grades into an adjacent breccia. At the top of the limestone member, thin, interbedded, siltstone and mudstone occur with the limestones. The mudstones are tan and the siltstones are buff in color; both lithologies are sandy, calcareous, soft, crumbly, slope-formers.

The contact between the limestone member and overlying Upper Gypsum Member of the San Andres Formation is poorly exposed and missing from most parts of the map area. Dissolution and erosion has removed all of the Upper Gypsum Member except for a small isolated outcrop in the southeast quarter of sec. 22, T.4S., R.2E.. Although exposures are lacking the contact is assumed to be conformable.

Upper Gypsum Member-The Upper Gypsum Member comprises 49 feet of mudstone and gypsum. The mudstones are tan in color, gypsiferous, poorly indurated, calcareous and have speckled hematite stain on weathered surfaces. The gypsum is pure white, with alternating light and darker layers at the base, discontinuous, grading laterally into an adjacent breccia. The breccia contains pebble-to boulder-size, chaotic oriented, angular fragments of mudstone and thin-bedded gypsiferous limestone, medium to coarse, subrounded quartz grains in some intergranular spaces and localized vugs and caverns partially filled with precipitated carbonate.

The contact between the San Andres Formation and overlying Bernal Formation is an unconformable boundary. Erosion and dissolution resulting in a karst surface occurred prior to deposition of the Bernal Formation. Throughout most of the map area the upper gypsum member was removed and the Bernal Formation was deposited across an erosional surface on top of the limestone member of the San Andres Formation.

Bernal Formation

The Bernal Formation formerly considered an uppermost member of the San Andres Formation was defined by Bachman (1953) from exposures near the towns of Bernal and Chapelle in San Miguel County. The Bernal Formation has been correlated with the Whitehorse Group in Oklahoma, parts of the Chalk Bluff Formation in southeast New Mexico (Dobrovolny and others, 1947 and Gorman and Robeck, 1946) and with the Artesia Group in southeast New Mexico (Tait and others, 1962). Age diagnostic fossils have not been found in the Bernal Formation; however, lithologic and stratigraphic characteristics indicate the Bernal is Upper Guadalupian, Ochoan or perhaps younger in age.

Exposures of the Bernal Formation are scarce within the map area. Nonresistant, isolated outcrops occur in the southwest and a belt (1/2 mile wide and 1 mile long) of resistant outcrops trending northeast lies in valleys and on slopes of the San Andres hills in the northcentral map area. A section composed of 99 feet of interbedded mudstone (39%), siltstone (28%), shale (12%) and sandstone (21%) was measured in the southwest quarter of section 4, T.5S., R.2E..

The lower half of the Bernal Formation contains alternating beds of mudstone and siltstone. The mudstones are buff to gray and maroon in color, poorly indurated, soft, crumbly and calcareous; the siltstones are red-brown and maroon in color, poorly sorted, soft to hard and contain

mica flakes, mudcracks and a few salt casts on bedding surfaces.

In the middle of the Bernal Formation a very thin conglomerate overlain by a thicker interbedded shale and siltstone sequence occurs. The conglomerate is red-brown in color, calcareous and composed of poorly sorted, cobble-size clasts of red-brown siltstone.

The upper half of the Bernal Formation contains alternating beds of mudstone and sandstone. The mudstones are tan and olive-green in color, laterally discontinuous and may be sandy, micaceous and/or calcareous in the lowermost beds. The sandstones are buff, tan and light brown in color, calcareous and contain fine to medium, poorly to moderately sorted, subround to subangular grains; mudcracks and mica flakes are the only recognizable features on bedding planes and the uppermost beds are commonly crossbedded. Soft sediment deformation, channel fill structures, and collapse features occur locally in the Bernal layers (fig. 6).

The contact between the Bernal Formation and overlying Dockum Group is disconformable. The contact is picked at the base of the lowermost conglomerate bed in the Santa Rosa Sandstone. The conglomerate is varicolored ranging from buff to brown and gray to purple in color, contains pebble-size clasts of the underlying mudstone and grades laterally into a brown sandstone with fine to medium, poorly sorted, subrounded grains in a well-indurated, calcareous, hard and

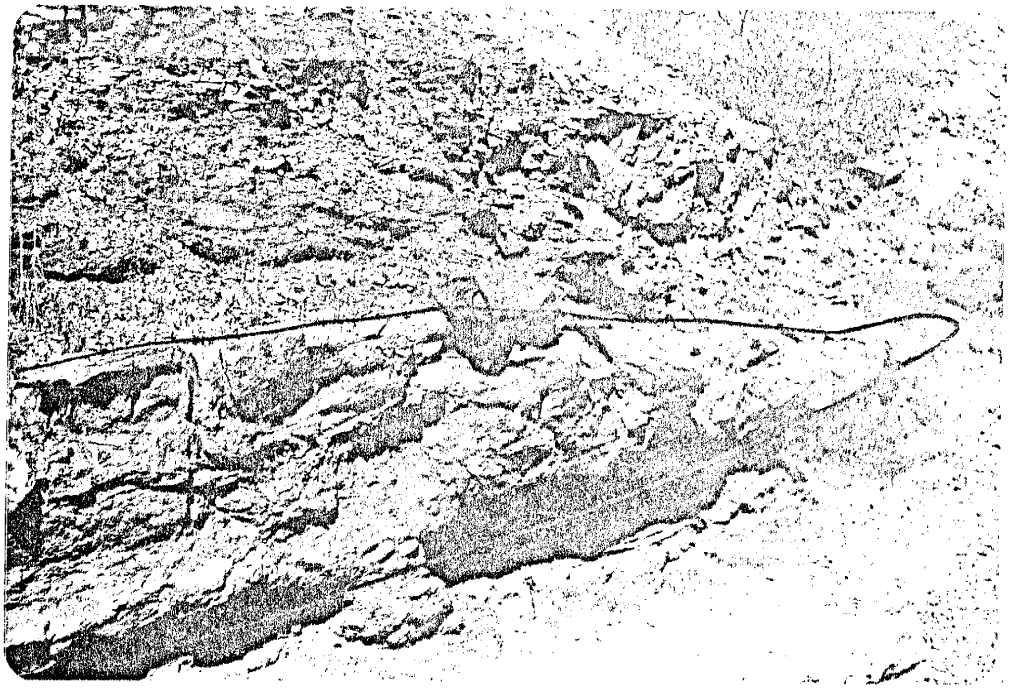

Figure 6. Outcrop of the Bernal Formation showing channel-fill structure. Location of photo; S.W. 1/4, Sec. 27, T.4S., R.2E..

brittle rock with hematite stain.

Upper Triassic Rocks

Dockum Group

The Dockum Group was described by Cummins (1890) from exposures near Dockum in western Dickens County, Texas and later extended into Kansas, Colorado and New Mexico by King and others (1942), Hendrickson and Jones(1952), Baldwin and Muehlberger (1959), and Jewett (1959).

The Dockum Group is subdivided into a lower sandstone unit and an upper shale unit containing interbedded siltstone, sandstone, mudstone and conglomerate. The lower sandstone unit named the Santa Rosa Sandstone by Darton (1919) for exposures along the Pecos River at Santa Rosa in Guadalupe County was later described in publication by Darton (1922). The Chinle Formation first described by Gregory (1916) for outcrops in the Chinle Valley in northeast Arizona overlies the Santa Rosa Sandstone. Outcrops of Santa Rosa Sandstone and Chinle Formation were mapped and described in the Little Black Peak quadrangle, Socorro and Lincoln Counties, by Smith and Budding (1959) and correlate well with red beds north of Carthage.

Fragments of a skull of the phytosaur Machaeroprosopus were discovered in Union County, New Mexico and Cimarron County, Oklahoma by Stovall and Savage (1939) and the discovery by Case (1916) of bone fragments in red beds at the old lime kiln near Carthage, New Mexico confirm an Upper Triassic age for the Dockum Group.

Exposures of the Dockum Group trend northeast from the lime kilns in the southwest part of the mapped area. This belt of outcrops, 1/2 to 3/4 miles wide, forms a valley on top of the underlying Bernal and San Andres Formations and a slope, leading up to offset ridges capped by the overlying Dakota Sandstone (fig. 7). The Dockum Group was measured at 3 locations in sec. 27 and 35, T.4S., R.2E. and has a composite thickness of 777 feet.

Santa Rosa Sandstone-The Santa Rosa Sandstone is composed of 236 feet of dominantly sandstone (49%), conglomerate (19%) and shale (18%) with lesser amounts of siltstone (7%) and mudstone (7%). A thin conglomerate with pebble-size clasts of tan mudstone and red siltstone marks the base of the Santa Rosa Sandstone. Overlying the basal conglomerate 50 feet of thinly interbedded siltstone, shale and sandstone occurs. The middle 70 feet includes medium-bedded siltstone and sandstone with thin mudstone, shale and conglomerate interbeds and represents a transitional phase between the underlying thinly interbedded section and overlying thickly bedded sandstone and conglomerate section. The upper 120 feet is dominantly thick-bedded sandstone and conglomerate with interbedded shale, mudstone and conglomerate lenses.

The siltstone and shale beds in the Santa Rosa Sandstone range from maroon to dark-brown in color and are commonly calcareous, sandy, moderately to poorly sorted, and micaceous; the layers are thin-bedded, contain mudcracks and ripple marks on bedding surfaces and are slope-formers in

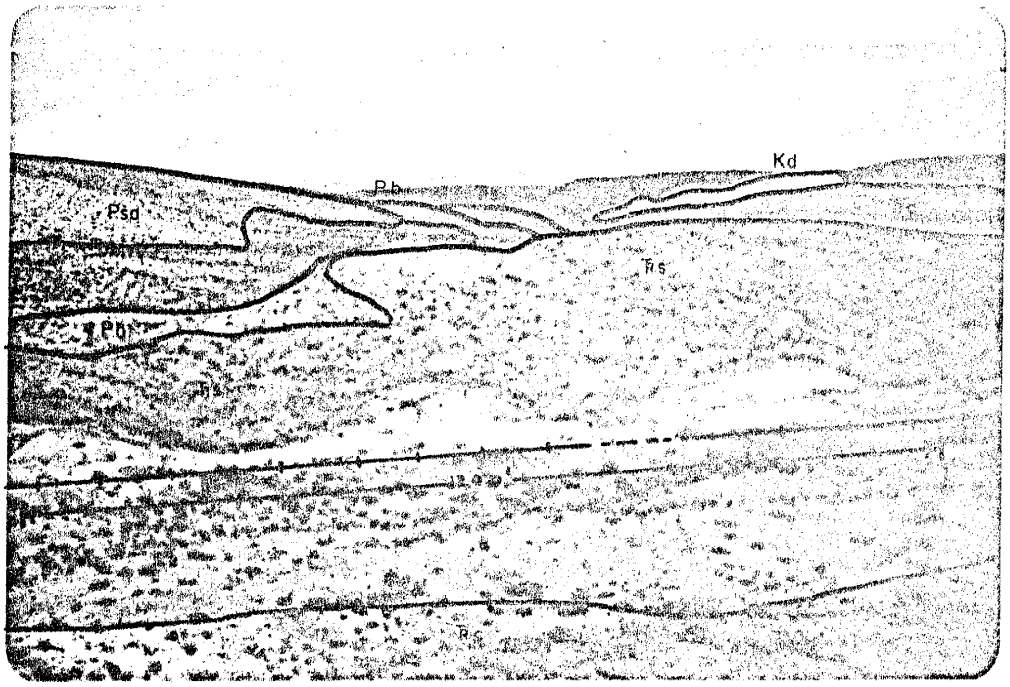

Figure 7. View looking northeast of San Andres, Bernal, Santa Rosa, Chinle, and Dakota outcrops in Canyon Agua Buena north of Carthage, old railroad in foreground was used to transport coal mined at Carthage to the lime kilns at the quarry. Location of photo; S.W. 1/4, Sec. 4, T.5S., R.2E..

ridges capped by more resistant sandstone and conglomerate beds. The sandstone beds are multicolored and may be maroon, dark-brown, tan or gray in color; they are commonly crossbedded and contain fine to coarse, subround to subangular, poorly to moderately sorted, frosted quartz, chert and mica grains with a trace of translucent smoky quartz and glauconite (?) grains in some beds. Mudcracks and silicified wood occur on top of a sandstone bed 50 feet below the top of the Santa Rosa. The conglomerates crop out as thin interbedded lenses and as thick massive, laterally discontinuous layers. They contain pebble-to cobble-size clasts of rounded quartz, chert, varicolored agate, and maroon mudstone and siltstone grains; some medium to coarse, moderately sorted, subround and subangular, translucent and frosted quartz and chert grains are found in laterally discontinuous sand stringers and intergranular spaces.

The contact between the Santa Rosa Sandstone and overlying Chinle Formation is gradational and conformable and unconformable. Due to the intertonguing and discontinuous nature of beds above and below the contact, lithologic characteristics of the contact change moving laterally. In the southwest mapped area the contact is chosen at the top of a thick conglomerate outcrop near the old lime kiln. This conglomerate is laterally discontinuous to the northeast where it intertongues with the underlying sandstone and overlying shale; in such a case the contact is chosen at the base of the lowermost shale bed in the Chinle

Formation.

Chinle Formation

The Chinle Formation contains dominantly shale (78%), with lesser amounts of thin to medium interbedded sandstone (9%), siltstone (2%) and mudstone (1%) with both thin and thick, massive bedded conglomerate (10%). The lowermost shale bed is light-gray and purple, unconsolidated and contains hematite concretions and gypsum crystals. Thick and massive conglomerate material overlies the basal shale. The conglomerate is gray and maroon in color and contains pebble-size, subround clasts of limestone and cobble-size, round clasts of carbonate. The conglomerate outcrops are easily weathered and most have been removed, leaving behind a residue of carbonate debris piled on top of the underlying shale. Overlying the basal conglomerate 330 feet of thick-bedded shale with a few interbeds of sandstone and conglomerate occur. The upper 240 feet includes a lower and upper shale unit with a section of medium to thick alternating beds of sandstone, siltstone, conglomerate and mudstone interbedded with shale in the middle.

The shale beds in the Chinle Formation are maroon to purple in color and commonly speckled with light-gray to white bleach spots, poorly indurated, crumbly, soft and contain nodular calcareous concretions (septarian). The sandstone beds occur in the upper half of the Chinle and are usually dark gray, weathered maroon in color, with fine to medium, moderately sorted, subround and subangular grains of

frosted quartz and pink chert and thin lenses of conglomerate. Near the top of the Chinle Formation a thick white to light-gray sandstone occurs; this bed is distinctive and can be traced across the map area for a considerable distance. Ripple marks and mudcracks are the only features recognized on bedding planes. Small isolated outcrops were found (N.W. 1/4 S.W. 1/4, sec. 15, T.4S., R.2E. and N.W. 1/4 N.E. 1/4 sec. 3, T.5S., R.2E.) to contain fossils (unidentified bivalves).

The contact between the Dockum Group and overlying Dakota Sandstone is an unconformable boundary. An erosional surface separates the Upper Triassic and Upper Cretaceous rocks. Local relief on this surface is minor; however, relief may be greater on a regional scale.

Upper Cretaceous Rocks

Dakota Sandstone

The Dakota Sandstone was originally defined and given group status by Meek and Hayden (1862) from exposures near Dakota City, Nebraska. Other writers have considered the Dakota as a series, stage, formation, or sandstone and have extended its usage to include lower to Upper Cretaceous sandstone beds in Nebraska, Colorado, Kansas, Minnesota, Montana, New Mexico, North Dakota, Oklahoma and Wyoming (Winchell (1875), Eldridge (1896), Lee (1912), Rubey and Bass (1925), Smith and Budding (1959), and others). The Dakota Sandstone has been subdivided into numerous age stratigraphic units; these various subdivisions are

difficult to correlate with equivalent age rocks from different regions and complicate the terminology involving the Dakota Sandstone. Rocks assigned to the Dakota Sandstone vary in stratigraphic detail and age from one place to another; however, their basic sequence and lithologic features remain constant. The Dakota Sandstone is used herein as a rock term for basal sandstones in the Upper Cretaceous rocks near Carthage, New Mexico and is not meant to imply a specific age nor correlation with Dakota outcrops from other areas.

Outcrops of the Dakota Sandstone occur in a thin (0.1-0.75 miles wide), northeast-trending belt of exposures across the southern portion of the map area. Low-lying hills in the valley north of Carthage are offset by numerous faults and are capped by resistant layers of the Dakota Sandstone. A section comprising 67 feet of thick-bedded sandstone and medium-to thick-interbedded sandstone, siltstone and shale was measured in sec. 3, T.5S., R.2E..

The lowermost unit in the Dakota Sandstone is a varicolored mudstone. The mudstone is shaly, gypsiferous and contains small, thin and discontinuous lenses of chert, shale and siltstone pebble conglomerate. The overlying sandstone is white to tan in color, massive, crossbedded and contains medium, rounded, well-sorted, frosted quartz grains, hematite stain and concretions with a few chert and quartz pebbles floating in the sandstone matrix near the top of the bed. Burrows, ripple marks and desert varnish are

locally abundant on weathered surfaces. Overlying the thick, lower sandstone bed, medium to thick, interbedded sandstone, mudstone, siltstone and shale occurs; these rocks range in color from light-gray to dark-brown and olive-green; they are silicified, intensely fractured, and lie in the middle of the Dakota Sandstone, separating the lower thick sandstone from the upper sandstone beds. The upper sandstone beds are buff to white in color and contain medium, rounded, well-sorted, translucent quartz grains in the top bed and frosted quartz grains in the underlying bed. The sandstones are crossbedded, poorly indurated, crumbly and hard, containing hematite and limonite concretions and a few localized fragments and partings of carbonaceous material (fig. 8 and 9). Bedding planes are generally stained with desert varnish and contain preserved ripple marks and burrow traces.

The contact between the Dakota Sandstone and overlying Mancos Shale is transitional, conformable and well-exposed in parts of the map area. The contact is picked at the top of the uppermost sandstone in the Dakota and at the base of a brown, thickly laminated, calcareous and fossiliferous siltstone and shale sequence.

Mancos Shale

The Mancos Shale was first described by Cross (1899) from outcrops in the Mancos Valley at Mancos Colorado. Subsequent workers have extended the Mancos Shale to include all of the strata between the underlying Dakota Sandstone

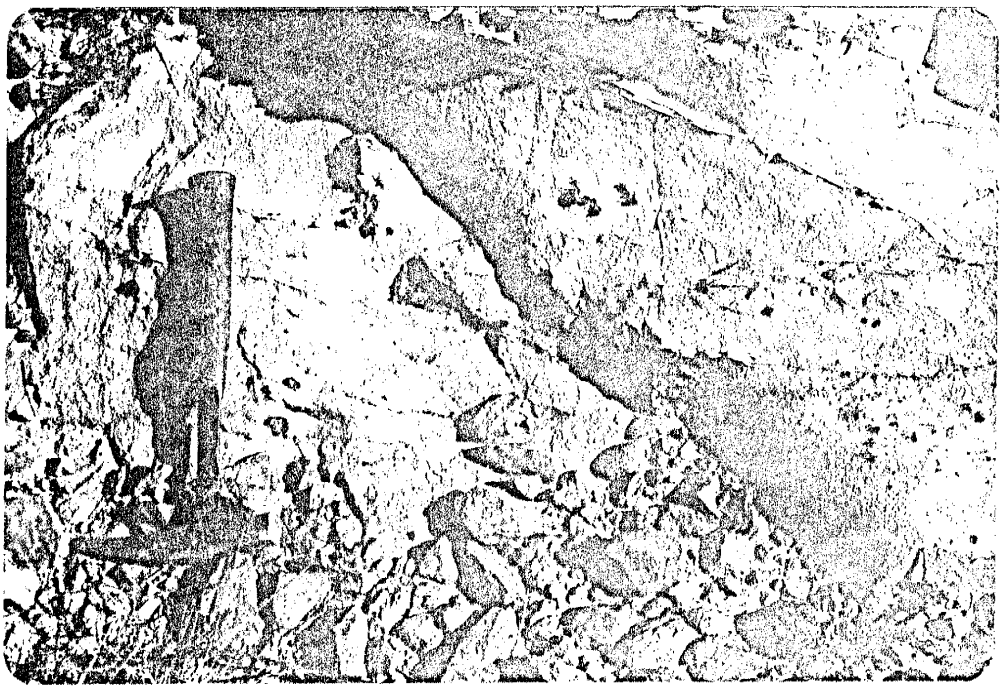

Figure 8. Hematite stain and concretions in the Dakota Sandstone. Location of photo; Sec. 3, T.5S., R.2E..

Figure 9. View of contact between the lower Shale Tongue of the Mancos Shale and the Dakota Sandstone, showing prospect (x) in carbonaceous partings. Location of photo; N.E. 1/4, Sec. 34, T.4S., R.2E..

and overlying Mesaverde Group in Colorado, Arizona, New Mexico, Wyoming and Utah (Lee (1912), Lupton (1914), Longwell and others (1923), and Reeside (1924)). The Mancos Shale has been subdivided into numerous stratigraphic units ranging from Greenhorn to Pierre in age. The lithology of these units does not correlate with equivalent age rocks from different areas; however, the same basic sequence and lithology does. Recent work at Carthage by Cobban and Hook (1979) has subdivided the Mancos Shale into three members, a lower Shale Tongue, the middle Tres Hermanos Sandstone Member and the D-Cross Shale Tongue. Studies by Hook (1981) and Cobban and Hook (1979) have located important guide fossils in the Upper Cretaceous Mancos Shale which are helpful in distinguishing contacts and indicate the Mancos layers are Cenomamian and Turonian in age. These data are not meant to imply a specific age correlation with Mancos outcrops from other areas.

Across the south and southwest region of the map area outcrops of the Mancos Shale are exposed. The lower shale member forms a valley and slope unit between the underlying Dakota Sandstone and overlying, cliff-forming Tres Hermanos Sandstone Member. The D-Cross Shale Tongue Member forms a valley and slope unit above the Tres Hermanos and below the cliff-forming Mesaverde Group. A complete section of Mancos Shale comprising 1007.6 feet of shale and sandstone was measured in sec. 8 and 16, T.5S., R.2E..

Lower Shale Tongue-The lower Shale Tongue of the Mancos

Shale is 443 feet thick and composed of thick beds of shale (87%), interbedded siltstone (5%), mudstone (3%), limestone (4%) and a trace of sandstone. The shale is thickly laminated and interbedded, with thin laminations of blocky calcite near the base; it grades upward into a thick unit of dark-gray to black shale with platy cleavage, hematite concretions, calcareous partings and a trace of gypsum. The shale is calcareous, crumbly, soft, weathers easily and contains a few fossils (pelecypods, vertebrate bone fragment and the tooth of a shark) and burrow traces near the base.

The contact between the lower Shale Tongue and overlying Tres Hermanos Sandstone Member of the Mancos Shale is conformable and documented with fossil evidence. Inoceramus arvanus has been located above the basal contact with the Dakota Sandstone and Collignoceras woolgari woolgari index fossils have been collected from the upper contact with the Tres Hermanos Sandstone (Cobban and Hook, 1979).

Tres Hermanos Sandstone Member-The Tres Hermanos Sandstone is composed dominantly of alternating sandstone (57%) and shale (33%) beds interbedded with two thin, fossiliferous limestone beds near the base and two mudstone beds in the middle of the section. The shale layers occur as slope-forming units capped by the more resistant sandstone beds. The sandstones are buff to tan and brown in color, and contain medium to fine, subangular, moderately to poorly sorted, frosted and translucent quartz and chert

grains with a trace of glauconite (?) and mica flakes. The sandstone layers are commonly crossbedded and contain hematite stain and concretions, mudcracks, ripple marks, and burrow traces; a few of the beds contain abundant pelecypod, cephalopod and gastropod fossil material (Plate 3). The shales are tan and gray in color, sandy, poorly indurated, crumbly, soft, and slightly calcareous.

The contact between the Tres Hermanos Sandstone and overlying D-Cross Shale Tongue of the Mancos Shale is conformable and well-exposed in the map area (fig. 10).

D-Cross Shale Tongue Member-The D-Cross Shale Tongue comprises 300 feet of dark-gray to black shale weathering light-gray. The D-Cross Shale has pelecypod fossils, mudcracks and is noncalcareous at the base; 25 to 30 feet from the base the shale becomes calcareous and white to brown calcareous concretions (septarian) form resistant caps on slopes of eroded shale (fig. 11); 125 to 150 feet from the base both calcareous and hematite concretions occur and the shale is sandy; 235 to 285 feet from the base fractures filled with gypsum and calcareous concretions with cone in cone structure were observed. Overlying the thick shale unit thinly interbedded sandstone overlain by a tan mudstone occurs. Cobban and Hook (1979) report the occurrence of Prionocyclus novimexicanus at the base and Lopha sannionis at the top of the D-Cross Shale Tongue.

The contact between the Mancos Shale and overlying Mesaverde Group is conformable and transitional. The

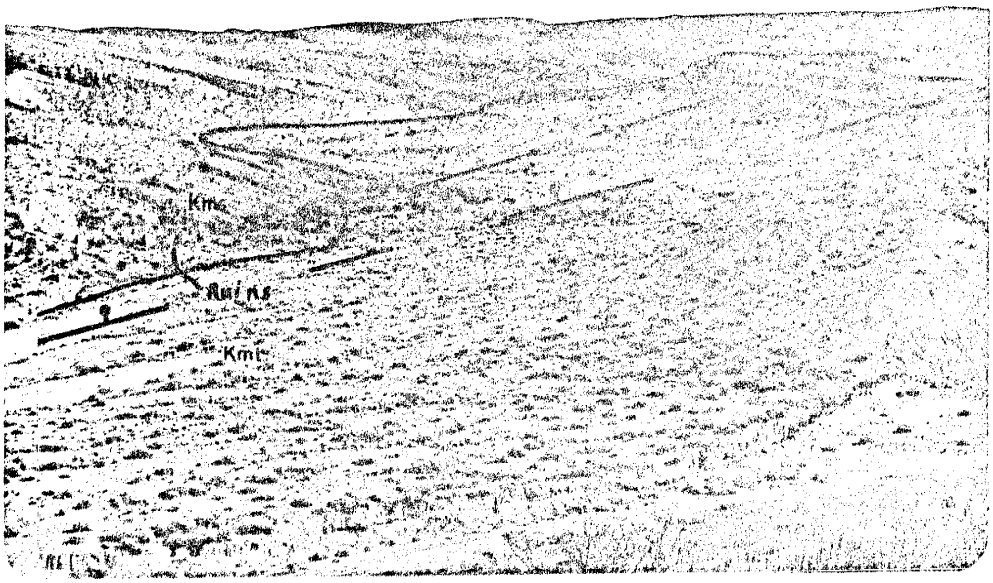

Figure 10. View east of the lower Shale Tongue, Tres Hermanos Sandstone Member, D-Cross Shale Tongue of the Mancos Shale and Mesaverde Group outcrops, ruins of old miners adobes on left. Location of photo; S.W. 1/4, Sec. 9, T.5S., R.2E..

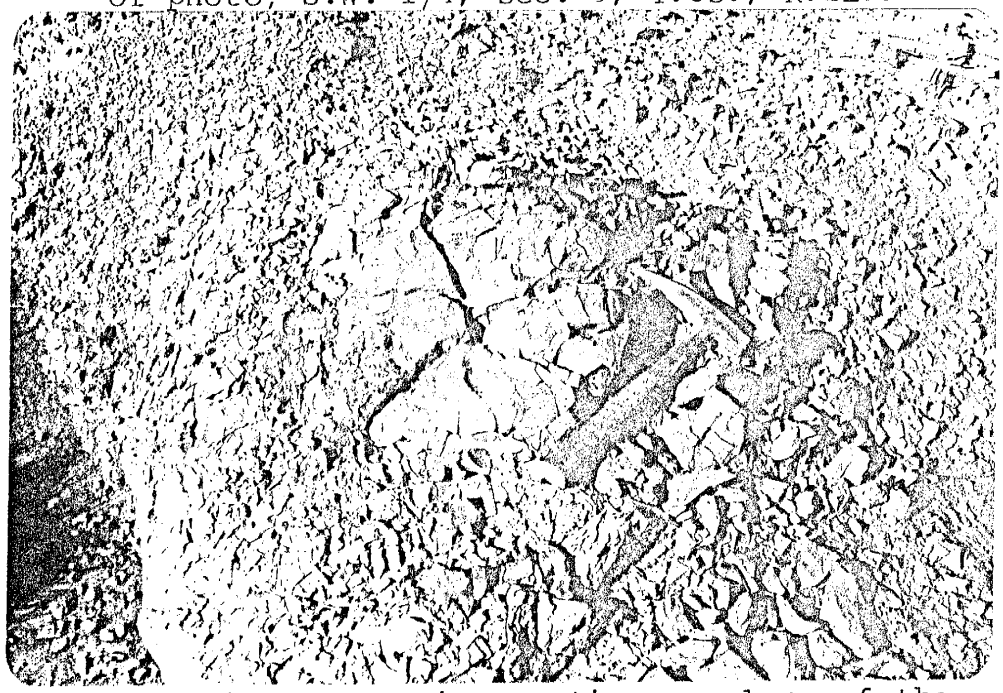

Figure 11. Septarian concretion resting on slope of the D-Cross Shale Tongue of the Mancos Shale. Location of photo; S.W. 1/4, Sec. 9, T.5S., R.2E..

contact is picked at the top of a tan, calcareous mudstone and at the base of a thin, buff sandstone.

Mesaverde Group

The Mesaverde Group was originally described by Holmes (1877) from exposures at Mesaverde in Montezuma County, Colorado. Subsequent workers have extended the Mesaverde Group to include Upper Cretaceous rocks overlying the Mancos Shale in Colorado, Arizona, New Mexico, Utah and Wyoming (Wegemann (1918), Sears (1925), Spieker and Reeside (1924), Pike (1947), and Bodine (1956)). Recently, McLafferty (1979) interpreted a transition in depositional environments between the Mancos Shale and Mesaverde Group from outcrops near Carthage.

Mesaverde Group outcrops form a belt bordering the southern edge of the mapped area, in addition to small outcrops that have been downfaulted against the Tres Hermanos Sandstone and Dakota Sandstone. Two incomplete sections of the Mesaverde Group were measured in secs. 9 and 16, T.5S., R.2E., resulting in a composite 61 feet of sandstone, shale and coal.

The basal Mesaverde contains 13 feet of medium-and thick-bedded, buff sandstone and green-gray shale. Overlying the lower zone, a thick buff sandstone with crossbedding and laterally discontinuous bedding, medium to coarse, subround to subangular, moderately to poorly sorted, frosted quartz grains and a trace of glauconite (?) occurs; the thick sandstone is calcareous, stained with hematite,

and has mudcracks, ripple marks and hematite concretions on bedding surfaces. A light-gray shale with platy cleavage and limonite concretions overlies the thick sandstone. The shale is crumbly, soft and sandy at the top. Three thin coal beds with thinner white to brown carbonaceous partings overlie the gray shale unit.

The contact between the Mesaverde Group and overlying Baca Formation is an angular unconformity and represents a period of erosion prior to deposition of the Baca sediment.

Tertiary Rocks

Baca Formation

The Baca Formation was named by Wilpolt and others (1946) from exposures in Baca Canyon in secs. 4, 5, 8 and 9, T.1N., R.4W., northern Bear Mountains, Socorro County. Gardner (1910) reported finding bone fragments and one tooth of a mammal in beds overlying the Mesaverde Group near Carthage. The tooth, identified by J.W. Gidley as belonging to Palaeosyops and indicative of middle Eocene age, is the first fossil evidence reported in the Baca. Recently, the Baca Formation has been the target of several studies; Snyder (1970) reported a late Eocene Protoreodon pumilus from outcrops near Datil, Cather (1980) interpreted a tectonic setting from outcrops near Magdalena, and Lucas and others (In Press) discovered titanothere teeth in the Baca outcrops near Carthage, New Mexico.

Isolated outcrops of the Baca Formation are located in the southeast part of the mapped area, where they form

gentle low-lying hills surrounded by flat-bottomed valleys of younger alluvial material. An exposure of the Baca Formation measured in a roadcut along U.S. Highway 380 in the southwest quarter of sec. 11, T.5S., R.2E. consists of 127 feet of conglomerate, sandstone and shale beds (fig. 12). The section measured includes one fault, does not include rock adjacent to the upper or lower contacts, and represents only a partial thickness of the Baca Formation.

A fault separates a lower shale (light-pink to red-brown in color, poorly indurated, calcareous, with thin lenticular lenses of pebble to cobble conglomerate (1 to 5 feet in length) from the adjacent conglomerate beds. Overlying the lower shale, alternating thick conglomerate and thinner sandstone beds occur. The conglomerate beds are light-pink to purple in color, contain pebble-to boulder-size, rounded fragments of brick-red siltstone and sandstone, gray limestone, light-pink to white granitic detritus, white quartzite, various colors of chert and traces of metavolcanic sediments, with coarse to very coarse, subangular, poorly sorted, intergranular quartz and chert grains. The conglomerate is poorly indurated and contains intergranular, precipitated carbonate with a radial axial cement texture. The sandstone beds are light-pink to red-brown in color, calcareous and are composed of medium to coarse, poorly sorted, subangular and poorly indurated quartz and chert grains, with a few lenticular and discontinuous lenses of pebble-to cobble-size grains of

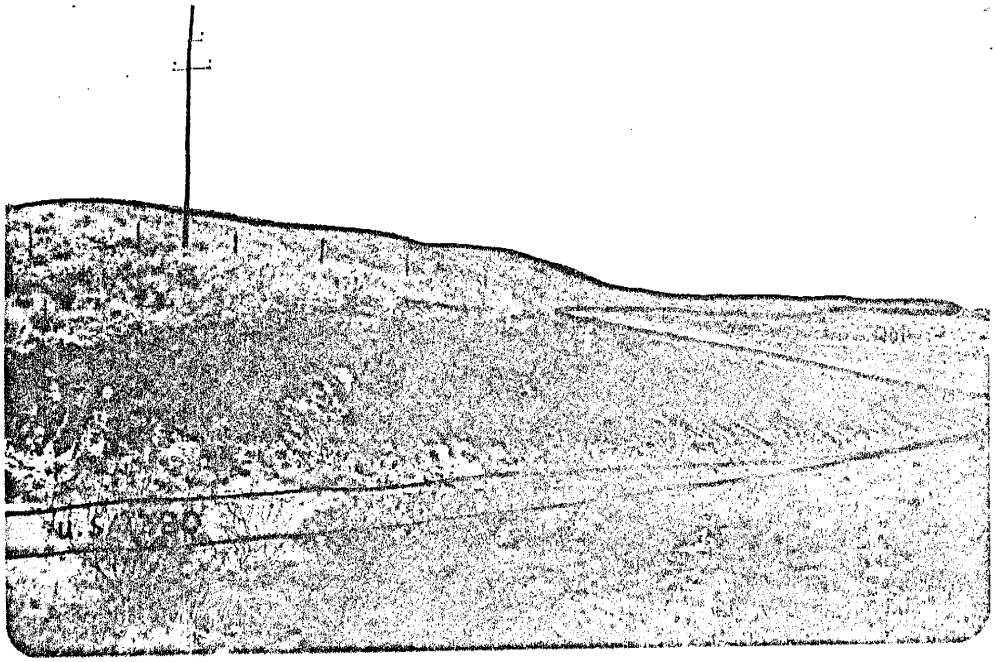

Figure 12. View southeast of Baca outcrop in roadcut along U.S. Highway 380. Location of photo; S.E. 1/4, Sec. 11, T.5S., R.2E..

brick-red siltstone and sandstone, gray limestone and white quartzite.

Santa Fe Formation

The Santa Fe Formation, first described by Hayden (1869) from exposures between the Sangre de Cristo and Jemez Mountains north of Santa Fe, New Mexico is the youngest rock unit exposed in the map area. The Santa Fe, given group status by some (Kottlowski (1953), and Disbrow and Stoll (1957)) and formational status by others (Givens (1957), Budding and others (1960), Wilpolt and Wanek (1951)) is considered a formation in this report.

Fossil studies by Denny (1940) from Santa Fe outcrops near San Acacia suggest a middle to Upper Pliocene age. However, exposures in Colorado, New Mexico and Texas range from Upper Oligocene to Middle Pleistocene in age. The Santa Fe has been subdivided into various members and formations in other areas which may, or may not, be age equivalents of Santa Fe beds in the mapped area.

Outcrops of the Santa Fe Formation are distributed along the western margin of the map area. These rocks have been downfaulted against Pennsylvanian and Permian strata in the north and Upper Triassic through Upper Cretaceous strata in the south. Reworking of unconsolidated Santa Fe deposits and deposition of recent alluvium has obscured many of the north-trending fault traces; however, just west of the old lime kiln the Santa Fe is clearly downfaulted against the Chinle Formation (fig. 13). This north-trending fault can

Figure 13. View north at fault trace between the Santa Fe Formation (left) and the Chinle Formation (right). Location of photo; S.E. 1/4, Sec. 5, T.5S., R.2E..

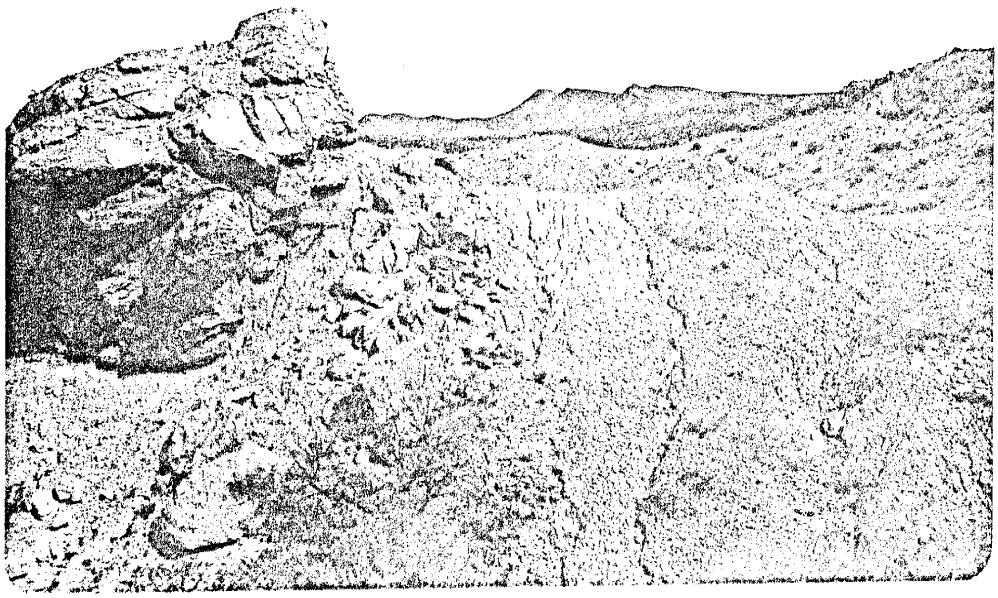

Figure 14. View north at fault trace between the Santa Fe Formation (left) and the lower Shale Tongue of the Mancos Shale, Cerro del Viboro on horizon. Location of photo; N.E. 1/4, Sec. 8, T.5S., R.2E..

be traced a short distance north, where it is obscured by pediment surfaces veneered with fluvial gravels. To the south of U.S. Highway 380, the fault separates the Dakota Sandstone and lower shale member of the Mancos Shale on the east from the downfaulted Santa Fe Formation on the west (fig. 14). In the study area, no attempts were made to differentiate the Santa Fe Formation from the younger soils and reworked alluvium overlying the Santa Fe Formation.

A composite partial section of the Santa Fe Formation was measured in an arroyo in the northeast quarter of sec. 8, T.5S., R.2E.. The section measured includes 70.5 feet of sandstone, mudstone and conglomerate.

The sandstone in the Santa Fe is commonly light-pink to tan in color, contains fine, subangular and poorly sorted, frosted quartz grains with pebble-to cobble-size clasts of gray limestone, brick-red siltstone and sandstone, and varicolored chert in thin discontinuous lenses and as randomly oriented, isolated clasts in the finer-grained sandstone. The conglomerates are light-pink to buff and brown in color and contain pebble-to boulder-size, rounded fragments of gray limestone, brick-red siltstone and sandstone, varicolored chert, assorted volcanic sedimentary rocks and calcareous concretions (fig. 15). Rocks of the Santa Fe Formation are calcareous, poorly indurated, westerly dipping, piedmont slope-formers capped by a thin veneer of unconsolidated soil and gravel. An angular unconformity with the underlying Cretaceous, Permian and

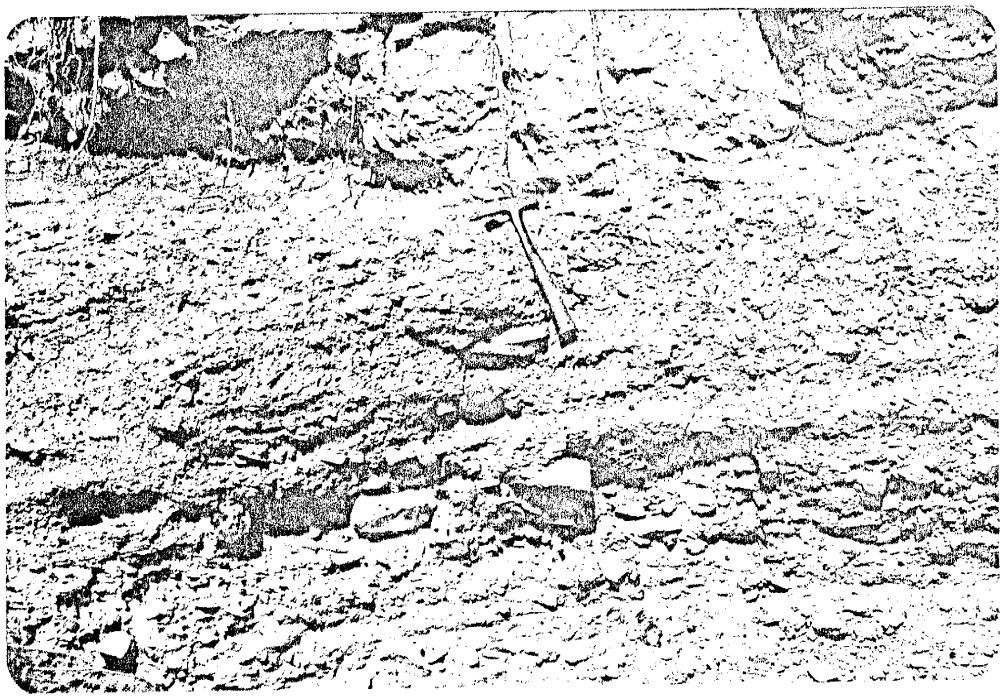

Figure 15. Conglomerate bed in the upper Santa Fe Formation with thin cover of soil. Location of photo; N.E. 1/4, Sec. 8, T.5S., R.2E..

Pennsylvanian rocks marks the base of the unit.

Tertiary Dikes And Sills

Tertiary dikes and sills believed to be contemporaneous and/or older than the Santa Fe Formation and younger than the Baca Formation occur in the N.E. 1/4 sec. 4, N.W. 1/4 sec. 3, T.5S., R.2E. and in the S.W. 1/4 sec. 8, S.E. 1/4 sec. 9, N.W. 1/4 sec. 15, T.4S., R.2E.. The intrusions are scarce and take the form of thin (less than 5 feet thick), dike and sill-like bodies.

The laterally discontinuous nature of the intrusions (rarely exceeding 300 feet in length) and the lack of contacts with Cenozoic rocks make them difficult to date. In the S.W. 1/4 sec. 8, T.4S., R.2E., a west-trending trending dike is coincident with a normal fault trace extending to the west, suggesting that the dike is younger or congruent in time with the faulting episode. According to Chapin (personnel comunication) the intrusions in the Cerro del Viboro area are similar, lithologically to Spears-age dikes in other areas. Spears-age dikes are present in the Joyita Hills, northern Jornado and in the Carthage areas. Herein, the Tertiary intrusions are assumed to be Miocene in age.

The intrusions are andesitic and porphyritic with subhedral to euhedral, phenocrysts of calcic plagioclase (approximately 1/16 inch wide and 1/8 inch long). On weathered surfaces, the phenocrysts have been preferentialy removed giving the rock a vesicular appearance. Contacts with Permian rocks in the northern mapped area are sharp and

show little evidence of alteration adjacent to the intrusions (fig. 16); a thin alteration zone (6 to 10 inches wide) extends into the Chinle Formation adjacent to a dike in the valley north of Carthage (fig. 17).

Quaternary Deposits

Alluvium

Minor amounts of Pleistocene and Recent alluvium in the form of valley fill, sandwash, fan material, bolson and locally dune sand and soil deposits occur in the study area. The deposits are composed of material from nearby outcrops and are located in the broad gentle valleys along fault zones and form the eastern border of the study area. The arid climate combined with low topographic relief favors the accumulation of wind blown sands in the southeastern part of the mapped area. The general lack of alluvium and abundance of outcrops make the Cerro del Viboro area near Carthage, New Mexico, an ideal spot to study upper Tertiary through Upper Pennslvanian strata and their related structures.

Structural Geology

The Cerro del Viboro area lies at the northwest end of the Jornada del Muerto Basin, where it forms an uplifted block of folded and faulted strata on the east side of the Rio Grande valley. To aid in discussion of the structural patterns, the study area is divided into three areas: the south-southeast corner, the central, and the north-northwest corner.

The south-southeast corner of the mapped area contains

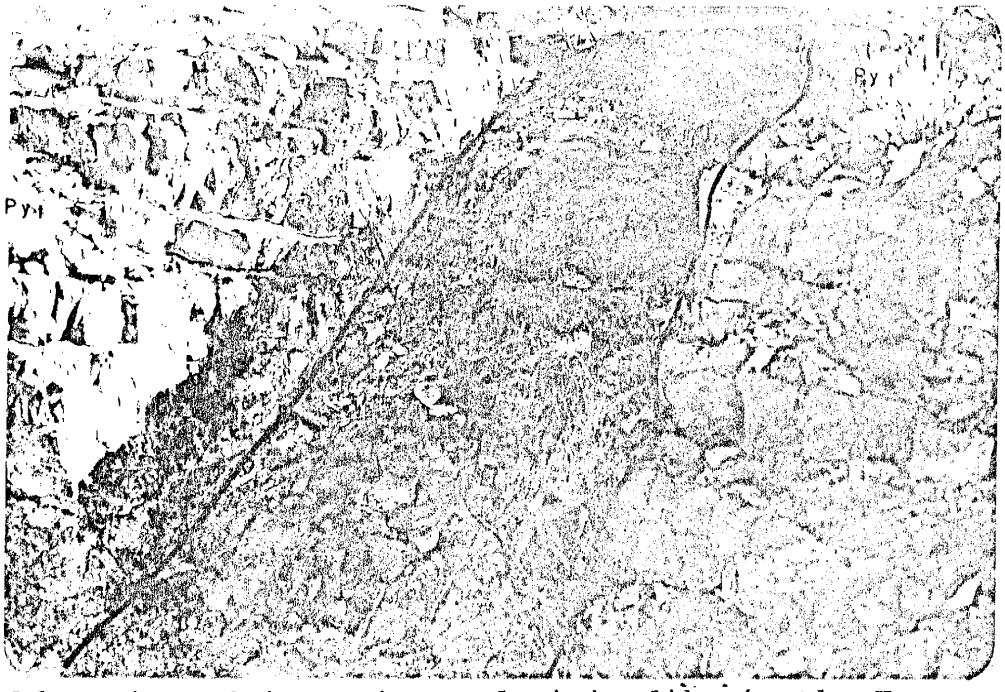

Figure 16. View of intrusive andesitic dike in the Torres Limestone Member of the Yeso Formation. Location of photo; N.W. 1/4, Sec. 15, T.4S., R.2E..

Figure 17. View of contact between intrusive andesitic dike and the Chinle Formation. Location of photo; N.W. 1/4, Sec. 3, T.5S., R.2E..

numerous north-trending normal faults in Upper Cretaceous strata. Most of the normal faults show 5 to 100 feet of stratigraphic displacement; however, as much as 1100 feet of displacement can be detected along some faults. The southerly dip of bedding and tilted attitude of the horst and graben blocks causes the throw along some fault planes to vary from 0 to 1000 feet. Folding due to drag along fault planes and subsidence of graben blocks is demonstrated in outcrops of the Tres Hermanos Sandstone Member in the E. 1/2 sec. 10, T.5S., R.2E.. On the eastern edge of the study area a north-trending, asymmetric anticline and syncline occur. The anticline and syncline dip steeply on the east limb, gently on the west limb and plunge to the south. The folds are broken by numerous normal faults with minor displacement (<25 feet), and are downfaulted on the east against younger rocks of the Mancos Shale and Mesaverde Group. The closely spaced normal faults so evident in the Dakota Sandstone are attenuated by underlying mudstones and other incompetent beds when traced northward and are difficult to follow due to identical lithologies within the Chinle Formation.

The central part of the map area contains extensive outcrops of the San Andres Formation. The San Andres layers form a southerly plunging anticlinorium, downfaulted on the west against Tertiary strata and bounded on the east by Permian and Triassic rocks. Near the old lime kiln, Triassic rocks are downfaulted against the San Andres. This

fault can be traced a short distance north where it is covered by younger sediments. In the S.W. 1/4 sec. 28 and N.W. 1/4 sec. 33, T.4S., R.2 E., a low-angle fault is found between north-and northwest-trending normal faults. The fault is very low-angle, nearly congruent with bedding, and occurs between the Joyita Sandstone and Torres Limestone members, of the Yeso Formation; the Canas Gypsum Member has been tectonically removed. Along north-trending normal faults to the east, the Bernal Formation and Santa Rosa Sandstone have been downfaulted against the San Andres Formation. Folds occur in the San Andres layers and are commonly related to drag along major fault zones or collapse structures associated with dissolution and karst activity of the underlying limestones.

In the north-northwest corner of the map area, low-angle faults are offset by north-trending normal faults and a northwest-trending normal fault. The low-angle fault surfaces have been folded, and are exposed where erosion has breached the anticlinal flexures. The youngest strata taking part in the low-angle faulting are Permian in age. The fault planes are very low-angle, nearly congruent with bedding, and occur between the uppermost limestone in the Torres and various portions of younger Permian rocks. In the N.W. 1/4 of sec. 15, T.4S., R.2E, two fault planes of similar geometry occur. A low-angle fault dipping northwest separates the Torres Limestone from the Glorieta Sandstone, and a similar fault occurs between the Glorieta Sandstone

and overlying San Andres Limestone beds (fig. 18, 19 and 20).

The north-trending normal faults in the north-northwest area have small (<25 feet) to large (~600 feet) displacement, truncate and displace the low-angle faults and are fewer in number as compared to the southern map area.

The northwest-trending normal fault located in the N.E. 1/4 sec. 21, T.4S., R.2E., down on the northeast (1900 feet), can be traced north of the map area in sec. 8, T.4S., R.2E., where it is eventually covered by deposits of the Santa Fe Formation. A short distance to the southeast the northwest-trending fault is obscured by deposits of alluvium.

In sec. 20, 21 and 29, T.4S., R.2E., tight asymmetric folds in the lowermost limestone bed of the Torres Member occur. These folds are elongate, closely spaced, north-trending, asymmetric, dip steeply on the east limb and gently on the west limb and ordinarily plunge to the south. The resistant limestone bed and prevalent erosional pattern has preserved opposite limbs and crests of folds connected in outcrop (fig. 21).

North-trending normal faults, low-angle faults, a northwest-trending normal fault, and folded beds are common structural features in the Cerro del Viboro area near Carthage, New Mexico. Drag folds associated with faulting offset folds along fault zones; compressive folds lacking nearby fault structures indicate the folding occurred prior

Figure 18. View southeast at fault contact between the Glorieta Sandstone and San Andres Limestone. Location of photo; N.W. 1/4, Sec. 15, T.4S., R.2E..

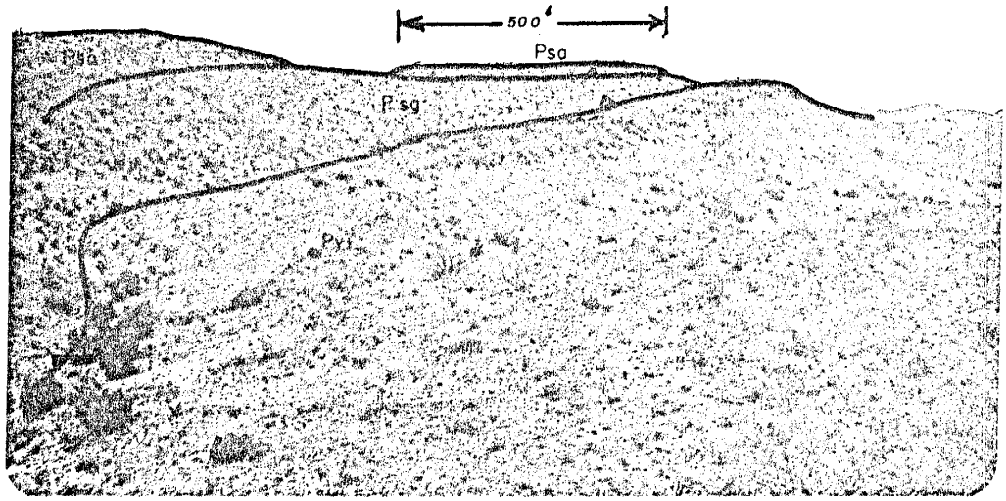

Figure 19. View northwest at fault contacts between the Torres, San Andres Limestone and Glorieta Sandstone. Location of photo; N.E. 1/4, Sec. 15, T.4S., R.2E..

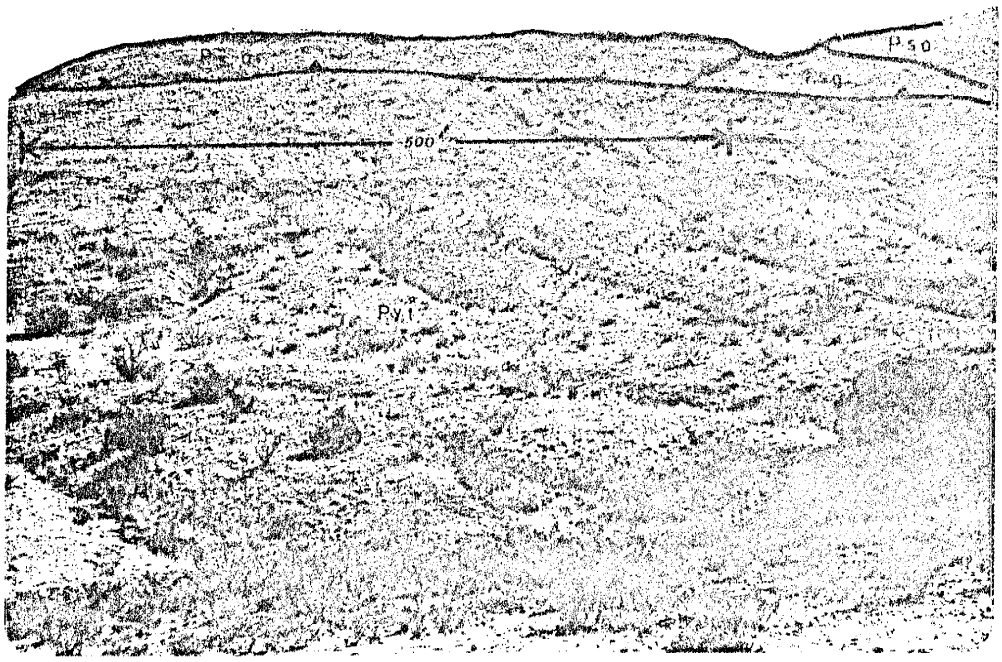

Figure 20. View east of fault trace between the San Andres Formation and Torres Limestone of the Yeso Formation. Location of photo; N.E. 1/4, Sec. 15, T.4S., R.2E..

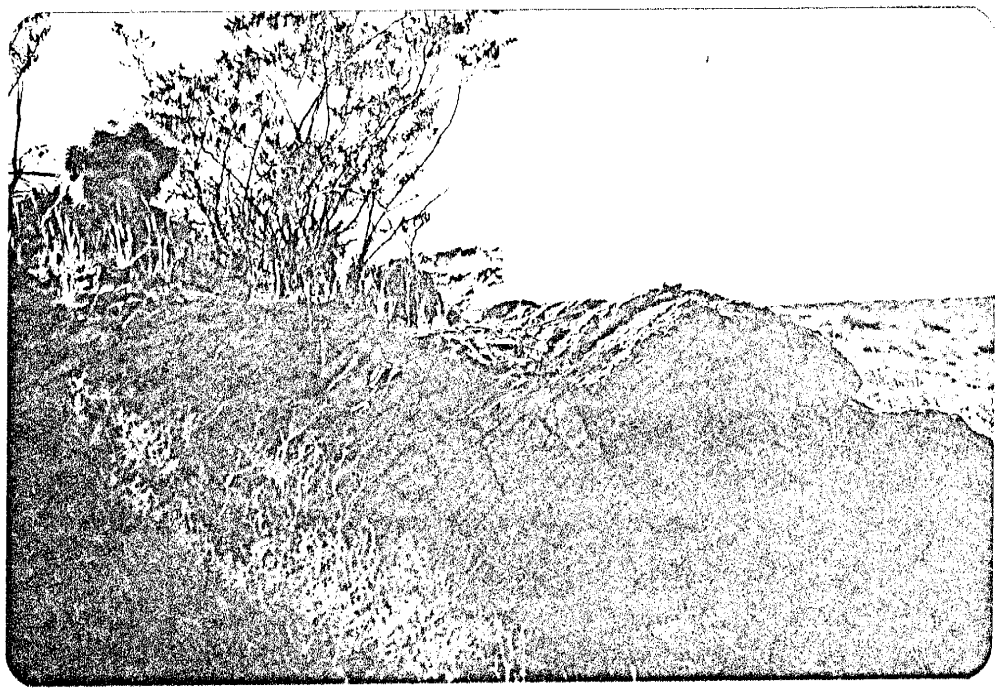

Figure 21. View southeast of tight asymmetric fold in the Torres Limestone. The fold flanks dip approximately 45 east, 15 west; the axis plunges to the south. Location of photo; S.E. 1/4, Sec. 20, T.4S., R.2E..

to and contemporaneous with the episodes of faulting. The low-angle faults are displaced by north-and northwest-trending normal faults; northwest normal faulting truncates some north-trending normal faults.

GEOLOGIC HISTORY

During the late Paleozoic, the southern end of the Ancestral Rocky Mountains formed an uplifted and deformed north-trending belt of rocks east of the study area (Chapin and Seager, 1975). Thick marine shale, sandstone and limestone beds indicate Paleozoic seas covered the region in the Pennsylvanian (Smith, 1964). Gradual retreat of Pennsylvanian seas is noted by increasing amounts of arkosic beds interbedded with limestone in the upper Madera Limestone. The alternating arkosic and limestone beds suggest transgressive-regressive cycles oscillated over the study area at the end of the Pennsylvanian.

Thick shale and arkose beds in the Bursum Formation represent the final regression of Pennsylvanian seas at the begining of Permian time. Siltstone, shale and sandstone beds represent the Abo Formation; the prevalent red color, abundance of ripple marks, channel fill structures and leaf prints indicate the environment was terrestrial and fluvial in nature at the time.

Sandstone, siltstone and shale beds in the Meseta Blanca Sandstone Member represent the earliest indication of advancing Permian seas. The alternating red and gray color of individual beds, abundance of salt casts, ripple marks,

and mudcracks and lack of skeletal and nonskeletal carbonate grains suggest the Meseta Blanca was deposited in a nearshore, supratidal environment. Further encroachment of Permian seas deposited sandstone and limestone beds of the Torres Member. Permian seas were cyclic and deposited the Canas Gypsum Member during a period of retreat when evaporation and dessication prevailed. The Joyita Sandstone and Glorieta Sandstone beds, overlain by San Andres Limestone, represent a repetition of the encroachment of Permian seas across the area. The upper gypsum member of the San Andres Formation represents the final withdrawl of Permian seas from the region. As the seas regressed, evaporation and dessication resulted in deposition of thick gypsum beds.

Subaerial exposure resulted in dissolution and development of a karst surface on top of the San Andres Formation. Siltstone, mudstone and sandstone of the Bernal Formation was deposited on the karst surface of the San Andres. The red-brown and buff color, abundance of mudcracks, trace of salt casts, lack of fossils and nonskeletal carbonate grains indicate the Bernal Formation was deposited in a terrestrial environment subjected to periods of alternating wetting and dessication.

If lower Triassic sediments were deposited in the region, they were removed by erosion prior to deposition of siltstone, sandstone, shale and conglomerate beds of the Upper Triassic Santa Rosa Sandstone. The maroon to brown

color, ripple marks, mudcracks, petrified wood, bedding features and lithologies of the Santa Rosa beds indicate a terrestrial environment controlled by active fluvial processes. The terrestrial conditions persisted through the Upper Triassic. However, thick maroon and purple shale with thin siltstone and conglomerate beds common to the Chinle Formation trend toward finer grain sizes and lack ripple marks as compared to the Santa Rosa, thus suggesting that topographic relief in the region was lower during deposition of Chinle layers. Thin conglomerate stringers in the Upper Triassic and lowermost beds of the Upper Cretaceous are the earliest indicators of epeirogenic movements in the area.

If Jurassic or Lower Cretaceous sediments were deposited in the region, they were removed prior to deposition of Upper Cretaceous strata. Upper Cretaceous sandstone, shale, siltstone and mudstone beds of the Dakota were deposited on an erosional surface on the Chinle Formation. The crossbedded, well-sorted sandstone beds of the Dakota lack fossils; however, the presence of ripple marks, burrows and mudcracks suggest that these beds are nearshore beach or dune deposits and represent the begining of the last transgression of marine seas across the region. Further transgression of Upper Cretaceous seas resulted in deposition of the dark-gray to black lower Shale Tongue of the Mancos Shale. A short period of regression followed by transgression brought about deposition of sandstone, siltstone and shale beds representing the Tres Hermanos

Sandstone Member. The Tres Hermanos beds are buff to brown and contain mudcracks, ripple marks, burrows, petrified wood and fossils (pelecypods, cephalopods and gastropods) indicative of a nearshore beach/lagoon environment. The dark shales of the D-Cross Shale Tongue, indicative of offshore deposition, represent the final transgressive stage of Upper Cretaceous seas.

The final regression of the late Cretaceous sea from the Cerro del Viboro area resulted in a transition from marine to continental deposits. As the seas retreated to the northeast, beach, marsh/lagoon, floodplain, and estuary environments traversed the Carthage area depositing sandstone, shale and coal beds of the Mesaverde Group (McLafferty, 1979). Cretaceous rocks younger than the lower Mesaverde Group are absent from the area; if deposited, they were subsequently removed by erosion.

In late Cretaceous to middle Eocene time compressional stress of the Laramide orogeny was superimposed on the Cerro del Viboro area. Deformation during the Laramide included folding, low-angle faulting and uplift of strata. The asymmetry and axial trends of the folds and direction of slickensides indicate that the major compressive stress and movement of of the upper plate along low-angle faults was from west to east.

Erosion during and immediately following the Laramide resulted in removal of lower Mesaverde and younger rocks from the southern part of the map area, and Permian and

younger limestone, sandstone and siltstone from the northern region of the map area. The eroded material from the preexisting uplifts was deposited in adjacent low-lying areas and represents the Baca Formation. Conglomerate, sandstone and shale beds of the Baca Formation are red in color, calcareous, contain vertebrate fauna and are indicative of deposition by active fluvial processes in a terrestrial environment with considerable topographic relief.

In late Oligocene to early Miocene time, extensional stress of the Rio Grande rift was superimposed on the Cerro del Viboro area. Rift deformation is represented by north-trending normal faults which bound tilted and alternating horst and graben fault blocks. It is presumed that intrusion of Tertiary dikes occurred concurrent with the extensional fault systems.

In the Pliocene, valley fill, conglomerate, and bolson sediments of the Santa Fe Formation were downfaulted against Cretaceous through Pennsylvanian rocks, and also deposited unconformably (angular) on top of older strata. The Santa Fe Formation represents deposition in a terrestrial environment of high topographic relief that occurred during rifting.

From Pleistocene to Recent, bolson and valley fill deposits have been filling the local depressions. The Jornada del Muerto basin southeast of the study area is a closed basin that has continued to fill; whereas, the Rio

Grande valley to the west was incised as present stream and tributary systems developed.

ECONOMIC GEOLOGY

Mining

The lowermost Carthage coal bed is relatively pure, bituminous in rank, produces an excellent coke, and was the target of early miners in the area. The earliest mining reported in the Carthage coal field began in 1861 with the opening of the Goverment mine by goverment troops (Gardner, 1910). Numerous prospects and old abandoned mines occur in different parts of the Carthage coal field. However, old records have been lost and only information concerning the Goverment, Bernal, Hilton and Emerson mines has been recorded (Gardner, 1910 and Storrs, 1902). By 1948 most of the reserves were depleted and only one mine was still working; presently the Carthage coal field is inactive. Read and others (1950) list reserves for the combined Carthage and Jornada (in sec. 8, T.3S., R.3E.) coal fields at 37.8 million short tons. Structure and a shallow ground water table have been controlling factors in mining development; faulting has displaced coal beds into blocks of various sizes and shapes and the encroachment of ground water (below 25 feet) makes extension of underground workings difficult. Further development of the Carthage coal field is uneconomic at this time.

Limestone was quarried in the S.E. 1/4 sec. 5 and S.W. 1/4 sec. 4, T.5S., R.2E.. Coal mined at Carthage was used to

fire the old lime kiln near the quarry. It is presumed that only a small amount of limestone was quarried and that closing of the Carthage coal mines brought an end to the lime business also.

Numerous prospects and old miners diggings are scattered across the Cerro del Viboro area. Solution holes in the San Andres Limestone, carbonaceous partings in the Upper Cretaceous rocks and nearly all faults associated with carbonate rocks, silicified zones, or porous and permeable sandstones have received attention from previous prospectors. Thus far, the attempts have been unrewarding.

Ranching and Farming

The present economy in the study area is supported by ranching and farming and is highly dependent on local water supplies. Due to the arid climate and lack of vegetation, ground water from wind-driven water wells is relied on to grow forage and water cattle. Small wells produce water from the Chinle Formation along fault zones, or in alluvial material and are located in the southeastern quarter, along the westcentral edge and in the northeastern quarter of the map area. In the north part of the study area, three wells produce poor-quality water from Permian limestone and sandstone beds. The Permian beds contain water with high sulfate and carbonate levels; the water is seldom used and is less desirable than water produced from alluvium or the Chinle Formation in other parts of the map area.

Oil and Gas

In the Carthage area, the highly faulted strata and breached anticlines of Permian and younger rock have been considered unfavorable locations for the accumulation of hydrocarbons (Wilpolt and Wanek, (1951), and Anonymous, (1963)). A better understanding of the timing and nature of structural events may improve the possibility for future oil and gas discoveries in the area.

Prior to the Laramide orogeny the Paleozoic strata may have generated and stored large volumes of hydrocarbon material. With the compressive forces brought about during the Laramide orogeny, relocation of preexisting reservoirs and entrapment of migrating fluids into tight folds and beneath low-angle faults may have occurred. The localized and limited extent of middle or late Cenozoic intrusions are believed to have had little or no effect on the accumulation of hydrocarbons in the area. The extensional forces brought about during rifting may have allowed leakage from previously formed reservoirs; however, it is possible that hydrocarbons released by north-trending normal faults may have been hydrodynamically trapped in the resultant graben structures.

A potential for future discoveries of coal and hydrocarbons exists in the Cerro del Viboro area. Laramide structures have the greatest potential for future discoveries of hydrocarbon materials. Drilling and seismic efforts in the future should focus on Laramide folds and low-angle faults in areas where relatively little extensional

deformation has occurred. The eastern border of the mapped area and the Jornada del Muerto basin are relatively unexplored and present favorable prospecting areas for future coal and hydrocarbon reserves.

APPENDIX

The appendix includes a field and petrographic description of Upper Pennsylvanian to Recent rocks measured in the Cerro del Viboro area. Classification systems and descriptive terminology incorporated in the appendix were derived from other sources.

For thin-section work, classification charts from Dunham (1962) and Folk (1962) were used to describe carbonate rocks, and a classification chart from Pettijohn and others (1973) was used to describe terrigenous sandstones.

In the field, all rocks were classified as either sandstone, siltstone, shale, mudstone, limestone, gypsum, coal, conglomerate, arkose, breccia, or slope cover, as defined in the Glossary of Geology (1974).

The following is a list of characteristics described in the field and in thin section, in parenthesis, the previous writers who describe nomenclature (as used herein) descriptive of that characteristic: Note, many of the following references are taken from the class notes of Dr. J. MacMillan.

Grain size (Wentworth, 1922)
Sorting (Pettijohn, Potter, and Siever, 1973)
Roundness (Krumbein and Sloss, 1963)
Elongation (Folk, 1968)
Textural maturity (Folk, 1951)
Contact index (Graton and Fraser, 1935)
Matrix (Dickinson, 1970)
Grain contacts (Taylor, 1950)
Induration (MacMillan, 1981)
Bedding (Ingram, 1954)

The following are criteria used to describe intergranular material in carbonate rocks: Micrite; dark, cloudy, clay size, generally 3 to 5 microns in size, equant crystals, tight packing. Neomorphic spar; size (> 5 microns), a little clearer and less cloudy than micrite, may contain relict grain outlines, subequant to equant crystals, considered microspar and pseudospar by others. Precipitated spar; crystals (> 15 microns in size) with straight line crystal contacts, precipitated in available pore space, generally clear, and grain supported.

A Jacob staff, clinometer, and a hand held Brunton compass were used to measure interval thicknesses in the field. A Zeiss petrographic microscope (provided by the New Mexico Institute of Mining and Technology) was used to describe composition and texture of thin-sections in the lab.

Petrographic Descriptions

Slide: Kmv-4

Rock Name: Feldspathic Lithic Arenite (Mesaverde Group)

Characteristics of Total Rock

Average Grain Size: 1.5 mm.; 2.0 O;
Wentworth Grade; fine to medium sand
Sorting: Index; 1.5, Class; poorly-sorted
Average Roundness: Index; 0.3, Class; subangular
Elongation: Index; < 0.60, Class; very elongate
Textural Maturity (present); immature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; 1.5%
Contact: Index; 2.7, Range; 0-6, No. Grains; 60
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) line; 3) concavoconvex

Percent of Rock or Stratum

88% Detrital Grains (including protomatrix)
3% Cement; poikilotopic calcite cement randomly scattered patches, thin meniscus of silica cement.
6% Matrix: Epimatrix / Orthomatrix; 1/10
Epimatrix; few relict grains of mica preserved with Fe-oxide stain
Orthomatrix; thin Fe-oxide dusting on most grains and cement
Pseudomatrix; N.O.
3% Present Porosity; macro and micro intergranular pores

Percent of Detrital Grains

52% Quartz: Size; 0.25 mm., fine to medium
Shape; anhedral
Elongation Index; < 0.60, very elongate
Polycrystalline / Monocrystalline; 1/3
Monocrystalline: (medium sand-size)
Inclusions; vacuoles of glass 60%, regular inclusions of muscovite, sericite and rutile 15%
Extinction; undulose 30%, slightly undulose 15%, straight 55%
Polycrystalline: (medium sand-size)
No. of crystals / grain; 13.5
Range; 3-37, No. of grains; 20
Contact between crystals; concavoconvex and suture
Size range of crystals; 0.01-0.2 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.
7% K-Spar: Size; 0.2 mm., Shape; subhedral
Elongation Index; < 0.60, very elongate

Roundness; subangular, Twinning; traces of cleavage in orthoclase, rods of perthite in microcline
Orthoclase 60%, Microcline 40%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 3/1

____3%____ Plagioclase Feldspar: AN# (Michelle Levy) 11-29, oligoclase
Range; 6-34, No. of grains; 4
Shape; subhedral, Size; 0.18 mm.
Elongation Index; < 0.60, very elongate
Roundness; subangular
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/3
Zoned / unzoned; N.O.
Inclusions; 30% muscovite, sericite, and rutile

___20%____ Chert
___N.O.___ Lithic Fragments
____3%____ Micas (total)
Dark / Light; 1/3, with bent and curved laminae
Dark; trace of biotite altered to muscovite and calcite
Light; muscovite and sericite veinlets, often partially altered to calcite

____7%____ Clays (protomatrix); red-brown to black Fe-oxide stained, structureless material, unrelated to any diagenetic alterations

____1%____ Nonopaque Heavy Minerals; rutile grains and regular inclusions, glauconite (?)

____7%____ Opaque Heavy Minerals; hematite and/or magnetite

____N.O.__ Others

Slide: Kms-7

Rock Name: Lithic Arkosic Arenite (Tres Hermanos Sandstone)

Characteristics of Total Rock

Average Grain Size: 0.1 mm.; 3.25 O;
Wentworth Grade; very fine sand
Sorting: Index; 0.5, Class; moderately sorted
Average Roundness: Index; 0.5, Class; subround
Elongation: Index; 0.65, Class; subelongate
Textural Maturity (present); immature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; 4.75%
Contact Index; 2.9, Range; 0-6, No. Grains; 50
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) concavoconvex; 3) line

Percent of Rock or Stratum

___82%____ Detrital Grains (including protomatrix)
____8%____ Cement; calcite with a poikilotopic texture

___10%___ Matrix: Epimatrix / Orthomatrix; 1/5
Epimatrix; relict grain outlines of altered mica and feldspar
Orthomatrix; thin Fe-oxide dusting on few grains
Pseudomatrix; red-brown paste near borders of bent mica and feldspar

____1%____ Present Porosity; micro intergranular pores

Percent of Detrital Grains

___72%___ Quartz: Size; 0.1 mm.
Shape; anhedral
Elongation Index; 0.65, subelongate
Polycrystalline / Monocrystalline; 0.01
Monocrystalline: (medium sand-size)
Inclusions; small vacuoles of glass 60%, regular inclusions of rutile and sericite 5%
Extinction; undulose 5%, slightly undulose 15%, straight 80%
Polycrystalline: (medium sand-size)
No. of crystals / grain; 10
Range; 8-12, No. of grains; 3
Contact between crystals; concavoconvex
Size range of crystals; 0.1 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

____7%____ K-Spar: Size; 0.15 mm., Shape; subhedral
Elongation Index; 0.62, elongate
Roundness; subround, Twinning; perthite in microcline, cleavage traces in orth.
Orthoclase 30%, Microcline 70%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 7/5

____5%____ Plagioclase Feldspar: AN# (Michelle Levy) 12-28 oligoclase
Range; 7-28, No. of grains; 10
Shape; sub-anhedral, Size; 0.133 mm.
Elongation Index; 0.62, elongate
Roundness; subround
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/1
Zoned / unzoned; N.O.
Inclusions; N.O.

____5%____ Chert

___N.O.___ Lithic Fragments

____3%____ Micas (total)
Dark / Light; 1/3
Dark; biotite, light green pleochroic, altered
Light; muscovite and sericite, thin lenticular crystals with curved laminae

____5%____ Clays (protomatrix); red-brown to black paste filling some intergranular pore throats

___Tr.____ Nonopaque Heavy Minerals; rutile grains and few

inclusions, trace of glauconite (?)
____3%____ Opaque Heavy Minerals; red-brown and black, medium sand-size grains of hematite
___N.O.___ Others

Slide: Kms-3

Rock Name: after Folk (1962); Terrigenous Biomicrudite
after Dunham (1962); Terrigenous Packstone
(Tres Hermanos Sandstone)

Carbonate Constituents (% of the rock)
_N.O._ Ooids
__5%__ Peloids: varieties; round (0.2-0.5 mm.), well-sorted, structureless, black
_30%__ Skeletal Material; pelecypod shells, dissarticulated with only cross lamellar layers preserved, some have been removed by dissolution, forming moldic pores in which precipitated blocky spar with a drusy texture has partially filled pores.
__10%_ Micrite (not including diagenetic alterations of above constituents):
___5%_ Neomorphic Spar: size, shape, occurrence;
__10%_ (Precipitated) Spar: (varieties based on size, shape and occurrence)
blocky spar with a drusy texture, partially fills moldic pores of preexisting bivalves.

Other Constituents (%of the rock)
__38%_ Terrigenous Debris: varieties and occurrence; very fine sand-size (0.075 mm. in diameter), well sorted, subangular, quartz, feldspar and lesser amounts of muscovite, hematite, and chert.
___1%_ Organic Material: occurrence; brown to red black, structureless masses enveloping some shells, located in some interstitial pores.
___1%_ Present Pore Space: varieties and occurrence; micro intergranular pores

Slide: Kd-5

Rock Name: Sublith-arenite (Dakota Sandstone)

Characteristics of Total Rock
Average Grain Size: 0.125 mm.; 3.0 O;
Wentworth Grade; very fine to fine sand
Sorting: Index; 1.0, Class; poorly sorted
Average Roundness: Index; 0.5, Class; subround
Elongation: Index; 0.67, Class; intermediate
Textural Maturity (present); immature

Textural Maturity (at time of deposition); submature
Percent Floating Grains; 10%, more in bore holes filled with silt
Contact Index; 2.6, Range; 0-6, No. Grains; 60
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) line; 3) concavoconvex

Percent of Rock or Stratum

___78%___ Detrital Grains (including protomatrix)
___15%___ Cement; silica cement, hyaline texture
____7%___ Matrix: Epimatrix / Orthomatrix; 1/10
Epimatrix; relict grain outlines of mica with cleavage planes
Orthomatrix; thin film of Fe-oxide and chlorite stain coating intergranular cement and chert grains preferent.
Pseudomatrix; N.O.
___N.O.___ Present Porosity

Percent of Detrital Grains

___85%___ Quartz: Size; 0.125 mm., very fine to fine sand
Shape; anhedral
Elongation Index; 0.67, intermediate
Polycrystalline / Monocrystalline; 1/25
Monocrystalline: (medium sand-size)
Inclusions; inclusions of glass in 40% of grains, 10% with regular inclusions of acicular rutile and mica.
Extinction; 30% undulose, 40% slight undulose, 30% straight
Polycrystalline: (medium sand-size)
No. of crystals / grain; 11
Range; 5-23, No. of grains; 15
Contact between crystals; concavoconvex some suture
Size range of crystals; 0.01-0.05 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.
____1%___ K-Spar: Size; 0.1 mm., Shape; anhedral
Elongation Index; 0.62, elongate
Roundness; subround, Twinning; perthite in microcline
Orthoclase 70%, Microcline 30%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; N.O.
Inclusions; vacuoles of glass and few regular inclusions of rutile in K-Spar
___N.O.___ Plagioclase Feldspar
____8%___ Chert
___N.O.___ Lithic Fragments
____2%___ Micas (total)
Dark / Light; 1/5
Dark; biotite, traces that have not been altered to chlorite or muscovite

Light; muscovite grains and minute crystals of sericite partially and often completley altered to chlorite

3% Clays (protomatrix); peloids, small oval, black, well-sorted, structureless

1% Nonopaque Heavy Minerals; rutile, regular inclusions and grains, hornblende, olivine

Tr. Opaque Heavy Minerals; hematite and/or magnetite

N.O. Others

Slide: Kd-8

Rock Name: Quartz Arenite (Dakota Sandstone)

Characteristics of Total Rock

Average Grain Size: 0.27 mm.; 1.75 O; Wentworth Grade; medium sand
Sorting: Index; 0.35, Class; well-sorted
Average Roundness: Index; 0.65, Class; rounded
Elongation: Index; > 0.75, Class; very equant
Textural Maturity (present); supermature
Textural Maturity (at time of deposition); supermature
Percent Floating Grains; 8%
Contact Index; 3.24, Range; 0-8, No. Grains; 50
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) concavoconvex; 3) line

Percent of Rock or Stratum

82% Detrital Grains (including protomatrix)

2% Cement; silica cement partially fills some pore throats

1% Matrix: Epimatrix / Orthomatrix; N.O.
Epimatrix; N.O.
Orthomatrix; very thin dusting of Fe-oxide on some intergranular cement and few chert and feldspar grains
Pseudomatrix; N.O.

15% Present Porosity; macro intergranular pores

Percent of Detrital Grains

94% Quartz: Size; 0.27 mm., medium sand
Shape; anhedral
Elongation Index; > 0.75, very equant
Polycrystalline / Monocrystalline; 1/80

Monocrystalline: (medium sand-size)
Inclusions; vacuoles of glass in 60%, regular inclusions of rutile and muscovite in 15% of grains
Extinction; 15% undulose, 20% slight undulose, 65% straight

Polycrystalline: (medium sand-size)
No. of crystals / grain; 17.4

Range; 6-35, No. of grains; 5
Contact between crystals; concavoconvex
Size range of crystals; 0.05-0.01 mm.
Shape of crystals; anhedral
Prefered orientation of crytals; N.O.

1% K-Spar: Size; 0.27, Shape; anhedral
Elongation Index; > 0.75, very equant
Roundness; rounded, Twinning; untwinned
Orthoclase 100%, Microcline N.O., Sanidine N.O.
K-Spar / Plagioclase Feldspar; N.O.

N.O. Plagioclase Feldspar
3% Chert
N.O. Lithic Fragments
1% Micas (total)
Dark / Light; N.O.
Dark; N.O.
Light; thinly shreded crystals of muscovite and minutely crystalline sericite, slightly bent and curved laminae

1% Clays (protomatrix); black, structureless, intergranular material unrelated to any diagenetic alterations

Tr. Nonopaque Heavy Minerals; glauconite (?)
Tr. Opaque Heavy Minerals; hematite
N.O. Others

Slide: Trc-2

Rock Name: after Folk (1962): Terrigenous Intrasparudite
after Dunham (1962): Terrigenous Grainstone
(Chinle Formation)

Carbonate Constituents (% of the rock)

72% Intraclasts: varieties; round (0.2-4.0 mm. in diameter) poorly sorted, dark gray clasts of carbonate containing discontinuous fractures, fine-grained terrigenous debris, point contacts and often suture borders between grains

N.O. Ooids
N.O. Peloids
N.O. Skeletal Material; very small (< 0.25 mm.) material in some intraclasts appears to be fossiliferous but cannot be identified

N.O. Micrite
N.O. Neomorphic Spar
10% (Precipitated) Spar: (varieties based on size, shape and occurrence)
partially fills intergranular pores and intragranular fractures, radial fibrous texture, forms embayed and suture contacts with carbonate intraclasts

Other Constituents (%of the rock)

__5%__ Terrigenous Debris: varieties and occurrence; very fine to medium sand-size, subangular quartz grains with lesser amounts of andalusite and muscovite, few olivine grains (highly altered with black inclusions of matrix)

__3%__ Organic Material: occurrence; black paste and thin film on some intergranular spar and grain surfaces

_10%__ Present Pore Space: varieties and occurrence; macro intergranular pores, minute intragranular fracture pores

Slide: Trc-13

Rock Name: Lithic Arkosic Arenite (Chinle Formation)

Characteristics of Total Rock

Average Grain Size: 0.22 mm.; 2.25 O; Wentworth Grade; fine sand
Sorting: Index; 1.5, Class; poorly sorted
Average Roundness: Index; 0.35, Class; subangular
Elongation: Index; < 0.60, Class; very elongate
Textural Maturity (present); immature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; 2.3%, is higher due to very fine sand floating in silt size matrix
Contact Index; 4.0, Range; 0-7, No. Grains; 45
Grain to Grain Contacts in Decreasing Abundance: 1) point 2) concavoconvex; 3) line

Percent of Rock or Stratum

___90%___ Detrital Grains (including protomatrix)

____3%____ Cement; minor amounts of poikilotopic calcite in localized patches surrounding feldspar grains, rest is silica cement

____6%____ Matrix: Epimatrix / Orthomatrix; 1/10
Epimatrix; relict grains of biotite and feldspar preserved with Fe-oxide stain
Orthomatrix; dusting of Fe-oxide on intergranular cement, feldspar, chert and lithic fragments
Pseudomatrix; part. altered feldspar and mica grains

____1%____ Present Porosity; micro intergranular pores and few macro pores partially filled with silica cement

Percent of Detrital Grains

___23%____ Quartz: Size; 0.22 mm.
Shape; anhedral
Elongation Index; < 0.60, very elongate
Polycrystalline / Monocrystalline; 1/20

Monocrystalline: (medium sand-size)
Inclusions; 20% irregular shaped vacuoles of glass, 5% regular inclusions of rutile and granular massses of muscovite
Extinction; 50% undulose, 20% slight undulose, 30% straight
Polycrystalline: (medium sand-size)
No. of crystals / grain; 33
Range; 19-62, No. of grains; 8
Contact between crystals; concavoconvex
Size range of crystals; 0.01-0.1 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

___25%___ K-Spar: Size; 0.2 mm., Shape; subhedral
Elongation Index; <0.60, very elongate
Roundness; subangular, Twinning; rods of perthite in microcline, inclusions in cleavage traces of orthoclase
Orthoclase 50%, Microcline 50%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 2.5

___10%___ Plagioclase Feldspar: AN# (Michelle Levy) 12-28 oligoclase
Range; 5-35, No. of grains; 11
Shape; subhedral, Size; 0.13 mm.
Elongation Index; < 0.60, very elongate
Roundness; subangular
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/1
Zoned / unzoned; 1/10
Inclusions; embayment contacts and inclusions of calcite, antiperthite twinning in some plagioclase, few acicular inclusions of rutile and muscovite, abund. vacuoles of glass

___10%___ Chert

___15%___ Lithic Fragments; few quartz grains with rounded syntaxial rim cement, dark brown to olive-green in refracted light, white in reflected light, silt to clay size material with few very fine sand-size grains of quartz (floating)

____1%____ Micas (total); bent and curved laminae
Dark / Light; 3/1
Dark; biotite, grain outlines altered to black pseudomatrix, few relict grains
Light; muscovite and some sericite, grains and inclusions

____1%____ Clays (protomatrix); red-brown and black intergranular material, structureless, and unrelated to diagenetic alterations

____2%____ Nonopaque Heavy Minerals; rutile grains and inclusions, grains of tourmaline, garnet

___12%___ Opaque Heavy Minerals; hematite, steel blue,

red and black, magnetite, steel blue to black, leucoxene, white, pyrite, brass yellow, (note: all opaque heavy minerals were determined using reflected light only)

1% Others; grains of either sericite (low relief) or natrolite radiating fibrous aggregates

Slide: Trs-19

Rock Name: Feldspathic Lithic Arenite (Santa Rosa Sandstone)

Characteristics of Total Rock

Average Grain Size: 0.55 mm.; 0.75 O; Wentworth Grade; coarse sand
Sorting: Index; 1.0, Class; poorly sorted
Average Roundness: Index; 0.25, Class; subangular
Elongation: Index; 0.61, Class; elongate parallel to strat.
Textural Maturity (present); immature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; N.O.
Contact Index; 5, Range; 4-8, No. Grains; 30
Grain to Grain Contacts in Decreasing Abundance:
1) concavoconvex; 2) line; 3) point

Percent of Rock or Stratum

85% Detrital Grains (including protomatrix)
Tr. Cement; silica rim cement, very thin
5% Matrix: Epimatrix / Orthomatrix; 1/3
Epimatrix; relict ghost outline of some feldspar grains, both plag. and k-spar
Orthomatrix; thin Fe-oxide dusting on few grains especially on granular sericite material
Pseudomatrix; red and black, paste, discontinuous, adjacent to altered mica and feldspar grains
10% Present Porosity; macro intergranular pores

Percent of Detrital Grains

23% Quartz: Size; 0.55 mm.
Shape; anhedral
Elongation Index; 0.61, elongate
Polycrystalline / Monocrystalline; 1/5
Monocrystalline: (medium sand-size)
Inclusions; 90% of grains with vacuole inclusions of glass, 35% with regular inclusions of rutile and muscovite
Extinction; N.O.
Polycrystalline: (medium sand-size)
No. of crystals / grain; 22
Range; 7-65, No. of grains; 15
Contact between crystals; concavoconvex

and jagged
Size range of crystals; 0.02-0.1 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

____7%____ K-Spar: Size; 0.3 mm., Shape; anhedral
Elongation Index; 0.67, intermediate
Roundness; subround, Twinning; trace in orthoclase, perthite in microcline
Orthoclase 70%, Microcline 30%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 7/4

____4%____ Plagioclase Feldspar: AN# (Michelle Levy) 10-30 oligoclase
Range; 10-34, No. of grains; 5
Shape; subhedral, Size; 0.3 mm.
Elongation Index; 0.62, subelongate
Roundness; subangular
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/2
Zoned / unzoned; N.O.
Inclusions; regular inclusions of rutile and sericite in plagioclase

___35%____ Chert

___20%____ Lithic Fragments; poorly sorted brick-red and brown siltstone and shale grains, also, quartz grains with rounded syntaxial cement and few grains of strained polycrystalline quartz

____3%____ Micas (total)
Dark / Light; N.O.
Dark; N.O.
Light; sericite, granular, intergranular with abundant hematite stain, few needles of sericite

_____7%___ Clays (protomatrix); black to dark red-brown, intergranular, poorly sorted, structureless material not related to diagenetic alterations

___N.O.___ Nonopaque Heavy Minerals;

_____1%___ Opaque Heavy Minerals; black hematite and/or magnetite

___N.O.___ Others

Slide: Pb-4

Rock Name: Feldspathic Lithic Arenite (Bernal Formation)

Characteristics of Total Rock

Average Grain Size: 0.075 mm.; 3.75 O;
Wentworth Grade; very fine sand
Sorting: Index; 1.75, Class; well-sorted
Average Roundness: Index; 0.4, Class; subangular
Elongation: Index; 0.70, Class; subequant
Textural Maturity (present); immature
Textural Maturity (at time of deposition); mature
Percent Floating Grains; N.O.

Contact Index; 5, Range; 2-8, No. Grains; 22
Grain to Grain Contacts in Decreasing Abundance:
1)concavoconvex; 2) point; 3) line; 4) suture

Percent of Rock or Stratum

___83%___ Detrital Grains (including protomatrix)
___5%___ Cement; calcite with poikilotopic texture in localized patches, thin film of silica cement in other areas
___2%___ Matrix: Epimatrix / Orthomatrix; N.O.
Epimatrix; N.O.
Orthomatrix; thin dusting of Fe-oxide on intergranular cement and grains
Pseudomatrix; N.O.
___10%___ Present Porosity; (note: estimate may be anomolously high due to excessive amount of grain plucking and cracking of sample during thin section preparation)

Percent of Detrital Grains

___69%___ Quartz: Size; 0.075 mm.
Shape; anhedral
Elongation Index; 0.70, subequant
Polycrystalline / Monocrystalline; N.O.
Monocrystalline: (medium sand-size)
Inclusions; vacuoles of glass in 30% of grains
Extinction; 15% undulose, 10% slight undulose, 75% straight
Polycrystalline: (medium sand-size); N.O.
___5%___ K-Spar: Size; 0.05 mm., Shape; anhedral
Elongation Index; > 0.75, equant
Roundness; subround, Twinning; perthite in microcline
Orthoclase 20%, Microcline 80%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 5/2
___2%___ Plagioclase Feldspar: AN# (Michelle Levy) 12-28 oligoclase
Range; 8-23, No. of grains; 5
Shape; subhedral, Size; 0.05 mm.
Elongation Index; 0.65, subelongate
Roundness; subround
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/1
Zoned / unzoned; N.O.
Inclusions; vacuoles in most K-spar, regular inclusions of sericite, rutile and glass in feldspar
___10%___ Chert; very fine grain size
___N.O.___ Lithic Fragments
___5%___ Micas (total)
Dark / Light; 1/3
Dark; trace of biotite

Light; small prismatic needles of sericite parallel to stratification, few prismatic pieces of muscovite

____2%____ Clays (protomatrix); black intergranular paste unrelated to any diagenetic alterations and lacking any cement texture

____2%____ Nonopaque Heavy Minerals; rutile both as rounded grains and as inclusions in feldspar, trace of hornblende, and one grain of garnet

____5%____ Opaque Heavy Minerals; magnetite and/or hematite

___N.O.___ Others

Slide Psa-2

Rock Name: after Folk (1962): Biomicrudite
after Dunham (1962): Packstone
(San Andres Limestone)

Carbonate Constituents (% of the rock)

_N.O._ Intraclasts

_N.O._ Ooids

__3%__ Peloids: varieties; black to dark brown, oval shape, structureless, (0.1 mm. in diameter)

_60%__ Skeletal Material; crinoid columnals, pelecypods, Brachiopods, gastropods

_31%__ Micrite (not including diagenetic alterations of above constituents):

__5%__ Neomorphic Spar: size, shape, occurrence;

_N.O._ (Precipitated) Spar

Other Constituents (%of the rock)

__1%__ Terrigenous Debris: varieties and occurrence;

_N.O._ Organic Material

_N.O._ Present Pore Space

Slide: Psa-3

Rock Name: after Folk (1962): Biopelmicrite
after Dunham (1962): Wackestone
(San Andres Limestone)

Carbonate Constituents (% of the rock)

_N.O._ Intraclasts

_N.O._ Ooids

_15%__ Peloids: varieties; black, round, well-sorted, (0.05 mm. in diameter), lack internal structure

_12%__ Skeletal Material; crinoid columnals and echinoid spines, pelecypods

_68%__ Micrite (not including diagenetic alterations of above constituents):

__3%__ Neomorphic Spar: size, shape, occurrence; replaces fossil material fills moldic pores
_N.O._ (Precipitated) Spar

Other Constituents (%of the rock)
_N.O._ Terrigenous Debris
_Tr.__ Organic Material
__2%__ Present Pore Space: varieties and occurrence;

Slide__Psa-13____

Rock Name: after Folk (1962): Biopelmicrite
after Dunham (1962): Wackestone
(San Andres Limestone)

Carbonate Constituents (% of the rock)
__Tr._ Intraclasts: varieties; (0.5-0.75 mm.) angular, dark black, lack internal structure
_N.O._ Ooids
_25%__ Peloids: varieties; (0.2 mm. in diameter), oval, black, lack internal structure
_15%__ Skeletal Material; pelecypods, crinoid columnals
_41%__ Micrite (not including diagenetic alterations of above constituents):
_15%__ Neomorphic Spar: size, shape, occurrence; relict outlines of shell material and crinoids
__2%__ (Precipitated) spar: varieties based on size, shape and occurrence)
small localized, discontinuous, (1-2 mm.) spots of clear calcite with cleavage, fills intergranular and fracture pores

Other Constituents (%of the rock)
_N.O._ Terrigenous Debris
_N.O._ Organic Material
__2%__ Present Pore Space: varieties and occurrence; micro intergranular porosity

Slide: Psg-1

Rock Name: Quartz Arenite (Glorieta Sandstone)

Characteristics of Total Rock
Average Grain Size: 0.2 mm.; 2.25 O;
Wentworth Grade; fine sand
Sorting: Index; 0.35, Class; well-sorted
Average Roundness: Index; 0.7, Class; rounded
Elongation: Index; > 0.75, Class; very equant
Textural Maturity (present); supermature
Textural Maturity (at time of deposition); supermature

Percent Floating Grains; N.O.
Contact Index; 5, Range; 3-9, No. Grains; 40
Grain to Grain Contacts in Decreasing Abundance:
1) concavoconvex; 2) line; 3) point;

Percent of Rock or Stratum

___85%___ Detrital Grains (including protomatrix)
____5%____ Cement; poikilotopic calcite in small randomly oriented patches, slight trace of thin silica cement, pores partially filled
___Tr.____ Matrix: Epimatrix / Orthomatrix; N.O.
Epimatrix; N.O.
Orthomatrix; very thin Fe-oxide dusting on some intergranular cement
Pseudomatrix; N.O.
___10%____ Present Porosity; intergranular macro pores

Percent of Detrital Grains

___96%____ Quartz: Size; 0.2 mm.
Shape; anhedral
Elongation Index; > 0.75, very equant
Polycrystalline / Monocrystalline; 1/60
Monocrystalline: (medium sand-size)
Inclusions; 40% of grains with vacuole inclusions of glass, trace of regular inclusions of rutile
Extinction; 15% undulose, 30% slight undulose, 55% straight
Polycrystalline: (medium sand-size)
No. of crystals / grain; 7
Range; 3-20, No. of grains; 5
Contact between crystals; concavoconvex
Size range of crystals; 0.01-0.05 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.
____1%_____ K-Spar: Size; 0.2 mm., Shape; anhedral
Elongation Index; 0.65, subelongate
Roundness; rounded, Twinning; perthite
Orthoclase N.O., Microcline 100%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 2/1
___Tr.____ Plagioclase Feldspar: AN# (Michelle Levy) 15 oligoclase
Range; 10-30, No. of grains; 2
Shape; anhedral, Size; 0.15 mm.
Elongation Index; equant
Roundness; rounded
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/1
Zoned / unzoned; N.O.
Inclusions; N.O.
____3%____ Chert; white and orange
___N.O.___ Lithic Fragments
___N.O.___ Micas (total)

___N.O.___ Clays (protomatrix)
___N.O.___ Nonopaque Heavy Minerals
____Tr.___ Opaque Heavy Minerals; very few dark black to red-brown, magnetite and/or hematite
___N.O.___ Others

Slide: Psg-10

Rock Name: Sublitharenite (Glorieta Sandstone)

Characteristics of Total Rock
Average Grain Size: 0.26 mm.; 2.0 O; Wentworth Grade; medium sand
Sorting: Index; 0.4, Class; well-sorted
Average Roundness: Index; 0.7, Class; rounded
Elongation: Index; > 0.75, Class; very equant
Textural Maturity (present); supermature
Textural Maturity (at time of deposition); supermature
Percent Floating Grains; N.O.
Contact Index; 3.7, Range; 1-6, No. Grains; 30
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) concavoconvex; 3) line;

Percent of Rock or Stratum
___86%___ Detrital Grains (including protomatrix)
____4%___ Cement; poikilotopic, isolated, small patches of calcareous cement, partially fills pore throats
___N.O.___ Matrix: Epimatrix / Orthomatrix; N.O.
___10%___ Present Porosity

Percent of Detrital Grains
___92%___ Quartz: Size; 0.26 mm.
Shape; anhedral
Elongation Index; very equant
Polycrystalline / Monocrystalline; N.O.
Monocrystalline: (medium sand-size)
Inclusions; trace of small prismatic and acicular inclusions of rutile, vacuoles of glass in 30% of grains
Extinction; 10% undulose, 30% slight undulose, 60% straight
____2%___ K-Spar: Size; 0.2 mm., Shape; subhedral
Elongation Index; > 0.75, very equant
Roundness; rounded, Twinning; perthite
Orthoclase N.O., Microcline 100%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; N.O.
___Tr.___ Plagioclase Feldspar: AN# (Michelle Levy) 15 oligoclase
Range; 10-30, No. of grains; 3
Shape; subhedral, Size; 0.2 mm.
Elongation Index; 0.65, subelongate

Roundness; rounded
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 1/1
Zoned / unzoned; N.O.
Inclusions; small vacuoles of glass

5%	Chert
N.O.	Lithic Fragments
N.O.	Micas (total)
N.O.	Clays (protomatrix)
N.O.	Nonopaque Heavy Minerals
1%	Opaque Heavy Minerals; black magnetite and/or hematite
N.O.	Others

Slide: Pyj-11

Rock Name: Sublitharenite (Joyita Sandstone)

Characteristics of Total Rock

Average Grain Size: 0.15 mm.; 2.75 O;
Wentworth Grade; fine sand
Sorting: Index; 0.5, Class; moderate
Average Roundness: Index; 0.55, Class; subround
Elongation: Index; > 0.75, Class; very equant
Textural Maturity (present); submature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; N.O.
Contact Index; 5.5, Range; 3-8, No. Grains; 40
Grain to Grain Contacts in Decreasing Abundance:
1) concavoconvex; 2) point; 3) line;

Percent of Rock or Stratum

90%	Detrital Grains (including protomatrix)
2%	Cement; silica cement with sericite veinlets and minor amount of hematite stain
2%	Matrix: Epimatrix / Orthomatrix; 1/5 Epimatrix; few relict grains with only Fe-oxide stain present Orthomatrix; trace of thin Fe-oxide stain on intergranular cement Pseudomatrix; N.O.
6%	Present Porosity; macro and micro intergranular pores

Percent of Detrital Grains

75%	Quartz: Size; 0.15 mm., fine sand Shape; anhedral Elongation Index; > 0.75, very equant Polycrystalline / Monocrystalline; 0.01 Monocrystalline: (medium sand-size) Inclusions; regular inclusions of rutile and muscovite 10% of grains,

vacuoles of glass 60% of grains
Extinction; 30% undulose, 20% slight undulose, 50% straight
Polycrystalline: (medium sand-size)
No. of crystals / grain; 9
Range; 3-18, No. of grains; 4
Contact between crystals; concavoconvex
Size range of crystals; 0.01-0.05 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

5% K-Spar: Size; 0.1 mm., Shape; subhedral
Elongation Index; 0.65, subelongate
Roundness; subround, Twinning; perthite in microcline, orthoclase untwinned
Orthoclase 10%, Microcline 90%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 5/1

1% Plagioclase Feldspar: AN# (Michelle Levy) 12-28 oligoclase
Range; 12-32, No. of grains; 2
Shape; subhedral, Size; 0.05 mm.
Elongation Index; 0.65, subelongate
Roundness; subround
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 2/3
Zoned / unzoned; N.O.
Inclusions; regular inclusions of rutile and muscovite, vacuoles of glass

7% Chert

N.O. Lithic Fragments

3% Micas (total)
Dark / Light; N.O.
Dark; N.O.
Light; sericite veinlets and muscovite grains

2% Clays (protomatrix); partially fills some pore throats black and red black, structureless, unrelated to any diagenetic alterations

2% Nonopaque Heavy Minerals; glauconite (?), olivine, inclusions of rutile in feldspar and quartz grains

5% Opaque Heavy Minerals; magnetite and/or hematite

N.O. Others

Slide; Pyc-4

Rock Name: after Folk (1962): Micrite
after Dunham (1962): Mudstone
(Canas Gypsum Member)

Carbonate Constituents (% of the rock)

N.O. Intraclasts

N.O. Ooids

N.O. Peloids

_N.O._ Skeletal Material
__75%_ Micrite (not including diagenetic alterations of above constituents):
_N.O._ Neomorphic Spar
_N.O._ (Precipitated) Spar

Other Constituents (%of the rock)
_N.O._ Terrigenous Debris
__5%__ Organic Material: occurrence; (0.5 mm. in diameter) patches of circular, dark brown to black material
__20%_ Present Pore Space: varieties and occurrence; due to improper grinding of thin section, caused by excessive grain plucking from specimen during thin section preparation

Slide: Pyt-3

Rock Name: after Folk (1962): Peloidal Terrigenous Micrite
after Dunham (1962): Terrigenous Wackestone
(Torres Limestone)

Carbonate Constituents (% of the rock)
_N.O._ Intraclasts
_N.O._ Ooids
__3%__ Peloids: varieties; very small (< 0.05 mm. in diameter), oval shape, black
_N.O._ Skeletal Material;
__87%_ Micrite (not including diagenetic alterations of above constituents):
_N.O._ Neomorphic Spar
_N.O._ (Precipitated) Spar

Other Constituents (%of the rock)
__8%__ Terrigenous Debris: varieties and occurrence; quartz sand floating in carbonate matrix, concentrated in zones parallel to stratification, alternating layers (0.05 mm. in diameter) of coarse silt to fine sand
__1%__ Organic Material: occurrence;
__1%__ % Present Pore Space: varieties and occurrence;

Slide: Pyt-5

Rock Name: Lithic Arkose (Torres Limestone)

Characteristics of Total Rock
Average Grain Size; 0.5 & 0.15 mm. (bimodal), 1.0 and 2.75 O Wentworth Grade; coarse and fine sand
Sorting: Index; 1.5, Class; poorly sorted
Average Roundness: Index; 0.6, Class; subround
Elongation: Index; > 0.75, Class; very equant

Textural Maturity (present); immature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; N.O.
Contact Index; 5, Range; 2-10, No. Grains; 30
Grain to Grain Contacts in Decreasing Abundance: 1) point
2) line; 3) concavoconvex

Percent of Rock or Stratum

90% Detrital Grains (including protomatrix)
Tr. Cement; silica
5% Matrix: Epimatrix / Orthomatrix; N.O.
Epimatrix; N.O.
Orthomatrix; Fe-oxide dusting on altered feldspar grains
Pseudomatrix; Fe-oxide mass adjacent to and commonly in embayement contact with feldspar grains
5% Present Porosity; micro and macro intergranular pores

Percent of Detrital Grains

70% Quartz: Size; 0.1-1.0 mm.
Shape; anhedral
Elongation Index; > 0.75, very equant
Polycrystalline / Monocrystalline; 1/35
Monocrystalline: (medium sand-size)
Inclusions; 10% vacuoles, trace of regular inclusions of glass
Extinction; 65% straight, 20% slightly undulose, 15% undulose
Polycrystalline: (medium sand-size)
No. of crystals / grain; 6
Range; 4-15, No. of grains; 10
Contact between crystals; concavoconvex
Size range of crystals; 0.1-0.5 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

15% K-Spar: Size; 1.5 mm., Shape; anhedral to sub.
Elongation Index; 0.62, elongate
Roundness; subround, Twinning; trace of perthite twinning in microcline, cleavage traces in orthoclase
Orthoclase 80%, Microcline 20%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 3/1

5% Plagioclase Feldspar: AN# (Michelle Levy) 11 oligoclase
Range; 6-3, No. of grains; 13
Shape; subhedral, Size; 0.5-1.5 mm.
Elongation Index; 0.65, subelongate
Roundness; rounded
Plagioclase Twinned / Untwinned; 10/1
A-twins / C-twins; 2/1
Zoned / unzoned; N.O.
Inclusions; abundant vacuoles and

regular inclusions of glass and acicular rutile and epidote inclusions on most feldspar grains

____5%____ Chert
__N.O.____ Lithic Fragments;
___Tr.____ Micas (total)
Dark / Light; N.O.
Dark; N.O.
Light; 1-grain of muscovite with bent laminae
____3%____ Clays (protomatrix); black pore filling mass, does not appear to be associated with any altered grains
__N.O.____ Nonopaque Heavy Minerals
____2%____ Opaque Heavy Minerals; magnetite and/or hematite grains, rounded (< 0.5 mm. in diameter)
__N.O.____ Others

Slide: Pyt-29

Rock Name: Arkosic Lithic Arenite (Torres Limestone)

Characteristics of Total Rock

Average Grain Size: 0.15 mm.; 2.75 O; Wentworth Grade; fine sand
Sorting: Index; 1.0, Class; poorly
Average Roundness: Index; 0.6, Class; subround
Elongation: Index; 0.72, Class; subequant
Textural Maturity (present); submature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; N.O.
Contact Index; 6, Range; 2-9, No. Grains; 25
Grain to Grain Contacts in Decreasing Abundance: 1) line; 2) point; 3) concavoconvex

Percent of Rock or Stratum

___91%____ Detrital Grains (including protomatrix)
____5%____ Cement; intergranular, pore filling silica and and syntaxial rim cement
____3%____ Matrix: Epimatrix / Orthomatrix; N.O.
Epimatrix; N.O.
Orthomatrix; thin dusting of Fe-oxide on cement and grains
Pseudomatrix; N.O.
____1%____ Present Porosity

Percent of Detrital Grains

___70%____ Quartz: Size; 0.05-0.2 mm. range
Shape; anhedral
Elongation Index; > 0.75, very equant
Polycrystalline / Monocrystalline; 1/30
Monocrystalline: (medium sand-size)
Inclusions; regular sericite and

acicular inclusions of rutile, vacuoles of glass
Extinction; 70% straight, 10% slight undulose, 20% undulose
Polycrystalline: (medium sand-size)
No. of crystals / grain; 10
Range; 4-25, No. of grains; 5
Contact between crystals; concavoconvex
Size range of crystals; 0.05-0.1 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

____7%____ K-Spar: Size; 0.15, Shape; subhedral
Elongation Index; 0.65, subelongate
Roundness; rounded, Twinning; untwinned
orthoclase perthite rods in microcline
Orthoclase 30%, Microcline 70%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 2.25

____3%____ Plagioclase Feldspar: AN# (Michelle Levy) 15 oligoclase
Range; 10-30, No. of grains; 9
Shape; subhedral, Size; 0.15 mm.
Elongation Index; 0.65, subelongate
Roundness; rounded
Plagioclase Twinned / Untwinned; 100%
A-twins / C-twins; 1/1
Zoned / unzoned; N.O.
Inclusions; regular sericite and small vesicular inclusions

___12%____ Chert

____1%____ Lithic Fragments; quartz grains with rounded syntaxial rim cement

____2%____ Micas (total); muscovite is replacing biotite and both are being altered to chlorite
Dark / Light; 1/1
Dark; biotite
Light; muscovite

____2%____ Clays (protomatrix); red-brown, fine-grained, fills pore throats in localized discontinuous patches

____1%____ Nonopaque Heavy Minerals; glauconite (?)

____2%____ Opaque Heavy Minerals; black magnetite and/or hematite

___N.O.___ Others

Slide: Pym-37

Rock Name: Arkose (Meseta Blanca Sandstone)

Characteristics of Total Rock

Average Grain Size: 0.28 mm.; 1.75 O;
Wentworth Grade; medium

Sorting: Index; 0.5, Class; moderate

Average Roundness: Index; 0.85, Class; well rounded
Elongation: Index; > 0.75, Class; very equant
Textural Maturity (present); submature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; 3%
Contact Index; 3, Range; 0-6, No. Grains; 25
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) line; 3) embayment; 4) concavoconvex;

Percent of Rock or Stratum

87% Detrital Grains (including protomatrix)
11% Cement; poikilotopic, pale yellow, some cleavage, most granular, fills pore throats, embayed contact with feldspar grains
2% Matrix: Epimatrix / Orthomatrix; N.O.
Epimatrix; N.O.
Orthomatrix; thin Fe-oxide dusting on grain surfaces
Pseudomatrix; intergranular blobs on feldspar grain, Fe-oxide
2% Present Porosity; may be high due to grain plucking and fracturing of rock during thin section preparation

Percent of Detrital Grains

70% Quartz: Size; 0.3 mm.
Shape; anhedral
Elongation Index; > 0.75, very equant
Polycrystalline / Monocrystalline; 1/50
Monocrystalline: (medium sand-size)
Inclusions; 20% of grains with vacuoles of glass, 5% with acicular inclusions of rutile
Extinction; 40% straight, 45% undulose, 15% slight undulose
Polycrystalline: (medium sand-size)
No. of crystals / grain; 20
Range; 15-30, No. of grains; 4
Contact between crystals; concavoconvex and line
Size range of crystals; 0.05-0.2 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

14% K-Spar: Size; 0.3 mm., Shape; subhedral
Elongation Index; 0.64, subelongate
Roundness; well, Twinning; microperthite
Orthoclase 30%, Microcline 70%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 2.0

7% Plagioclase Feldspar: AN# (Michelle Levy) 10 & 30
Range; 8-34, No. of grains; 10
Shape; anhedral, Size; 0.28 mm.
Elongation Index; 0.73, equant
Roundness; well rounded

Plagioclase Twinned / Untwinned; 10/1
A-twins / C-twins; 1/1
twin planes are bent
Inclusions; acicular inclusions of rutile in both plag. and K-spar, regular inclusions of salt (?), abundant vacuoles of glass

____3%____ Chert
____3%____ Lithic Fragments; fragments of quartz grains with syntaxial rim cement incorporating halos of hematite stain
___N.O.___ Micas (total)
____1%____ Clays (protomatrix);
___Tr.____ Nonopaque Heavy Minerals; glauconite (?), garnet
____2%____ Opaque Heavy Minerals; zircon
___N.O.___ Others

Slide: Pa-4

Rock Name: Subarkose (Abo Formation)

Characteristics of Total Rock

Average Grain Size: 0.075 mm.; 3.75 O;
Wentworth Grade; very fine sand
Sorting: Index; 0.35, Class; well
Average Roundness: Index; 0.6, Class; subround
Elongation: Index; 0.73, Class; equant
Textural Maturity (present); immature
Textural Maturity (at time of deposition); supermature
Percent Floating Grains; N.O.
Contact Index; 7, Range; 4-9, No. Grains; 30
Grain to Grain Contacts in Decreasing Abundance:
1) concavoconvex; 2) suture; 3) line; 4) point;

Percent of Rock or Stratum

___84%____ Detrital Grains (including protomatrix)
___10%____ Cement; fracture filling precipitated cement and cement with poikilotopic texture, dolomitized, abundant rhombohedra, pale yellow with spots of dark brown hematite stain
____6%____ Matrix: Epimatrix / Orthomatrix; 1/5
Epimatrix; few relict grains of either mica or feldspar, thin rectangular (< 0.5 mm. in length)
Orthomatrix; thin Fe-oxide coating some grains
Pseudomatrix; intergranular masses of Fe-oxide matrix and also along some bent mica flakes
___Tr.____ Present Porosity; intergranular pores partialy filled with carbonate cement or matrix

Percent of Detrital Grains

___85%___ Quartz: Size; 0.075 mm.
Shape; anhedral
Elongation Index; 0.73, equant
Polycrystalline / Monocrystalline; 0.01
Monocrystalline: (medium sand-size)
Inclusions; vacuoles in 40% of grains, trace of acicular needles of rutile
Extinction; 30% straight, 30% slight undulose, 40% undulose
Polycrystalline: (medium sand-size)
No. of crystals / grain; 4
Range; 3-9, No. of grains; 5
Contact between crystals; concavoconvex and suture
Size range of crystals; 0.02-0.06 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.

____3%____ K-Spar: Size; 0.06 mm., Shape; euhedral
Elongation Index; 0.61, elongate
Roundness; subangular, Twinning; perthite in microcline, orthoclase untwinned
Orthoclase 30%, Microcline 70%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 1.5

____2%____ Plagioclase Feldspar: AN# (Michelle Levy) 18 oligoclase
Range; 16-40, No. of grains; 6
Shape; subhedral, Size; 0.05 mm.
Elongation Index; 0.6, elongate
Roundness; subangular
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; 5/1
Zoned / unzoned; N.O.
Inclusions; trace of antiperthite, small acicular inclusions of rutile

___Tr.___ Chert

___N.O.___ Lithic Fragments

____2%____ Micas (total); fragments parallel to bedding and commonly bent
Dark / Light; 1/3
Dark; biotite
Light; lenticular splinters of muscovite

____2%____ Clays (protomatrix); pore filling, black to red brown, structureless, unrelated to diagenetic alterations

____2%____ Nonopaque Heavy Mine[illegible]

Rock Name: after Folk (1962): Terrigenous Biosparudite
after Dunham (1962): Terrigenous Packstone
(Bursum Formation)

Carbonate Constituents (% of the rock)

N.O. Intraclasts
N.O. Ooids
2% Peloids: varieties; rounded, black, structureless, well-sorted, (0.2 mm. in diameter)
20% Skeletal Material; crinoid columnals, echinoid spines, pelecypods, fusulinids, brachiopods
5% Micrite (not including diagenetic alterations of above constituents): intergranular, black, structureless
21% Neomorphic Spar: size, shape, occurrence;
15% (Precipitated) Spar: (varieties based on size, shape and occurrence)
blocky carbonate cement precipitated in moldic pores of pelecypods with a slight drusy texture, fracture filling, and also shelter pore filling with geopetal structures

Other Constituents (%of the rock)

30% Terrigenous Debris: varieties and occurrence; quartz, plagioclase, and potassium feldspar grains (0.15 mm. grain size), moderate sorted, round, equant grains in thin layers parallel to stratification and also randomly distributed throughout rest of rock
3% Organic Material: occurrence; micrite envelopes and intergranular material
6% % Present Pore Space: varieties and occurrence; fracture and intergranular pores

Slide: Pbu-6

Rock Name: Lithic Arkose (Bursum Formation)

Characteristics of Total Rock

Average Grain Size: 0.91 mm.; 0.25 O; Wentworth Grade; coarse sand
Sorting: Index; 2.0, Class; very poor
Average Roundness: Index; 0.35, Class; subangular
Elongation: Index; 0.73, Class; equant
Textural Maturity (present); immature
Textural Maturity (at time of deposition); submature
Percent Floating Grains; 6.5%
Contact Index; 4.5, Range; 0-18, No. Grains; 45
Grain to Grain Contacts in Decreasing Abundance: 1) point; 2) concavoconvex; 3) sutured; 4) line;

Percent of Rock or Stratum

___84%___ Detrital Grains (including protomatrix)
___10%___ Cement; poikilotopic carbonate cement
____5%___ Matrix: Epimatrix / Orthomatrix; 1/100
Epimatrix; one relict mica grain replaced by matrix
Orthomatrix; Fe-oxide coating on intergranular cement and feldspar grains preferentially
Pseudomatrix; discontinuous paste near boundaries with feldspar and few sericite grains
____1%___ Present Porosity; micro intergranular pores in calcite cement

Percent of Detrital Grains

___45%___ Quartz: Size; 0.91 mm.
Shape; anhedral
Elongation Index; 0.73, equant
Polycrystalline/Monocrystalline; 1/50
Monocrystalline: (medium sand-size)
Inclusions; glass vacuoles 15% of quartz grains
Extinction; 60% undulose, 20% straight, 20% slight undulose
Polycrystalline: (medium sand-size)
No. of crystals / grain; 8
Range; 3-20, No. of grains; 15
Contact between crystals; concavoconvex and suture
Size range of crystals; 0.1-1.0 mm.
Shape of crystals; anhedral
Prefered orientation of crystals; N.O.
___32%___ K-Spar: Size; 0.1-2.5 mm., Shape; subhedral
Elongation Index; < 0.60, very elongate
Roundness; subround, Twinning; 50% of orthoclase and all of microcline has perthite twinning
Orthoclase 90%, Microcline 10%, Sanidine N.O.
K-Spar / Plagioclase Feldspar; 30
____1%___ Plagioclase Feldspar: AN# (Michelle Levy) 13-27 oligoclase
Range; 13-27, No. of grains; 1
Shape; subhedral, Size; 1.0 mm.
Elongation Index; 0.62, elongate
Roundness; angular
Plagioclase Twinned / Untwinned; N.O.
A-twins / C-twins; N.O.
Zoned/unzoned; larger orthoclase grains are zoned with halos of Fe-oxide stain
Inclusions; inclusions of glass in 70% of orthoclase, regular inclusions of acicular and prismatic rutile and sericite in 30% of orthoclase

____3%____ Chert
___15%____ Lithic Fragments; polycrystalline fragments of strained quartz (1-3 mm. in diameter) with poorly sorted (0.1-2.0 mm. in diameter) quartz grains with concavoconvex contacts and undulose extinction, subround, also few quartz grains with rounded syntaxial rim cement
____2%____ Micas (total); bent and curved laminae, trace of altered muscovite to hematite
Dark / Light; N.O.
Dark; N.O.
Light; sericite needles and veinlets, trace of muscovite, regular inclusions of sericite in quartz and feldspar grains
____2%____ Clays (protomatrix); black, irregular shape, small patches of intergranular material not related to diagenetic alterations
___Tr.____ Nonopaque Heavy Minerals; acicular needles and prismatic inclusions of rutile in quartz and feldspar grains
___N.O.___ Opaque Heavy Minerals
___N.O.___ Others

Slide: Cma-14

Rock Name: after Folk (1962): Oobiomicrudite
after Dunham (1962): Oolitic Packstone
(Madera Limestone)

Carbonate Constituents (% of the rock)

_N.O._ Intraclasts
_15%__ Ooids: varieties; oolites, nucleus altered to neomorphic spar
__3%__ Peloids: varieties; dark circular blebs (0.3 mm. in diameter), moderately sorted, structureless
_35%__ Skeletal Material; crinoid columnals, echinoid spines, coralline algae, rugosids, ostracods, gastropods, brachiopods, bryozon
_15%__ Micrite (not including diagenetic alterations of above constituents):
__7%__ Neomorphic Spar: size, shape, occurrence; small, isolated, loaf shaped blebs in micrite intergranular material
_15%__ (Precipitated) Spar: (varieties based on size, shape and occurrence)
in shelter pore of coral and algae, blocky cement with rhombic cleavage, fills thin fracture also

Other Constituents (%of the rock)

_N.O._ Terrigenous Debris
_N.O._ Organic Material
_Tr.__ Present Pore Space: varieties and occurrence; micro pores along grain boundaries

Field Descriptions for Composite Columnar Section

Interval	Description	Thickness (in feet)
Alluvium-(Section not measured)		
Angular Unconformity		
Santa Fe Formation-(Section measured in the N.W./4 N.E./4 of sec. 8, T.5S., R.2E.)		
Tsf-6	Conglomerate, buff to light-pink, unconsolidated cobble to boulder-size gray limestone, brick-red sandstone and siltstone, chert, and calcareous concretions.	25.0
Tsf-5	Mudstone, brown fresh, buff to pink weathered, sandy, poorly-sorted, root marks and woody material, poorly indurated, calcareous.	5.0
Tsf-4	Conglomerate, pink to brown varicolored, poorly indurated, poorly sorted, pebble to cobble-size gray limestone, brick-red siltstone and sandstone, and intergranular coarse to very coarse, subangular, frosted quartz, varicolored chert grains, and volcanic sediments.	4.0
Tsf-3	Sandstone, dark brown fresh, buff to pink weathered, poorly sorted, coarse, subangular grains with conglomeratic lenses of cobble size gray limestone and brick-red siltstone, calcareous.	3.5
Tsf-2	Conglomerate, light-pink to buff, crossbedded with pebble to boulder-size gray limestone and brick-red siltstone and sandstone, with thin interbedded sandstone stringers of coarse to very coarse, poorly sorted grains, calcareous.	5.0
Tsf-1	Sandstone, light brown fresh, light-pink to tan weathered, unconsolidated, poorly sorted, cobble-to clay-size material, crumbly, soft, calcareous, light gray bleach spots.	28.0
		Total 70.5
Angular Unconformity		
Baca Formation-(Section measured in the N.W./4 S.E./4 of sec. 11, T.5S., R.2E.) (lower beds covered by alluvium)		
Tb-8	Conglomerate, purple fresh, light-pink weathered, pebble to boulder-size clasts of gray limestone and brick-red siltstone and sandstone, with low-angle crossbedding, crumbly, soft, abundant intergranular carbonate cement.	12.0
Tb-7	Conglomerate, light purple to pink, cobbles with few floating boulder-size clasts of gray limestone and brick-red sandstone and	17.0

	siltstone, poorly indurated, crumbly, soft, abundant intergranular precipitated carbonate cement.	
Tb-6	Conglomerate, light-pink to maroon, lenticular shaped lens of poorly indurated, pebble to boulder-size, rounded clasts of gray limestone, brick-red siltstone and sandstone, trace of metavolcanic sediments.	15.0
Tb-5	Sandstone, red-brown to tan fresh, light-pink to maroon weathered, medium to coarse, moderately sorted, poorly indurated, crumbly, soft, calcareous.	7.0
Tb-4	Conglomerate, light-pink to maroon, poorly indurated, pebble to boulder-size, rounded clasts of gray limestone, brick-red siltstone and sandstone, and fine to medium intergranular sand and precipitated carbonate cement.	3.6
Tb-3	Sandstone, light-pink to maroon, medium to coarse, poorly sorted, subangular, chert and frosted quartz grains, with few pebble to cobble-size grains of maroon siltstone, gray limestone, chert and trace of metavolcanic sediments, calcareous.	6.2
Tb-2	Conglomerate, light-pink to maroon, pebble to boulder-size clasts of brick-red siltstone, gray limestone, metavolcanic sediments, poorly indurated, crumbly, soft, with intergranular precipitated carbonate cement partially filling pore throats with a radial axial texture.	36.2
	Broken by Faulting	
Tb-1	Shale, light-pink to brick-red, poorly indurated, crumbly, soft, calcareous, thin lenses of pebble conglomerate, light gray to blue-green bleach spots.	30.0
	Total	127.0
	Angular Unconformity	
Mesaverde Group-	(Section measured in the N.W./4 S.E./4 sec. 9, and N.W./4 N.W./4 sec. 16, T.5S., R.2E.) (uppermost beds covered by younger Tertiary deposits)	
Kmv-10	Coal, black, highly fractured.	0.5
Kmv-9	Mudstone, brown to tan, shaly, carbonaceous, slight platy cleavage, crumbly soft.	2.5
Kmv-8	Coal, black, shiny luster, no observable physical impurities, vertical joint pattern.	3.2
Kmv-7	Mudstone, brown, shaly, carbonaceous, poorly indurated, crumbly soft.	0.3
Kmv-6	Coal, black, shiny luster, highly fractured.	1.5
Kmv-5	Shale, light gray to tan, soft, crumbly, limonite concretions, sandy and carbonaceous	17.0

at the top.

Kmv-4	Sandstone, buff fresh, buff and tan weathered, medium to coarse, moderate to poorly sorted, subround to subangular, frosted quartz grains, trace of glauconite (?), hematite intergranular stain, rind halos, and concretions, ripple marks and mudcracks, calcareous.	22.5
Kmv-3	Shale, green-gray fresh, buff weathered, with thin-interbeds of carbonaceous mudstone, crumbly soft, slight platy cleavage, and hematite stain.	7.0
Kmv-2	Sandstone, buff, fine to medium, poorly sorted, with interlayers of hematite concretion and box work material, poorly indurated, crumbly, soft, and calcareous.	3.5
Kmv-1	Sandstone, buff fresh, buff to tan weathered, medium, subround to subangular, moderate to poorly sorted, frosted quartz grains, with abundant hematite concretions.	2.8
	Total	60.83

Mancos Shale-(Section measured in the S.E./4 sec. 8, and the N.W./4 N.W./4 of sec. 16, T.5S., R.2E.)

Conformity

D-Cross Shale Tongue

Kmu-4	Mudstone, Tan fresh, buff weathered, shaly, sandy at top, crumbly, soft, calcareous.	8.0
Kmu-3	Shale, buff to tan, interbedded with thin sandstone stringers (1-2 inches thick).	3.0
Kmu-2	Sandstone, buff to tan fresh, brown to tan weathered, fine to medium, moderately sorted, subangular, frosted and translucent quartz, white chert, and hematite grains, poorly indurated, crumbly, soft, calcareous.	1.5
Kmu-1	Shale, dark gray to black fresh, light gray weathered, platy cleavage, hematite concretions and calcareous concretions with cone in cone structure, pelecypod fossil material, fractures filled with gypsum, noncalcareous at the base, upper 250 feet calcareous, sandy in the middle, mudcracks on bedding surfaces.	287.5
	Total	300.0

Conformity

Tres Hermanos Sandstone Member

Kms-34	Sandstone, green-brown fresh, dark-brown weathered, fine to medium, subangular, poorly sorted, frosted quartz and white chert grains, calcareous, burrows, ripple marks, mudcracks.	9.5
Kms-33	Sandstone, buff, fine to medium, subangular, poorly sorted, frosted and translucent quartz and white chert grains, burrows, ripple marks.	2.5

Kms-32	Sandstone, buff fresh, buff to tan weathered, fine to coarse, poorly sorted, crumbly, soft.	5.0
Kms-31	Sandstone, white to buff fresh, buff to brown weathered, medium subangular, moderately sorted, translucent and frosted quartz, hematite rind halos, thin-bedded, hard, brittle, calcareous, burrows, ripple marks, pelecypod fossil material.	6.0
Kms-30	Sandstone, dark-brown fresh, buff to dark brown weathered, interbedded with siltstone, crumbly, soft, poorly indurated, calcareous, hematite concretions, and fossiliferous (pelecypods and cephalopods).	17.7
Kms-29	Sandstone, buff to tan, medium, moderate sorting, subangular, frosted and translucent quartz, chert, trace of glauconite (?), crumbly, soft, very thick-bedded, massive cliff former, hematite stain and concretions, mudcracks, burrows, abundant coiled cephalopods and pelecypod fossils and casts.	18.5
Kms-28	Shale, buff and light gray, basal 28.7 feet shaly mudstone, top 10 feet sandy shale.	37.2
Kms-27	Shale, buff to green-brown, interbedded with siltstone, mudcracks, burrows, manganese oxide stain (desert varnish).	10.5
Kms-26	Sandstone, buff, maroon, and brown varicolored, medium to coarse, moderate to poorly sorted, translucent and frosted quartz and white chert grains, crossbedded, calcareous, hematite rind halos and concretions, silicified petrified wood.	7.1
Kms-25	Shale, light gray fresh, buff to tan weathered, poorly indurated, brittle, very soft, slightly calcareous.	4.0
Kms-24	Sandstone, tan fresh, buff to tan weathered, moderately sorted, hard, crumbly, mudcracks, burrows, desert varnish.	3.0
Kms-23	Mudstone, gray to brown fresh, buff to tan weathered, poorly indurated, crumbly, soft.	10.5
Kms-22	Sandstone, dark-brown, fine, moderate sorting, chert, mica, burrows, mudcracks, hematite and manganese oxide stain.	1.6
Kms-21	Shale, tan fresh, maroon, purple, and tan weathered, crumbly soft, hematite stain.	5.0
Kms-20	Sandstone, tan, fine to medium, poorly sorted, translucent and frosted quartz grains, thin-bedded, hematite concretions, mudcracks, burrows, conglomerate lenses at top containing pebble-size grains of tan mudstone and siltstone.	13.6
Kms-19	Sandstone, tan fresh, dark-brown weathered, fine to coarse, moderate to poorly sorted,	6.1

	crossbedded, massive cliff former, calcareous, conglomerate lenses with pebble size clasts of gray and tan mudstone.	
Kms-18	Shale, tan fresh, buff weathered, soft, brittle, carbonaceous, hematite stain.	6.4
Kms-17	Sandstone, tan fresh, tan to brown weathered, subangular, poorly sorted, frosted quartz and chert grains, with few pebble clasts of gray and tan mudstone, hematite stain, calcareous.	3.2
Kms-16	Mudstone, gray and tan, poorly indurated.	9.0
Kms-15	Sandstone, buff to gray fresh, tan weathered, medium, subangular, moderately sorted, translucent and frosted quartz, trace of chert and glauconite (?) grains, crossbedded, soft, crumbly, nodular hematite concretions, burrows, ripple marks.	2.6
Kms-14	Shale, tan fresh, buff weathered, sandy, poorly indurated, crumbly, soft, calcareous.	4.0
Kms-13	Sandstone, red, tan, and brown varicolored, medium, subrounded, moderately sorted, frosted quartz, trace of chert and glauconite(?), poorly indurated, hematite stain and concretions.	3.6
Kms-12	Sandstone, green-gray fresh, buff to tan weathered, fine to medium, subangular, moderately sorted, translucent quartz, and trace of glauconite (?) grains, crossbedded, hematite rind halos, mudcracks, burrows.	22.7
Kms-11	Sandstone, tan fresh, buff to tan weathered, fine to medium, moderate to poorly sorted grains, thin-crossbed sets, mudcracks, burrows, hematite stain and concretions, and few small pelecypod fossils.	15.4
Kms-10	Shale, dark gray fresh, tan and gray weathered, sandy, crumbly, soft, hematite stain.	4.6
Kms-9	Limestone, dark gray fresh, dark-brown weathered, sandy, laterally discontinuous, thin discontinuous lenses of pelecypod material.	1.6
Kms-8	Shale, tan fresh, buff to tan weathered, crumbly, soft, brittle.	4.3
Kms-7	Sandstone, olive-green fresh, tan to brown weathered, subround to subangular, moderately sorted, frosted quartz grains, crossbedded, calcareous.	2.7
Kms-6	Shale, tan fresh, gray to buff weathered, sandy, brittle, soft, hematite stain.	10.8
Kms-5	Sandstone, tan fresh, brown and tan weathered, fine, subangular, moderately sorted grains, abundant fossils (pelecypods and cephalopods).	3.7
Kms-4	Sandstone, tan fresh, tan to brown weathered,	6.5

	fine to medium, subround, moderately sorted grains, crossbedded, mudcracks, calcareous.	
Kms-3	Limestone, dark-brown and gray fresh, tan and dark-brown weathered, thinly-bedded with lenses of fossiliferous (pelecypods) sandstone, shell layers laterally discontinuous.	2.2
Kms-2	Shale, brown fresh, tan weathered, sandy, poorly indurated, crumbly, soft.	1.0
Kms-1	Sandstone, tan fresh, buff to tan weathered, fine, moderately sorted, subround grains, crossbedding, frosted quartz, mica flakes, burrows, mudcracks.	2.5
	Total	264.6

Conformity

Lower Shale Tongue

Kml-22	Shale, buff to gray and tan, platy cleavage, poorly indurated, crumbly, soft, hematite concretions.	34.0
Kml-21	Shale, light gray, thinly-bedded, fissile, platy cleavage, poorly indurated, crumbly, soft, hematite concretions.	70.0
Kml-20	Sandstone, shale, and limestone, buff to tan, thinly-interbedded, limonite stain, fossiliferous (pelecypods), burrows, leaf prints.	9.0
Kml-19	Shale, black fresh, gray weathered, thinly bedded, fissile, platy cleavage, crumbly, soft, calcareous.	32.5
Kml-18	Shale, tan to brown fresh, buff weathered, platy cleavage, crumbly, soft, calcareous.	6.5
Kml-17	Sandstone, shale, and limestone, buff to tan, thinly-interbedded, hematite stain, carbonaceous and fossiliferous (pelecypods).	5.5
Kml-16	Shale, dark gray to black fresh, gray weathered, platy cleavage, crumbly, soft, calcareous.	36.5
Kml-15	Limestone, dark gray to black fresh, tan to buff weathered, hard, brittle, hematite stain, mudcracks, few fossils (pelecypods and cephalopods).	1.5
Kml-14	Shale, dark gray and black fresh, light gray weathered, crumbly, soft, platy cleavage, calcareous.	2.6
Kml-13	Limestone, dark gray fresh, buff to tan weathered, very hard, crumbly, fractures filled with white blocky calcite, mudcracks, abundant small pelecypods.	1.0
Kml-12	Shale, dark gray to black fresh, light and dark gray weathered, soft, brittle, fissile, platy cleavage, hematite concretions, calcareous.	44.0
Kml-11	Siltstone, light gray, soft, crumbly, calcareous.	0.5

Kml-10	Shale, dark gray to black fresh, light gray weathered, fissile, platy cleavage, hematite concretions, calcareous.	97.0
Kml-9	Sandstone, dark gray fresh, tan to brown weathered, very fine, moderately sorted grains, thinly-bedded, hematite concretions, burrows, load casts, calcareous.	1.0
Kml-8	Shale, dark gray to black fresh, light gray weathered, platy cleavage, crumbly, soft, gypsum crystals, hematite concretions, thin horizontal calcareous partings every 5-feet.	30.0
Kml-7	Shale, dark gray to black, siltstone, buff to tan, thinly-interbedded, hematite stain and concretions, load casts, burrows, fossiliferous (pelecypods).	15.3
Kml-6	Shale, black fresh, light to dark gray weathered, platy cleavage, soft, brittle, calcareous partings (1/4 to 1 inch thick) parallel to bedding, hematite concretions, calcareous.	8.2
Kml-5	Siltstone, shale, and limestone, brown and gray fresh, buff to tan weathered, thinly interbedded, hematite nodular concretions, burrows, fossiliferous (pelecypods), calcareous.	18.5
Kml-4	Mudstone, dark gray to black fresh, buff to gray weathered, shaly, fissile, platy cleavage, hematite stain, soft, calcareous.	9.2
Kml-3	Siltstone and shale, buff to tan, thinly interbedded, blocky calcite partings (1/4 to 1 inch thick).	1.3
Kml-2	Mudstone, tan fresh, buff to gray weathered, fissile, platy cleavage, brittle, soft, calcareous.	5.7
Kml-1	Siltstone and shale, brown fresh, buff to tan weathered, thickly-laminated and interbedded (1/16 to 1/2 inch thick), shale and blocky calcite partings (1/8 inch thick), fossiliferous (pelecypods).	13.2
	Total	443.0

Conformity

Dakota Sandstone-(Section measured in the N.E./4 N.W./4, sec. 3, T.5S., R.2E.)

Kd-9	Sandstone, buff to gray and white fresh, buff to tan weathered, fine to medium, rounded, well-sorted, translucent quartz and trace of chert grains, conglomerate lenses with pebble size clasts of white and black chert at the top, well silicified, crossbedded, hematite stain, desert varnish, burrows, ripple marks.	7.2
Kd-8	Sandstone, buff to white fresh, buff to tan and white weathered, medium, rounded, well sorted frosted quartz grains, crossbedded,	10.0

	poorly indurated, crumbly, hard, rind halos, speckles and nodular concretions of hematite, fractures filled with white silica, ripple marks, mudcracks.	
Kd-7	Siltstone, dark-green, fresh, dark-brown, tan, and buff weathered, poorly sorted, silicified, very hard, brittle, hematite stain and box work, desert varnish, mudcracks.	3.1
Kd-6	Shale, dark gray to black fresh, light gray weathered, crumbly, soft, platy cleavage, fissile, slightly calcareous.	7.0
Kd-5	Siltstone, dark-green fresh, dark-brown, black, and olive-green weathered, moderately sorted, silicified, hard, brittle, well indurated, fractured, soft sediment deformation, desert varnish.	4.5
Kd-4	Mudstone, dark-brown to maroon fresh, gray to tan weathered, poorly indurated, crumbly, soft, calcareous.	6.2
Kd-3	Sandstone, green to brown fresh, dark-brown, olive-green, tan, and pink varicolored weathered, medium to silt-clay size, very poorly-sorted, silicified, well-indurated, hard, brittle, hematite stain.	3.0
Kd-2	Sandstone, white to tan fresh, tan to orange brown weathered, massive bedded cliff former, medium, rounded, well-sorted, frosted quartz grains with minor amounts of intergranular white, silt and clay-size material, crossbedded, limonite stain and speckles and nodular concretions of hematite, few quartz and chert pebbles floating in sandstone at top of bed, burrows, ripple marks.	22.3
Kd-1	Mudstone, light gray, buff, tan, brick-red, varicolored, shaly, gypsiferous, platy cleavage, contains small pebbles of chert, shale and siltstone, hematite and limonite rind halos of stain.	3.7
	Total	67.0

Unconformity

Dockum Group

Chinle Formation-(Section measured in the N.W./4 sec. 5, T.4S., R.2E.)

Trc-28	Shale, maroon and purple, erosional contact with overlying Dakota Sandstone, poorly indurated, calcareous concretions, white to green-gray bleach spots.	95.0
Trc-27	Conglomerate, dark-brown to maroon, pebble size clasts of sandstone, siltstone, and limestone, laterally discontinuous, crumbly, soft, calcareous.	1.5
Trc-26	Sandstone, white to light gray fresh, buff to	13.0

	maroon weathered, medium, moderately sorted, subangular, translucent quartz, chert, and feldspar grains, mudcracks, ripple marks, laterally discontinuous thin lens of pebble conglomerate at top.	
Trc-25	Conglomerate, dark-brown to maroon, pebble size clasts of gray sandstone, siltstone, and limestone, laterally discontinuous, poorly indurated, crumbly, soft, calcareous.	5.7
Trc-24	Sandstone and siltstone, white and maroon, thinly-interbedded, crossbedded.	6.0
Trc-23	Shale, maroon and purple, pebble to boulder size calcareous concretions, poorly indurated, laterally discontinuous.	5.0
Trc-22	Siltstone and shale, maroon to purple, interbedded, fractured, brittle, soft.	3.5
Trc-21	Mudstone, dark-brown, brittle, soft, poorly indurated, highly fractured.	5.0
Trc-20	Sandstone, dark gray fresh, maroon to dark brown weathered, fine to medium, moderate to poorly-sorted, well-indurated grains, hard, brittle, fractured.	3.0
Trc-19	Shale and siltstone, dark gray fresh, maroon to purple weathered, interbedded, crumbly, soft, concretions, fractured, calcareous.	10.0
Trc-18	Sandstone, gray fresh, maroon and purple weathered, medium, moderately sorted, subangular grains, frosted quartz, crossbedded, thin to medium-bedded, interbedded, conglomerate lenses 2-3 inches thick).	12.5
Trc-17	Shale, maroon fresh, purple weathered, sandy at top, poorly indurated, calcareous concretions, light gray bleach spots, calcareous.	105.0
Trc-16	Sandstone, dark gray fresh, brown to purple weathered, fine, moderately sorted, subround to subangular, translucent quartz and trace of chert grains, crossbedded, light gray bleach spots, calcareous.	4.0
Trc-15	Shale, maroon, unconsolidated, calcareous concretions.	4.0
Trc-14	Sandstone, dark gray fresh, buff and maroon weathered, fine to medium, moderately sorted, subrounded, translucent quartz, chert and feldspar grains, crossbedded, well-indurated, hard, brittle, ripple marks, calcareous.	3.7
Trc-13	Shale, maroon, poorly indurated, localized sandstone and mudstone lenses (1/2 inch thick), calcareous concretions parallel to bedding.	15.7
Trc-12	Sandstone, maroon and gray, fine to medium, subangular to subround, moderate to poorly	6.5

	sorted, frosted quartz, feldspar, trace of chert, highly fractured, few lithic fragments of maroon shale, white to light gray bleach spots.	
Trc-11	Conglomerate, gray and maroon, pebble-size clasts of gray limestone and maroon and purple siltstone, and shale, laterally discontinuous.	3.3
Trc-10	Shale, dark-brown to maroon fresh, purple weathered, unconsolidated, few concretions, calcareous.	15.0
Trc-9	Shale, maroon and purple, very thinly bedded, platy cleavage, brittle, soft, light gray to blue-green bleach spots.	10.0
Trc-8	Shale, maroon fresh, purple weathered, crumbly, soft, calcareous concretions, light gray bleach spots, highly fractured.	8.7
Trc-7	Conglomerate, maroon and dark gray, pebble size clasts of gray limestone and maroon shale, interbedded in sandstone with coarse, poorly sorted, subangular, frosted quartz, white chert, and pink feldspar grains, well indurated, hard, brittle.	7.5
Trc-6	Shale, dark brown to maroon fresh, purple weathered, unconsolidated, few concretions, calcareous.	40.0
Trc-5	Shale, purple and dark gray, very hard and brittle, calcareous concretions with light gray to buff bleach halos, highly fractured.	4.5
Trc-4	Shale, maroon and purple, also gray, buff and tan, interbedded mudstone stringers, poorly indurated, nodular calcareous concretions, light gray and blue-green bleach spots.	102.2
Trc-3	Conglomerate, green-gray to maroon fresh, dark-brown to maroon weathered, pebble-size clasts of gray and green limestone, calcareous concretions, and circular limestone cobbles.	35.0
Trc-2	Conglomerate, green-gray and maroon fresh, dark-brown to maroon weathered, pebble-size clasts of green-gray limestone, well indurated, brittle, hard, calcareous.	1.5
Trc-1	Shale, light gray and purple, unconsolidated, crumbly, soft, trace of gypsum crystals, abundant calcareous concretions parallel to bedding.	14.2
		Total 541.0

Conformity

Santa Rosa Sandstone-(Section measured in the N.E./4 S.E./4, sec. 27, T.4S., R.2E., and in the S.E./4 S.E./4, sec. 5, T.5S., R.2E.)

Trs-38	Conglomerate, brown and maroon fresh, tan to gray weathered, rounded, pebble to cobble	23.0

size clasts of black, white, and yellow chert, white quartz, and varicolored agate, poorly indurated, crumbly, soft, intergranular and interbedded stringers of medium to coarse, moderately sorted, subrounded sand grains, massive bedded, cliff former lenticular shape, laterally discontinuous, limonite and hematite stain.

Trs-37	Sandstone, gray fresh, tan to maroon weathered, coarse, subangular, poorly sorted, translucent quartz, chert, glauconite (?), dark mica grains, grades laterally into conglomerate with pebble to cobble-size chert and quartz grains.	2.5
Trs-36	Conglomerate, gray and maroon fresh, buff to tan weathered, cobbles of black and pink chert, white quartz, and varicolored agate, laterally discontinuous.	1.5
Trs-35	Sandstone, maroon to dark brown, fine to medium, subrounded, poorly sorted, frosted quartz, mica, chert, well-indurated, soft, brittle, crossbedded, calcareous.	15.0
Trs-34	Sandstone, green-gray fresh, tan to green brown weathered, subrounded grains, moderately sorted, well-indurated, very hard and brittle, limonite stain.	3.0
Trs-33	Shale, maroon to purple, poorly indurated, crumbly, soft, trace of mica, calcareous.	2.5
Trs-32	Sandstone, gray to maroon fresh, maroon to purple weathered, fine to medium, subround, moderately sorted, translucent quartz, chert, and trace of mica and glauconite (?) grains, crossbedded, mudcracks.	12.0
Trs-31	Sandstone, light gray to buff fresh, buff to tan weathered, fine to medium, subround, moderate to poorly sorted, translucent and frosted quartz, trace of chert and mica, crossbedded, brittle, soft, hematite stain, silicified petrified wood.	8.8
Trs-30	Conglomerate, red-brown, pebbles of black, green, and white chert, gray and maroon mudstone and shale, pink feldspar, well indurated, hard, brittle, laterally discontinuous, limonite stain.	2.6
Trs-29	Sandstone, light gray to white fresh, buff to tan weathered, coarse, subround, moderately sorted, frosted quartz, chert, mica, and hematite grains, crossbedded, hematite and limonite stain.	23.0
Trs-28	Conglomerate, buff to pink fresh, tan to brown weathered, frosted quartz and chert sand, with pebbles of yellow, white, and black chert, mudstone, and limestone,	3.0

	moderately indurated, limonite stain, calcareous.	
Trs-27	Mudstone, maroon, poorly indurated, crumbly, soft, calcareous.	2.0
Trs-26	Sandstone, tan fresh, tan to brown weathered, coarse, subangular, poorly sorted grains.	1.0
Trs-25	Mudstone, maroon, poorly indurated, crumbly, soft, calcareous.	2.0
Trs-24	Sandstone, light gray fresh, buff to tan weathered, medium to coarse, poorly sorted, chert, frosted quartz, white feldspar, and hematite grains, poorly sorted, crossbedded, interbedded with cobble conglomerate lenses at the top.	11.0
Trs-23	Sandstone, tan to light gray fresh, buff to tan and purple weathered, coarse, subround, moderately sorted, frosted quartz, chert, white feldspar, and glauconite (?) grains, well-indurated, hard, brittle, crossbedded, rind halos of hematite stain.	8.5
Trs-22	Mudstone, maroon, poorly indurated, crumbly, soft, calcareous.	6.5
Trs-21	Sandstone, maroon fresh, brown to maroon weathered, medium to coarse, subangular, poorly sorted, translucent and frosted quartz, chert, white feldspar, and glauconite (?) grains, moderately indurated, hard, crumbly, slightly calcareous.	2.0
Trs-20	Shale, maroon, platy cleavage, crumbly, soft, light gray to blue-green bleach spots.	2.0
Trs-19	Sandstone, tan to light gray fresh, tan to buff weathered, coarse, subangular, poorly sorted, translucent smoky quartz, pink chert, white feldspar, glauconite (?) grains, hard, brittle, crossbedded, rind halos of hematite stain.	4.5
Trs-18	Shale, maroon, crumbly, soft, calcareous, interbedded with conglomerate, green-gray to maroon, containing pebble to cobble-size red brown siltstone, green and gray shale, and varicolored chert, well-indurated, hard, brittle, laterally discontinuous, calcareous.	9.5
Trs-17	Sandstone, green-gray fresh, gray and maroon weathered, medium to coarse, subround, moderately sorted, frosted quartz, white chert, mica, glauconite (?), crossbedded, calcareous.	2.5
Trs-16	Mudstone, maroon to brick-red, crumbly, soft, slight platy cleavage, calcareous, micaceous partings.	5.0
Trs-15	Sandstone, green-gray fresh, buff to light gray weathered, medium to coarse, subround to subangular, poorly sorted, frosted quartz,	6.6

	chert, white feldspar, mica, and glauconite (?), poorly indurated, crumbly, soft, crossbedded, calcareous.	
Trs-14	Siltstone, and shale, dark-brown fresh, maroon to brick-red weathered, thinly interbedded, poorly sorted (up to medium sand size), mudcracks, ripple marks, highly fractured, calcareous, light gray bleach spots.	15.0
Trs-13	Sandstone, maroon fresh, dark-brown weathered, fine to medium, poorly to moderate sorted, subangular, frosted quartz, chert, white feldspar, trace of mica, light gray bleach spots.	1.0
Trs-12	Shale, maroon, poorly indurated, platy cleavage, crumbly, soft, calcareous.	2.5
Trs-11	Sandstone, maroon and gray fresh, brick-red and gray weathered, fine to medium, poorly sorted, subround to subangular, frosted and translucent quartz, chert, mica, and glauconite (?) grains, calcareous.	5.0
Trs-10	Sandstone, light gray to buff fresh, tan and maroon weathered, fine to medium, poorly sorted, subrounded, frosted quartz, chert, and mica grains, moderately indurated, hard, crumbly, crossbedded, rind halos of hematite stain.	6.0
Trs-9	Sandstone, light gray fresh, buff weathered, fine to coarse, subround, poorly sorted, frosted quartz, chert, mica, and glauconite (?) grains, crossbedded, calcareous.	5.0
Trs-8	Shale, dark-brown fresh, maroon weathered, sandy, fine, rounded, quartz, chert, and mica, crumbly, soft, calcareous.	5.0
Trs-7	Siltstone and interbedded shale, dark-brown fresh, maroon weathered, crumbly, soft, platy cleavage, crossbedded, micaceous, ripple marks, mudcracks, light gray bleach spots, calcareous.	10.0
Trs-6	Shale, dark-brown fresh, maroon weathered, sandy, rounded, frosted quartz and white chert, poorly sorted, platy cleavage, soft, crumbly, micaceous, calcareous.	6.5
Trs-5	Sandstone, maroon and gray fresh, red-brown to gray weathered, fine to medium, round, moderately sorted, frosted quartz, chert, white feldspar, mica, light-blue-gray bleach spots, mudcracks, calcareous.	2.0
Trs-4	Siltstone and interbedded shale, dark-brown fresh, maroon weathered, moderate to poorly sorted, very thin (1/4-1 inch thick) bedded, slightly calcareous.	5.0
Trs-3	Sandstone, dark-brown fresh, maroon	2.0

weathered, fine to medium, subround, moderately sorted, frosted quartz, chert, mica, grains, thickly laminated shale partings (1/4-1/2 inches thick) at top, slightly calcareous.

Trs-2	Shale, maroon fresh, dark-brown to maroon weathered, hard, brittle, blue-green to light gray bleach spots, micaceous, interbedded with poorly sorted siltstone, mudcracks.	8.0
Trs-1	Conglomerate, varicolored, buff, brown, and gray to purple, pebble-size clasts of tan mudstone and red siltstone, laterally discontinuous, intertongues with sandstone, brown to gray fresh, maroon weathered, fine to medium, poorly sorted, well-indurated, hard, brittle, rind halos of hematite stain, calcareous.	3.0
	Total	236.0

Disconformity

Bernal Formation-(Section measured in the S.W./4 S.W./4 sec. 4, T.4S., R.2E.)

Pb-25	Sandstone, buff fresh, buff to tan weathered, fine to medium, subround, moderate to poorly sorted, frosted quartz, trace of glauconite (?) and biotite, hematite stain, calcareous.	1.0
Pb-24	Mudstone, green-brown fresh, buff to light gray weathered, thinly laminated (1/16 inch thick), soft, brittle.	4.5
Pb-23	Sandstone, tan fresh, buff and tan weathered, fine to coarse, poorly sorted grains, thin interbedded streaks of mudstone, hematite stain, calcareous.	1.0
Pb-22	Mudstone, olive-green fresh, buff to light gray weathered, brittle, moderately indurated.	3.0
Pb-21	Sandstone, buff fresh, buff to brown weathered, fine to medium, subround, poorly sorted grains, thin, laterally discontinuous crossbeds, hematite stain, mudcracks, calcareous.	1.0
Pb-20	Mudstone, olive-green fresh, buff weathered, brittle, soft, laterally discontinuous.	3.4
Pb-19	Sandstone, buff to light-brown fresh, tan weathered, medium, moderately sorted, subangular, frosted quartz grains, thin crossbed sets, calcareous.	5.5
Pb-18	Mudstone, tan fresh, tan and light gray weathered, crumbly, soft, hematite stain, calcareous.	3.0
Pb-17	Sandstone, light-brown fresh, buff and tan weathered, medium, moderately sorted, subrounded, frosted quartz, mica, white	7.4

	feldspar, and hematite grains, very thinly (1/2 inch thick) crossbedded, crumbly, soft, mudcracks, slightly calcareous.	
Pb-16	Mudstone, olive-green fresh, buff and light gray weathered, poorly indurated, crumbly, soft, sandy at top, micaceous, hematite stain, calcareous.	7.0
Pb-15	Sandstone, light-brown fresh, buff and tan weathered, medium, poorly sorted, subangular, frosted quartz, pink feldspar, and mica grains, thickly (1/4 inch thick) laminated bedding, hematite stain, mudcracks, calcareous.	2.0
Pb-14	Mudstone, olive-green fresh, buff to light gray weathered, poorly indurated, crumbly, soft, sandy at top, micaceous, hematite stain, calcareous.	3.6
Pb-13	Sandstone, light-brown fresh, buff and tan weathered, fine to medium, poorly sorted grains, laterally discontinuous, micaceous, hematite stain, mudcracks, calcareous.	0.5
Pb-12	Mudstone, tan fresh, buff to light gray weathered, crumbly, soft, slight platy cleavage, micaceous, calcareous.	5.0
Pb-11	Shale, maroon, and siltstone, brick-red, color grades to buff and tan locally, interbedded, light gray bleach spots, mudcracks, calcareous.	12.0
Pb-10	Conglomerate, red-brown fresh, brick-red weathered, silty, poorly sorted with cobble size clasts of red-brown siltstone, laterally discontinuous, calcareous.	0.5
Pb-9	Siltstone, maroon to red-brown fresh, brick-red weathered, moderately sorted, moderately indurated, hard, crumbly, mica flakes, blue green bleach spots, calcareous.	1.5
Pb-8	Siltstone, red-brown fresh, maroon to brick-red weathered, well-indurated, hard, brittle, blue-green bleach spots, mudcracks, calcareous.	0.5
Pb-7	Siltstone, red-brown and tan fresh, brick-red to tan weathered, poorly sorted, thickly laminated (1/4 inch thick), mica flakes, laterally discontinuous, calcareous.	2.5
Pb-6	Sandstone, tan, fresh, buff to tan and red brown weathered, fine to medium, poorly sorted grains, poorly indurated, hard, crumbly, hematite stain, mudcracks, burrows.	2.0
Pb-5	Siltstone and shale, red-brown and brown fresh, brick-red and tan weathered, interbedded, moderately indurated, hard, crumbly, mica flakes, blue-green to light gray bleach spots, salt casts, mudcracks,	13.5

	calcareous.	
Pb-4	Siltstone, maroon to red-brown fresh, brick red and tan weathered, well-indurated, hard, crumbly, mica flakes, light gray bleach spots, mudcracks, calcareous.	2.1
Pb-3	Mudstone, maroon fresh, maroon to brick-red weathered, interbedded with siltstone, brick red, light gray bleach spots, soft, crumbly, calcareous.	4.1
Pb-2	Siltstone, red-brown fresh, brick-red weathered, moderately indurated, crumbly, soft, mudcracks, green blue to light gray bleach spots, calcareous.	7.5
Pb-1	Mudstone, buff to gray fresh, tan weathered, poorly indurated, crumbly, soft, platy cleavage, laterally discontinuous, calcareous.	4.8
	Total	99.0

Unconformity

San Andres Formation-(Section measured in the S.E./4 sec. 22, N.W./4 N.W./4 sec. 28, S.E./4 S.E./4 sec. 21, T.4S., R.2E., and in the S.W./4 sec. 4, T.5S., R.2E.) (Maximum thickness measured at upper contact with Bernal Formation and at lower contact with Glorieta Sandstone Member)

Upper Gypsum Member

Psu-5	Siltstone, gypsiferous, brick-red, recrystallized crystals of gypsum surrounded by silt and clay.	1.0
Psu-4	Gypsum, white, laterally discontinuous, grades into limestone breccia with large, angular, boulder-size blocks of tan mudstone, dark gray gypsiferous limestone, with interbedded sandstone lenses containing medium to coarse, subround, frosted quartz sand, large vug to cavern size cavities filled with precipitated carbonate.	37.0
Psu-3	Mudstone, tan, poorly indurated, gypsiferous, hematite stain, calcareous.	1.5
Psu-2	Gypsum, white, thickly laminated, alternating light and dark layers (1/4 to 1/2 inch thick) at base.	4.0
Psu-1	Mudstone, tan fresh, buff to tan weathered, gypsiferous, poorly indurated, micaceous, hematite stain, calcareous.	5.5
	Total	49.0

Conformity

Limestone Member

Psa-31	Limestone, gray, recrystallized, box work honey-comb texture, high porosity, soft sediment deformation, limonite stain.	1.0

Psa-30	Mudstone, tan fresh, buff to light gray weathered, crumbly, soft, highly fractured, slightly calcareous.	5.0
Psa-29	Limestone, buff to gray fresh, gray weathered, thinly bedded, soft sediment deformation, vuggy porosity, desert varnish, hematite stain, mudcracks, highly fractured.	1.5
Psa-28	Siltstone, buff fresh, buff to tan weathered, with interbedded mudstone, tan, sandy, calcareous.	4.5
Psa-27	Limestone, gray fresh, light gray weathered, brittle, hard, recrystallized, ripple marks, abundant calcite filled fractures, solution cavities.	3.0
Psa-26	Limestone, black fresh, gray, brown and black weathered, recrystallized, desert varnish coating silica residue on weathered surfaces.	6.0
Psa-25	Mudstone, tan and white fresh, buff to tan weathered, sandy, fine, moderately sorted, subround, frosted quartz grains, calcareous.	4.5
Psa-24	Limestone, dark-green to gray fresh, light green to gray weathered, sandy, fossiliferous (brachiopods, ostracods), hard, crumbly, silica residue with desert varnish coating on weathered surfaces, grades laterally into limestone breccia, mudcracks.	3.8
Psa-23	Limestone, gray, black, and brown fresh, light gray weathered, thinly (1-2 inches thick) bedded, caliche on weathered surfaces, mudcracks, fossiliferous (algae, brachiopods, crinoid columnals, gastropods, rugosids), fetid.	24.6
Psa-22	Limestone breccia at base, black fresh, light gray to gray weathered, with angular cobble to boulder-size blocks of gray limestone, grading upward into thinly bedded, black limestone, crumbly, brittle, fossiliferous (brachiopods, ooids, algae) fetid.	10.5
Psa-21	Mudstone, buff fresh, tan, gray, and white weathered, contains cobble-size clasts of gray limestone, calcareous.	1.0
Psa-20	Limestone, gray to tan fresh, light gray weathered, massive bedding, recrystallized, vuggy porosity, sandy, fossiliferous (brachiopods, algae, ooids, crinoid columnals), tan to buff, angular lithic fragments of tan mudstone and siltstone and gray limestone at the top.	4.6
Psa-19	Limestone, gray fresh, light gray weathered, thin (1/2-2 inches thick) bedding, interbedded with thinly (1/16-1/8 inch thick) laminated, tan to buff mudstone and shale partings, few brachiopods.	8.5
Psa-18	Limestone, dark gray to black fresh, light	3.5

	gray weathered, massive bedding, brittle, soft, fossiliferous (brachiopods, ooids), recrystallized.	
Psa-17	Mudstone, tan fresh, tan and purple weathered, platy cleavage, soft sediment deformation, crumbly, soft, fractured, mudcracks, calcareous.	1.0
Psa-16	Limestone breccia, gray and tan fresh, gray to red-brown weathered, pebble to boulder size angular fragments of light gray limestone with white intergranular and localized patches of fine to silt size-sand, hematite and limonite stain, grades laterally into thinly bedded, massive, gray, limestone.	7.0
Psa-15	Mudstone, tan fresh, buff to tan weathered, platy cleavage, crumbly, soft, localized vugs of precipitated, white, carbonate.	1.0
Psa-14	Limestone, dark gray to black fresh, gray weathered, recrystallized, laterally discontinuous, localized clasts of limestone and tan, fine to medium, moderately sorted, detrital sand, fossiliferous (brachiopods, crinoid columnals).	4.6
Psa-13	Limestone, black fresh, dark gray to black weathered, hard, brittle, massive bedding, highly fractured, fossiliferous (brachiopods and ooids), fetid.	10.0
Psa-12	Limestone, tan to gray fresh, dark gray to tan weathered, massive bedded at top, highly fractured, limestone breccia at base, mudcracks, ripple marks, fossiliferous (brachiopods, algae, crinoid columnals, gastropods), fetid.	24.0
Psa-11	Limestone, black fresh, dark gray weathered, thinly bedded, fossiliferous (brachiopods), fetid.	10.0
Psa-10	Sandstone, white to light gray fresh, buff, tan and pink weathered, medium, rounded, very well-sorted, translucent quartz grains, hematite stain, laterally discontinuous, calcareous.	6.0
Psa-9	Limestone breccia, black and gray, variable thickness, chaotic oriented blocks of limestone, fossiliferous (brachiopods, gastropods), grades laterally into thin bedded, black, fossiliferous limestone.	33.5
Psa-8	Limestone, dark gray fresh, brown to gray weathered, dissolution cavities, abundant fractures filled with white carbonate.	9.0
Psa-7	Limestone, gray fresh, gray to brown weathered, sandy (30%), medium, well-sorted, rounded, frosted quartz grains, mudcracks.	4.1
Psa-6	Limestone, black fresh, dark gray weathered,	8.9

	massive bedding, hard, brittle, carbonate filled fractures, fossiliferous (brachiopods, gastropods, crinoid columnals, algae), fetid.	
Psa-5	Limestone, maroon and black fresh, gray weathered, chert nodules and interlayers (1-3 inches thick), fossiliferous (brachiopods, algae, gastropods).	3.4
Psa-4	Limestone, black fresh, gray weathered, brittle, splintery, mudcracks, fetid.	5.0
Psa-3	Limestone, black to dark gray fresh, gray weathered, lenticular shape, chert nodules, hard, brittle, splintery, fractured, fossiliferous at base, fetid.	3.1
Psa-2	Limestone, black fresh, dark-green weathered, locally silicified, brittle, fossiliferous (brachiopods, gastropods, algae), strongly fetid.	6.2
Psa-1	Limestone, dark gray to maroon fresh, light gray weathered, laterally discontinuous, locally silicified, soft, brittle.	2.0
	Total	222.0

Conformity

Glorieta Sandstone Member

Psg-15	Sandstone, tan to light gray and white fresh, pink to buff weathered, fine to medium, subround, moderately sorted, frosted and translucent quartz grains, trace of chert, crossbedded, laterally discontinuous, massive cliff former, ripple marks, calcareous.	25.5
Psg-14	Sandstone, tan fresh, buff, tan, and pink weathered, medium, rounded, well-sorted, translucent quartz grains, crossbedded, ripple marks, mudcracks.	8.5
Psg-13	Sandstone, tan to white fresh, buff to tan weathered, medium, well-sorted, subrounded, translucent quartz grains, chert, crossbedded, moderately indurated, hard, crumbly, ripple marks, mudcracks, calcareous.	7.5
Psg-12	Sandstone, buff to white fresh, buff, tan, and pink weathered, medium, rounded, very well-sorted, frosted quartz and pink chert grains, rind halos of hematite stain, crossbedded, calcareous.	3.5
Psg-11	Sandstone, tan fresh, pink, tan, and buff weathered, fine to medium, moderately sorted, rounded, translucent quartz grains, hematite stain, mudcracks, calcareous.	7.0
Psg-10	Sandstone, pink and white fresh, buff to pink weathered, medium, rounded, very well-sorted, translucent quartz and chert grains, cliff former, poorly indurated, hard, crumbly, mudcracks, ripple marks.	7.8
Psg-9	Sandstone, white fresh, buff, tan, and pink	16.0

	weathered, fine, subround, well-sorted, translucent quartz grains, poorly indurated, soft, crumbly, crossbedded, rind halos of hematite stain, mudcracks, calcareous.	
Psg-8	Sandstone, buff to tan fresh, pink to tan weathered, medium, subround, well-sorted, translucent quartz grains, poorly indurated, hard, crumbly, rind halos, speckles, and nodular concretions of hematite, laterally discontinuous, irregular crossbedding, mudcracks, calcareous.	13.7
Psg-7	Sandstone, white fresh, buff to white weathered, medium, rounded, well-sorted, translucent quartz grains, laterally discontinuous, lenticular shape, calcareous.	5.0
Psg-6	Sandstone, white fresh, buff to pink weathered, fine to medium, rounded, well sorted, translucent quartz, trace of chert grains, rind halos of hematite stain, localized fractures (1/2 inch wide) filled with white carbonate, calcareous.	4.3
Psg-5	Sandstone, white to light gray fresh, buff weathered, medium, rounded, well-sorted, frosted quartz grains, crossbedded, calcareous.	7.5
Psg-4	Sandstone, pink, fine, well-sorted grains, low-angle crossbeds, calcareous.	6.5
Psg-3	Sandstone, tan and pink, fine to medium, subround, moderately sorted, frosted quartz grains, trace of chert and clear mica, thin bedded, calcareous.	4.2
Psg-2	Sandstone, buff to tan fresh, buff to pink weathered, medium, moderately sorted, subrounded grains, thin bedding, hematite stain, calcareous.	4.3
Psg-1	Sandstone, light gray to white fresh, buff to white weathered, medium, subround, well sorted, translucent and few frosted quartz grains, trace of white and red chert, moderately indurated, hard, crumbly, low angle crossbeds, massive bedding, speckles and nodules of hematite stain, mudcracks, calcareous.	11.5
	Total	132.8

Conformity

Yeso Formation-(Section measured in the N./2 of sec. 20, N.W./4 N.W./4 sec. 21, and S.W./4 S.W./4 sec. 21, T.4S., R.2E.)

Joyita Sandstone Member

Pyj-33	Sandstone, buff to pink fresh, tan, brown, and pink weathered, medium, subround, moderately sorted, frosted quartz grains, white intergranular very fine silt to clay	5.0

	size material, very low-angle crossbedding, hematite nodular concretions, calcareous.	
Pyj-32	Sandstone, white to light gray fresh, buff to white weathered, fine to medium, moderate to poorly sorted, subrounded, frosted quartz grains, soft, crumbly, speckles and nodular concretions of hematite, calcareous.	19.5
Pyj-31	Sandstone, maroon and orange brown fresh, pink, tan, and brown weathered, fine to medium, moderate to poorly sorted, subangular, frosted quartz, trace of chert and clear mica grains, soft, crumbly, mudcracks, hematite concretions, calcareous.	4.5
Pyj-30	Sandstone, tan fresh, buff to gray weathered, silty, very fine grain, trace of mica, thinly bedded, crumbly, soft, calcareous.	6.0
Pyj-29	Sandstone, tan fresh, orange, brown, brick-red and tan varicolored weathered, medium, subround, moderately sorted, frosted quartz grains, trace of chert, thin bedding, hematite stain, calcareous.	2.3
Pyj-28	Sandstone, buff to tan fresh, brick-red, maroon, and tan weathered, medium, subround to subangular, moderately sorted, frosted and translucent quartz, trace of chert, massive bedding, speckles and nodular concretions of hematite, calcareous.	10.0
Pyj-27	Sandstone, gray to light-tan fresh, buff to tan weathered, fine to medium, moderately sorted, subround to subangular, frosted and translucent quartz grains, trace of chert, thin bedding, poorly indurated, crumbly, soft, few hematite nodules.	4.6
Pyj-26	Sandstone, pink, fine to medium, moderately sorted, subround, frosted quartz, white feldspar, and trace of chert grains, hematite nodular concretions, slightly calcareous.	7.0
Pyj-25	Sandstone, tan, fine, subround, moderately sorted, frosted quartz, chert, and white feldspar grains, hematite concretions.	4.0
Pyj-24	Sandstone, red-brown, fine to medium, subround, moderately sorted, frosted quartz, chert, and white feldspar grains, low-angle crossbeds, mudcracks, hematite concretions, slightly calcareous.	6.0
Pyj-23	Siltstone, tan fresh, buff to gray weathered, crumbly, soft, thinly laminated (1/16 inch thick), hematite stain.	1.5
Pyj-22	Sandstone, dark-brown to maroon fresh, buff, to tan and maroon weathered, fine to medium, subround, poorly sorted, frosted quartz, white feldspar, and chert, slightly calcareous.	2.0

Pyj-21	Sandstone, tan and gray, fine, subround, moderately sorted, frosted quartz grains, moderately indurated, soft, brittle.	3.6
Pyj-20	Sandstone, red-brown and tan fresh, buff to tan, pink, and orange weathered, fine to medium, subangular to subround, moderately sorted, frosted quartz, chert, white feldspar, and clear mica grains, convolute bedding, mudcracks, light gray bleach spots, hematite concretions.	9.2
Pyj-19	Mudstone, dark green-gray fresh, light gray to tan weathered, platy, thinly laminated, crumbly, soft.	2.7
Pyj-18	Shale, maroon fresh, brick-red weathered, sandy, poorly sorted, platy cleavage, poorly indurated, crumbly, soft.	2.6
Pyj-17	Sandstone, tan fresh, tan to brown and red weathered, fine to medium, subangular to subround, moderately sorted, frosted quartz, orange and white feldspar, and clear mica grains, mudcracks, calcareous.	2.0
Pyj-16	Siltstone, dark brown and gray fresh, gray and maroon weathered, poorly sorted, poorly indurated, crumbly, soft, thin bedding.	1.1
Pyj-15	Sandstone, pink and tan, fine to very fine, poorly sorted, trace of mica and chert, laterally discontinuos bedding, hematite stain, mudcracks.	4.0
Pyj-14	Sandstone, gray fresh, tan to gray weathered, moderately sorted, subangular, frosted quartz grains, trace of chert.	2.5
Pyj-13	Sandstone, green-gray fresh, buff to tan and red-brown weathered, fine to medium, subangular to subround, poorly sorted, frosted quartz, speckles of hematite stain, mudcracks.	1.2
Pyj-12	Sandstone, green-gray fresh, buff to gray weathered, gypsiferous, fine grain, poorly sorted, poorly indurated, crumbly, soft.	2.5
Pyj-11	Sandstone, gray and tan fresh, buff to tan weathered, fine to medium, subround, moderately sorted, frosted quartz grains, thin, laterally discontinuous bedding, rind halos of hematite stain, mudcracks.	5.8
Pyj-10	Sandstone, gray and buff, interbedded, fine grain, poorly sorted, crumbly, soft, trace of chert, speckles of hematite stain.	9.7
Pyj-9	Sandstone, light gray to pink fresh, buff to red weathered, fine, subround to subangular, moderate to poorly sorted, frosted quartz grains, laterally discontinuous crossbeds, crumbly, soft, hematite nodules, calcareous.	6.5
Pyj-8	Sandstone, light gray fresh, buff to gray	3.8

	weathered, fine to medium, subround, moderately sorted, frosted quartz grains, mudcracks, slightly calcareous.	
Pyj-7	Sandstone, tan fresh, buff to pink weathered, fine subangular, moderately sorted, frosted quartz, white and black chert, and clear mica grains, slightly calcareous.	3.9
Pyj-6	Siltstone, red-brown and gray, poorly sorted, crumbly, soft, fine grain quartz, chert and mica.	1.5
Pyj-5	Sandstone, buff to brick-red, medium, subround, moderately sorted, frosted and translucent quartz, chert, and hematite grains, well-indurated, crumbly, hard, slightly calcareous.	1.0
Pyj-4	Sandstone, red to tan fresh, brick-red weathered, fine to medium, subround, poorly sorted, frosted quartz and white feldspar grains, light gray bleach spots, slightly calcareous.	6.1
Pyj-3	Conglomerate, varicolored, maroon to gray, sandy, pebble- size clasts of siltstone and shale surrounded by fine to medium, subangular, poorly sorted, translucent quartz grains, calcareous.	0.8
Pyj-2	Shale, gray fresh, maroon weathered, platy cleavage, thin calcite layers (1/8 inch thick), poorly sorted, very fine quartz, mica, and chert grains, calcareous.	1.2
Pyj-1	Sandstone, red to tan fresh, brick-red weathered, fine to medum, subround, poorly sorted, frosted quartz and white feldspar grains, few pebble-size clasts of mudstone, red-brown, light gray bleach spots, calcareous.	11.6
	Total	155.7

Conformity

Canas Gypsum Member

Pyc-9	Gypsum, white, no visible impurities, thickly laminated(1/4-1/8 inch thick) alternating dark and light layers, laterally discontinuous (60 feet in length).	4.8
Pyc-8	Mudstone, brick-red and green-gray, gypsiferous, thinly bedded, calcareous.	3.2
Pyc-7	Sandstone, gray and red-brown fresh, brick red weathered, very fine, poorly sorted grains, trace of mica, hematite stain, gray bleach spots, calcareous.	1.5
Pyc-6	Siltstone, maroon, gray, and tan, gypsiferous, crumbly, soft, slightly unconsolidated at base.	1.3
Pyc-5	Siltstone, pink, interbedded with mudstone, dark-brown, brecciated, pebble to cobble-size	1.2

clasts of mudstone at base, crumbly, soft, calcareous.

Pyc-4 Limestone, gray to tan fresh, gray to green gray weathered, recrystallized, highly fractured, poorly preserved, few fossils (algae). 1.7

Pyc-3 Mudstone, buff to yellow, sandy, hard, crumbly, calcareous. 4.7

Pyc-2 Limestone, black fresh, dark gray weathered, thin-bedded, soft sediment deformation, recrstallized, highly fractured, upper 1/2 foot is sandy, medium to coarse, poorly sorted, gradational into breccia at base, few fossils (gastropods), fetid. 4.8

Pyc-1 Breccia, varicolored, gray, red-brown, and tan, buff to gray, poorly sorted, angular fragments of sandstone completely silicified and angular fragments of dark gray to black limestone, very hard, brittle, laterally discontinuous. 12.0

Total 35.2

Conformity

Torres Limestone Member

Pyt-38 Sandstone, light gray fresh, buff to white weathered, thickness varies from 0-8 feet, fine, angular, moderately sorted, frosted quartz, chert, white feldspar, and mica grains, laterally discontinuous, grades into breccia containing angular, blocks of gray limestone and tan sandstone, highly fractured, well-indurated, hard, brittle, small vugs of opaline silica, hematite stain, desert varnish, calcareous. 7.6

Pyt-37 Limestone, gray fresh, light gray weathered, medium-bedded at base (3-6 inches thick), thicker bedded at top (1-2 feet thick), fossiliferous (brachiopods, algae, ooids). 15.8

Pyt-36 Limestone, black fresh, black to dark gray weathered, thin bedding (1/4-2 inches thick), soft sediment deformation, hard, brittle, fossiliferous (brachiopods, ostracods, crinoid columnals, gastropods). 11.0

Pyt-35 Breccia, varicolored, thickness varies from 0-7 feet, limestone blocks (6-10 inches in diameter) floating in brown, fine-grained sand and silt, precipitated carbonate with radial axial texture lining vugs. 6.5

Pyt-34 Sandstone, light gray to white fresh, buff to tan, and white weathered, fine to medium, poorly sorted, frosted quartz, white feldspar, chert and mica grains, poorly indurated, hard, brittle, rind halos of hematite stain. 16.0

Pyt-33	Limestone, dark gray fresh, gray to green weathered, with very thinly laminated (1/16 inch thick) interlayers of fine to very fine sand, laterally discontinuous, grades laterally into breccia.	6.5
Pyt-32	Breccia, varicolored, up to boulder-size, randomly oriented, gray limestone fragments, irregular masses and interlayered silicified zones, well-indurated, hard, brittle, grades laterally into dark gray, limestone.	12.0
Pyt-31	Sandstone, tan to light gray fresh, buff to tan and red weathered, fine to medium, subround, poor to moderately sorted, frosted quartz and chert grains, rind halos of hematite stain, light gray bleach spots.	20.0
Pyt-30	Limestone, dark gray, brown, and black fresh, dark gray to tan weathered, very thinly bedded (1/4-1/2 inch thick), thinly laminated (1/16 inch thick) interlayers of sand, hard, crumbly, fractures filled with white carbonate.	3.7
Pyt-29	Sandstone, light gray fresh, buff to tan weathered, very fine-grained, medium-bedded, with (1-3 inches thick) interbedded gray and tan mudstone and shale, well-indurated, hard, brittle, hematite stain, calcareous.	17.0
Pyt-28	Sandstone, tan fresh, brick-red to tan weathered, fine, subround, moderate to poorly sorted grains, thin (1/2-2 inches thick) interbedded, maroon siltstone, hematite stain.	19.7
Pyt-27	Sandstone, buff to tan, fine to medium, rounded, moderate to poorly sorted, frosted quartz, chert, and mica grains, hematite stain, calcareous.	3.7
Pyt-26	Limestone, dark gray to black fresh, tan to brown weathered, sandy, medium, subround, frosted quartz, white feldspar, and clear mica grains floating in limestone and in thin (1-2 inch thick) lenses interbedded with sandy limestone.	2.6
Pyt-25	Siltstone, gray and tan, crumbly, soft, thinly bedded, slight platy cleavage, micaceous, calcareous.	12.8
Pyt-24	Sandstone, brick-red, fine, poorly sorted grains, crumbly, soft, micaceous, light gray bleach spots.	19.4
Pyt-23	Siltstone, tan to red, thin-bedded, slightly calcareous, ripple marks.	6.5
Pyt-22	Sandstone, brick-red, fine to medium, moderate to poorly sorted, subround, translucent and frosted quartz grains, low angle crossbeds, crumbly, soft, calcareous.	32.9
Pyt-21	Limestone, dark gray and tan fresh, light	1.7

	gray weathered, crumbly, hard, fractures filled with white carbonate, vuggy porosity, mudcracks, hematite stain.	
Pyt-20	Siltstone, tan, sandy, fine, subround, frosted quartz grains, poorly preserved, mudcracks, calcareous.	5.5
Pyt-19	Limestone, dark gray fresh, tan weathered, very hard and brittle.	2.0
Pyt-18	Sandstone, buff to tan, fine, moderately sorted, subround, frosted quartz grains.	5.0
Pyt-17	Limestone, black fresh, green-gray to tan weathered, vuggy porosity, fossiliferous (brachiopods), mudcracks.	12.0
Pyt-16	Sandstone and siltstone, buff to white, interbedded, fine, subround, moderately sorted, translucent and frosted quartz, trace of hematite, calcareous.	16.0
Pyt-15	Sandstone, white fresh, buff to gray weathered, very fine to coarse, well-sorted, rounded, frosted quartz, white feldspar, mica, and glauconite (?) grains, radial axial carbonate (textured) in localized vugs and cavities, thins laterally, localized blocks of randomly oriented sandstone surrounded by "dogs tooth calcite", speckles of hematite stain, calcareous.	9.7
Pyt-14	Sandstone, tan, fine to very fine, moderately sorted grains, crumbly, soft, slightly calcareous.	10.0
Pyt-13	Limestone, brown fresh, gray weathered, medium interbedded (3-4 inches thick), sandy, fine to medium, quartz, white feldspar, and mica grains, high porosity, crumbly, soft.	5.0
Pyt-12	Limestone, dark gray fresh, light gray weathered, medium-bedded, vuggy porosity parallel to stratification, mudcracks.	4.5
Pyt-11	Mudstone, buff to yellow at top, maroon at base, crumbly, poorly indurated, trace of mica, hematite stain, calcareous.	12.8
Pyt-10	Sandstone, brick-red fresh, red-brown weathered, fine to medium, subround, moderately sorted, frosted quartz, and clear mica grains, salt casts, light gray bleach spots, calcareous.	15.5
Pyt-9	Sandstone, tan to pink fine to medium, poorly sorted grains, crumbly, soft, poorly preserved, thickly laminated (1/2-1/4 inch thick) interbeds of maroon and light gray mudstone and shale, calcareous.	25.0
	Correlated Across Fault	
Pyt-8	Limestone, black fresh, green-gray weathered, thin bedding, vuggy porosity, fossiliferous (brachiopods, gastropods) fetid.	13.6

Pyt-7	Shale, green and tan, interbedded with sandstone, buff to tan, fine to medium, subround, poorly sorted, frosted quartz grains, thin stringers (1/2-3 inches thick) of sandstone interbedded in thicker, medium 10-12 inches thick) beds of shale.	21.3
Pyt-6	Sandstone, red-brown to maroon fresh, brick-red weathered, fine to medium, subround, moderately sorted, thinly bedded (1-2 inches thick) with thickly laminated (1/4-1/8 inches thick) interbedded red and light gray shale layers, soft sediment deformation, ripple marks.	59.2
Pyt-5	Sandstone, tan fresh, buff to dark-brown, and black weathered, coarse, subround, poorly sorted, frosted quartz and white feldspar grains, crossbedded, hematite stain, desert varnish, ripple marks, calcareous.	6.0
Pyt-4	Sandstone, tan fresh, buff weathered, fine to medium, poorly sorted, thin-bedded, hematite stain.	3.6
Pyt-3	Sandstone, tan fresh, buff to light-brown weathered, medium to coarse, subround, poorly sorted, frosted and translucent quartz, interbedded with buff, sandstone, fine moderately sorted grains.	3.3
Pyt-2	Sandstone, tan fresh, buff to yellow weathered, very fine, subround, well-sorted grains, thin-bedded, speckles of hematite stain, slightly calcareous.	6.0
Pyt-1	Sandstone, tan fresh, buff to light-brown weathered, poorly sorted, subangular, frosted and translucent quartz, white feldspar, and chert grains, crossbedded, calcareous.	4.0
	Total	455.4

Conformity

Meseta Blanca Sandstone Member

Pym-43	Sandstone, tan to brown fresh, buff to brown weathered, medium, subangular, moderately sorted, translucent and frosted quartz, white feldspar, trace of chert, well-indurated, hard, brittle, thinly bedded.	8.8
Pym-42	Shale, light gray fresh, buff to gray weathered, poorly exposed and preserved.	9.1
Pym-41	Sandstone, white to buff fresh, buff to tan weathered, medium, moderately sorted, subangular, frosted quartz grains, white fine silt to clay size intergranular material.	12.5
Pym-40	Siltstone, dark-brown, thinly bedded, hard, brittle, well-indurated, ripple marks, mudcracks, salt casts.	13.0
Pym-39	Sandstone, buff to red-brown fresh, buff to tan and red weathered, medium, subround, moderately sorted, frosted quartz, white	2.0

	chert, and pink feldspar grains.	
Pym-38	Siltstone, brick-red, varies laterally from well to poorly sorted, moderately indurated, hard, crumbly.	3.0
Pym-37	Sandstone, maroon fresh, brick-red weathered, medium, rounded, moderately sorted, translucent quartz and pink and white feldspar grains.	9.6
Pym-36	Sandstone, brick-red, medium, subround, moderately sorted, frosted quartz, chert and white feldspar grains, poorly indurated, soft, brittle.	9.3
Pym-35	Sandstone, white to light gray fresh, buff to tan and red weathered, medium, subround, moderately sorted, frosted quartz, chert and mica grains, poorly indurated, crumbly, hard.	2.5
Pym-34	Sandstone, red-brown fresh, brick-red weathered, fine grain, well-sorted, hematite concretions, ripple marks.	15.0
Pym-33	Shale, red and gray, poorly exposed and preserved, slope former.	3.9
Pym-32	Siltstone, light gray fresh, buff to tan weathered, fine-grained, coarsens toward top, thinly laminated with (1/8 inch thick) shale partings, limonite stain.	5.5
Pym-31	Sandstone, maroon to red-brown fresh, brick-red weathered, fine, subround, well-sorted, frosted quartz grains, poorly indurated, crumbly, soft.	2.5
Pym-30	Sandstone, light gray to white fresh, buff to tan weathered, fine, well-sorted grains, thin bedded, well-indurated, hard, brittle.	3.7
Pym-29	Shale, red and gray, poorly exposed and preserved, slope former.	15.5
Pym-28	Shale, light gray, thinly bedded, well sorted, micaceous (biotite).	7.7
Pym-27	Sandstone, brick-red fresh, red-brown weathered, fine, subangular, well-sorted, frosted quartz grains, thinly bedded, ripple marks, few salt casts.	11.4
Pym-26	Siltstone, light gray fresh, buff to gray weathered, well-sorted, poorly indurated, hard, brittle, thickly laminated (1/4-1/2 inch thick), salt casts.	6.4
Pym-25	Sandstone, red-brown fresh, brick-red weathered, fine, well-sorted grains, moderately indurated, brittle, hard, ripple marks, slightly calcareous.	9.5
Pym-24	Siltstone, light gray fresh, buff weathered, well-sorted, thinly bedded (1/4-2 inches thick), thinly laminated (1/16-1/8 inches thick) and interbedded light gray shale, speckles of hematite stain, ripple marks, salt casts.	16.0

Pym-23	Sandstone, red-brown, fine-grained, moderately sorted, interbedded with light gray sandstone, fine-grained, well-sorted, thin bedding, ripple marks, mudcracks, salt casts.	14.5
Pym-22	Siltstone, green-gray fresh, gray-green weathered, fractured, well-sorted, poorly exposed and preserved.	1.7
Pym-21	Siltstone, tan fresh, buff to gray weathered, well-sorted, moderately indurated, hard, brittle, speckles of hematite stain.	1.7
Pym-20	Siltstone, buff to gray fresh, yellow-green to green-gray weathered, thickly laminated (1/4-1/2 inch thick) crenulated laminations, limonite stain, salt casts.	3.1
Pym-19	Sandstone, buff to red-brown, fine, well-sorted grains, moderately indurated, brittle, hard, ripple marks, slightly calcareous.	7.7
Pym-18	Siltstone and shale, gray to buff and dark red, thickly laminated (1/4-1/2 inch thick) and interbedded.	12.0
Pym-17	Siltstone, red-brown fresh, dark-brown weathered, well-sorted, poorly indurated, soft, brittle.	6.5
Pym-16	Siltstone and shale, light gray, very thin (1/8-1 inch thick) interbedded, poorly indurated, soft, brittle, ripple marks, mudcracks, salt casts.	5.0
Pym-15	Sandstone, maroon to red-brown fresh, brick-red weathered, fine, moderately sorted grains, poorly indurated, soft, brittle, thin bedding, ripple marks.	9.8
Pym-14	Shale, green-gray fresh, gray weathered, interbedded with buff to tan siltstone, soft, crumbly, ripple marks, mudcracks, salt casts.	9.8
Pym-13	Sandstone, red-brown and tan fresh, buff to brick-red weathered, very fine, poorly sorted grains, hematite stain.	1.7
Pym-12	Siltstone, white to gray fresh, green-gray weathered, thinly laminated (1/10 inch thick) and interbedded with gray shale, platy cleavage, moderately indurated, brittle, salt casts, calcareous.	1.2
Pym-11	Shale, green-gray fresh, gray weathered, moderately indurated, soft, brittle, salt casts, slightly calcareous.	2.5
Pym-10	Sandstone, red-brown, fine, well-sorted grains, thinly (2-3 inches thick) bedded, with thinly laminated (1/8 inch thick) and interbedded gray shale, ripple marks.	2.7
Pym-9	Siltstone, brick-red fresh, red-brown weathered, well-sorted, thin interbeds of	5.0

	shale at base, poorly indurated, soft, crumbly, slightly calcareous.	
Pym-8	Siltstone and shale, gray, thickly laminated (1/4-1/2 inch thick) and interbedded, poorly indurated, soft, brittle, platy cleavage, mudcracks, salt casts.	10.0
Pym-7	Siltstone, brick-red, well-sorted, poorly indurated, crumbly, soft, thin bedding (2-3 inches thick), salt casts.	8.0
Pym-6	Sandstone, white to buff fresh, gray to white weathered, fine, well-sorted grains, thin (1-2 inches thick) beds, poorly indurated, crumbly, soft.	1.7
Pym-5	Shale, maroon, platy cleavage, poorly indurated, soft, brittle, thin (2 inches thick) interbedded green-gray shale, salt casts.	9.5
Pym-4	Siltstone, brown and green fresh, green, gray, and maroon weathered, thickly (1/4 inch thick) laminated at base, salt casts, calcareous.	0.4
Pym-3	Shale, maroon to red-brown, crumbly, soft, green-gray bleach spots, slightly calcareous.	4.1
Pym-2	Mudstone, gray and maroon, moderately indurated, soft, brittle, grades locally into siltstone.	0.3
Pym-1	Shale, maroon and gray, thinly (1/16 inch thick) laminated, platy cleavage, moderately indurated, soft, brittle, light blue-green bleach spots.	8.0
		Total 293.8

Conformity

Abo Formation-(Section measured in the N./2 of sec. 17, T.4S., R.2E.)

Pa-29	Siltstone, red-brown to maroon fresh, red-brown to dark-green and black weathered, well indurated, very hard, brittle, ripple marks, desert varnish, calcareous.	10.0
Pa-28	Conglomerate, pink, poorly sorted, subround, pebble-size clasts of gray limestone and brick red siltstone and shale, pinches out locally.	1.5
Pa-27	Shale, maroon, moderately indurated, soft, brittle, poorly exposed.	10.0
Pa-26	Siltstone, maroon fresh, red-brown weathered, well-sorted, vuggy porosity, fractures filled with white carbonate, light-blue-green bleach spots, desert varnish, calcareous.	2.4
Pa-25	Mudstone, maroon, moderately indurated, crumbly, soft, light gray bleach spots.	12.5
Pa-24	Siltstone and shale, dark brown to red, thickly laminated (1/4-1/8 inch thick) and interbedded, well-sorted, crossbedded, light gray bleach spots, ripple marks, calcareous.	13.2

Pa-23	Siltstone, maroon fresh, dark-brown to red and black weathered, well-indurated, hard, brittle, calcareous partings, vuggy porosity.	1.0
Pa-22	Shale, maroon, well-indurated, hard, crumbly, poorly exposed and preserved.	3.5
Pa-21	Siltstone and shale, brick-red to black varicolored, interbedded with thickly laminated (1/4-1/2 inch thick) lenses of conglomerate, low-angle crossbedding, laterally discontinuous, desert varnish.	11.3
Pa-20	Siltsone, red-brown, well-indurated, hard, brittle, laterally discontinuous.	2.0
Pa-19	Shale, maroon, moderately sorted, poorly indurated, crumbly, soft, fractures filled with white carbonate, light gray and green color alterations.	31.0
Pa-18	Siltstone, dark-brown, medium (6-10 inches thick) beds, interbedded with thickly laminated (1/8 inch thick) shale and thinly bedded conglomerate (2-3 inches thick), vuggy porosity, ripple marks, burrows, leaf prints, desert varnish.	1.8
Pa-17	Shale, maroon, moderately indurated, soft, crumbly, poorly exposed slope former, white carbonate filling fractures and patches on weathered surfaces, white and light gray color alterations.	56.0
Pa-16	Siltsone, maroon and purple fresh, dark brown to red, and buff to tan weathered, well-sorted, low-angle (< 5 degrees) crossbedds, vuggy porosity, ripple marks, circular white to light gray bleach spots.	5.0
Pa-15	Shale, brick-red, unconsolidated, poorly exposed, calcareous.	12.6
Pa-14	Conglomerate, maroon fresh, dark-brown to brick-red weathered, silty, poorly sorted, pebble-size clasts of gray limestone, and brick-red siltstone and shale, and coarse to pebble-size frosted quartz grains, leaf prints, desert varnish.	0.8
	Correlated Across Fault	
Pa-13	Shale, brick-red, poorly indurated, crumbly, soft, poorly exposed, slope former.	11.0
Pa-12	Siltstone, dark-brown, and maroon to brick red shale, thickly laminated (1/4 inch thick), with thinly laminated (1/10 inch thick) shale partings, low-angle (< 5 degrees) crossbeds, leaf prints.	8.0
Pa-11	Shale, maroon, poorly sorted, poorly indurated, crumbly, soft, poorly exposed, slope former, calcareous.	40.0
Pa-10	Siltstone, maroon fresh, brick-red to black weathered, conglomeratic, poorly sorted, pebble-size clasts of gray limestone, and	1.4

	brick-red siltstone and shale, well indurated, hard, brittle, ripple marks, slightly calcareous.	
Pa-9	Shale, brick-red, thickly (1/8-3/4 inches thick) laminated, well-indurated, hard, brittle, ripple marks.	34.5
Pa-8	Conglomerate, maroon, pebble-size clasts of gray and tan limestone, and brick-red siltstone, vuggy porosity, well-indurated, hard, brittle, limonite stain.	2.6
Pa-7	Shale, maroon, slight platy cleavage, poorly indurated, crumbly, soft, calcareous.	7.4
Pa-6	Siltstone, maroon fresh, brick-red weathered, fractures filled with white carbonate, well indurated, brittle, hard, calcareous.	2.6
Pa-5	Shale, red-brown, poorly indurated, crumbly, soft, calcareous concretions at base, carbonate filled vugs near top.	30.0
Pa-4	Siltsone, brick-red to maroon fresh, dark brown to brick-red weathered, poorly sorted, ripple marks, leaf prints, calcareous.	3.5
Pa-3	Shale, brick-red, poorly indurated, crumbly, soft, poorly exposed, calcareous.	3.0
Pa-2	Siltstone, dark-brown to maroon fresh, dark red weathered, thickly (1/4 inch thick) laminated, well-indurated, hard, brittle, low angle crossbedded (5-10 degrees), fractured, ripple marks, leaf prints, calcareous.	2.8
Pa-1	Shale, maroon, poorly indurated, crumbly, soft, calcareous, base is overlain by alluvium.	48.4
	Total	369.8

Conformity

Bursum Formation-(Section measured in the W./2 of sec. 17, T.4S., R.2E.)

Pbu-19	Arkose, maroon to gray and green-gray fresh, pink to brown weathered, coarse to pebble size, subangular, translucent smoky quartz, chert, white and pink feldspar, and mica grains, low-angle crossbedded, calcareous.	5.0
Pbu-18	Arkose, maroon to brown fresh, brown to tan weathered, coarse, poorly sorted, quartz, chert, and feldspar grains, hematite stain, fractured, slightly calcareous.	4.5
Pbu-17	Shale, purple, poorly indurated, crumbly, soft, poorly exposed, slope former.	3.6
Pbu-16	Arkose, gray fresh, buff to tan weathered, pebble-size clasts of poorly sorted, subangular, white quartz, mica (biotite), and pink and white feldspar, few cobbles of subround, white quartz and pink feldspar floating in finer material, low-angle (< 10 degrees) crossbedding, moderately indurated,	11.0

	hard, brittle.	
Pbu-15	Arkose, light-brown to maroon fresh, tan to brown weathered, poorly sorted, coarse with some cobble-size grains of translucent smoky quartz, white feldspar, and mica flakes, variable continuity in grain size moving short distances laterally.	12.0
Pbu-14	Shale, maroon, unconsolidated, few nodular calcareous concretions, calcareous.	15.0
Pbu-13	Arkose, pink fresh, pink and tan weathered, poorly sorted, pebble-size grains of frosted quartz, white feldspar, and chert, well indurated, hard, brittle, fractured, splotches of hematite stain, calcareous.	6.0
Pbu-12	Shale, purple, unconsolidated, cobble-size, subangular to angular, calcareous concretions, slope former.	15.0
Pbu-11	Limestone, dark gray and brown fresh, light-gray to brown weathered, arkosic, thickly laminated (1/4 inch thick), interbedded sandstone and limestone, sand content increases toward top, abundant limestone intraclasts in upper 12-inches, fossiliferous (brachiopods, gastropods, algae, crinoid columnals), desert varnish.	11.2
Pbu-10	Arkose, varicolored, dark-brown, dark gray or dark-purple, low-angle (< 10 degrees) cross-stratification dipping southeast, poorly sorted, coarse to pebble grain size with thickly laminated (1/4-1/2 inches thick) and interbedded lenses of pebble to cobble-size grains, both containing quartz, chert, feldspar, and carbonate cement.	4.0
Pbu-9	Shale, maroon to red-brown, sandy, poorly indurated, crumbly, soft, poorly preserved, slope former, calcareous.	15.1
Pbu-8	Arkose, pink, pebble to coarse, subround, poorly sorted, white and black chert, frosted quartz, and white feldspar grains, coarsens toward base with more subangular quartz grains, very well-indurated, hard, brittle, thin (< 1/8 inch thick) fractures filled with white carbonate, slightly calcareous.	2.5
Pbu-7	Shale, purple, interbedded with siltstone, dark-brown to maroon, poorly sorted, poorly preserved, slope former.	22.0
Pbu-6	Arkose, tan to brown fresh, pink to brick-red weathered, poorly sorted, coarse to pebble size grains of quartz, chert, and pink feldspar, medium-bedded, very well indurated, hard, brittle, calcareous.	8.5
Pbu-5	Slope cover.	13.5
Pbu-4	Sandstone, dark-brown to maroon fresh, brick-	4.5

	red weathered, arkosic, coarse, moderately sorted, subangular grains of quartz and chert, moderately indurated, calcareous.	
Pbu-3	Arkose, maroon fresh, dark-brown to brick-red weathered, poorly sorted, coarse to pebble size, subround, frosted quartz, black chert and pink and white feldspar, very low-angle stratification (< 5 degrees) dipping southeast, well-indurated, hard, brittle, calcareous.	13.0
Pbu-2	Siltstone, purple fresh, dark-brown to purple weathered, sandy, poorly sorted, up to medium size grains of quartz and white feldspar, crossbedded, thickly laminaed (1/8-1/4 inch thick) interlayers of purple shale, poorly indurated, crumbly, soft, fissile, friable.	21.2
Pbu-1	Limestone, light gray fresh, gray, buff, and purple weathered, arkosic, fine to coarse, poorly sorted, subangular, chert, quartz, and clusters of pink feldspar grains, mudcracks, fossiliferous (brachiopods).	6.0
	Total	193.6

Disconformity

Magdalena Group-(Section measured in the E./2 sec. 18, and W./2 sec. 17, T.4S., R.2E.)

Madera Limestone-(only upper beds exposed)

Cma-18	Limestone, gray, arkosic, medium to coarse, subangular, poorly sorted, frosted and translucent quartz, chert, and pink feldspar grains, chert nodules, fossiliferous (brachiopods, crinoid columnals, rugosids).	7.0
Cma-17	Limestone, light gray to tan fresh, light gray to maroon weathered, arkosic, fine to medium, moderately sorted, subangular quartz grains, ripple marks, mudcracks, fossiliferous (brachiopods, crinoid columnals, coralline algae).	11.0
Cma-16	Conglomerate, gray to dark gray, few cobble size limestone intraclasts, abundant medium to coarse, subangular quartz and chert grains, grain supported, highly fossiliferous (brachiopods, rugosids, coralline algae), calcareous.	5.0
Cma-15	Limestone, gray, massive bedded, grain supported, soft, crumbly, fossiliferous (crinoid columnals, gastropods, coralline algae).	6.0
Cma-14	Limestone, light gray, massive bedded, grain supported, hard, crumbly, fossiliferous (crinoid columnals, coralline algae, gastropods).	9.4
Cma-13	Limestone, black fresh, dark gray weathered,	10.1

	thickly laminated (1/4-1/2 inches thick) bedding, hard, brittle, thin (1/16 inch wide) fractures filled with carbonate, mudcracks, fetid.	
Cma-12	Limestone, dark gray fresh, gray weathered, crumbly, hard, brittle, mudcracks, fossiliferous (brachiopods, crinoid columnals, gastropods, rugosids, algae).	8.3
Cma-11	Limestone, tan to gray, medium (4-6 inches thick) bedded, grain supported, fossiliferous (brachiopods, crinoid columnals, algae).	6.5
Cma-10	Limestone, gray fresh, light gray weathered, massive bedded, thin streaks and nodules of chert, fossiliferous (brachiopods, crinoid columnals).	12.0
Cma-9	Slope cover.	26.0
Cma-8	Limestone, gray to buff fresh, buff to tan weathered, mud supported, fossiliferous (crinoid columnals, gastropods).	8.0
Cma-7	Limestone, dark gray fresh, gray weathered, grain supported, highly fossiliferous (brachiopods, crinoid columnals, rugosids, coralline algae).	5.5
Cma-6	Limestone, dark gray fresh, light gray weathered, massive bedded, recrystallized, highly fossiliferus (brachiopods, crinoid columnals, coralline algae).	14.0
Cma-5	Slope cover.	5.0
Cma-4	Arkose, buff to white fresh, brown weathered, medium to coarse, moderately sorted with floating, subround, cobbles of quartz and feldspar, with larger (1-4 inches in diameter) cobbles of angular limestone, speckles of hematite stain.	2.5
Cma-3	Limestone, dark gray to black fresh, gray weathered, lenses and nodules of chert, medium bedded, fossiliferous (brachiopods, fusulinids, gastropods).	14.0
Cma-2	Limestone, gray fresh, light gray weathered, massive bedded, thin (2-4 inches thick) layers and nodules of chert, hard, brittle, highly fossiliferous (brachiopods, crinoid columnals, ostracods).	13.3
Cma-1	Shale, green-gray, thin (1/4-2 inches thick) bedded, fissile, interbedded with thicker (2-4 inches thick) brown limestone, upper 10-feet contains more limestone and less shale, few fossils (brachiopods, crinoid columnals), limonite stain, ripple marks, highly calcareous.	28.2
		Total 191.8

Identification of Samples in Plate 3

1. Gastropod (1.3 X natural size)
2. Pelecypod (1.25 X natural size)
3. Cephalopod (0.26 X natural size)
4. Collignoceras Springeri (0.71 X natural size)
5. Pina (0.70 X natural size)
6. Pelecypod
7. Pelecypod Internal molds (natural size)
8. Pelecypod

Photos taken by D. Wolberg, N. Mex. Bur. Mines and Min. Res., print reproduction by B. DeMarco, R. & D.D. photo lab.

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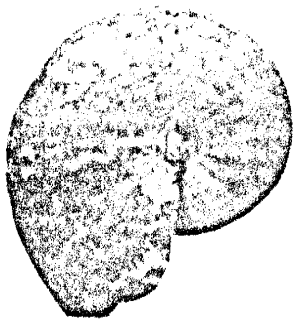
2.



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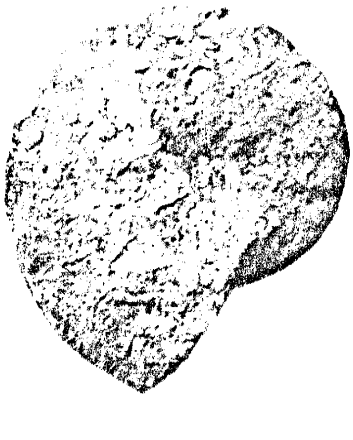

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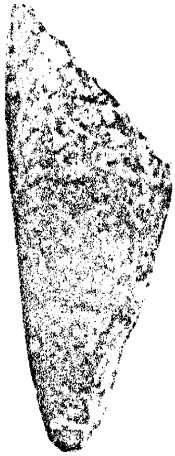

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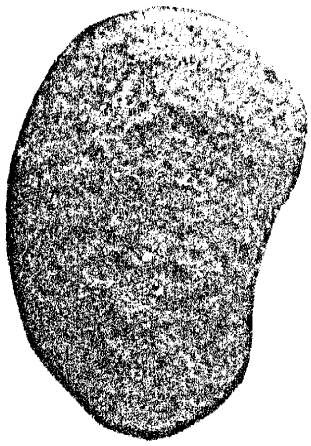

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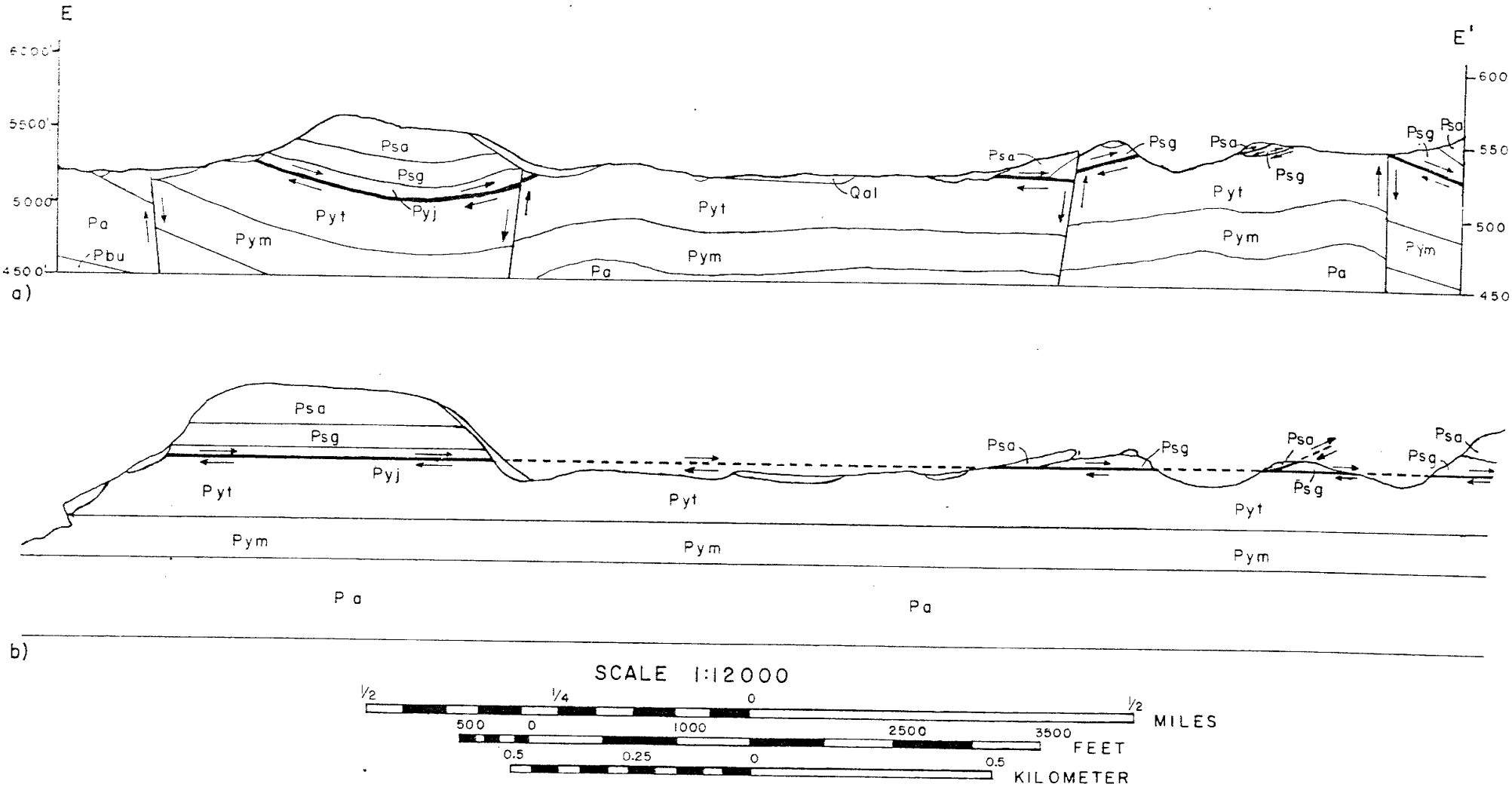
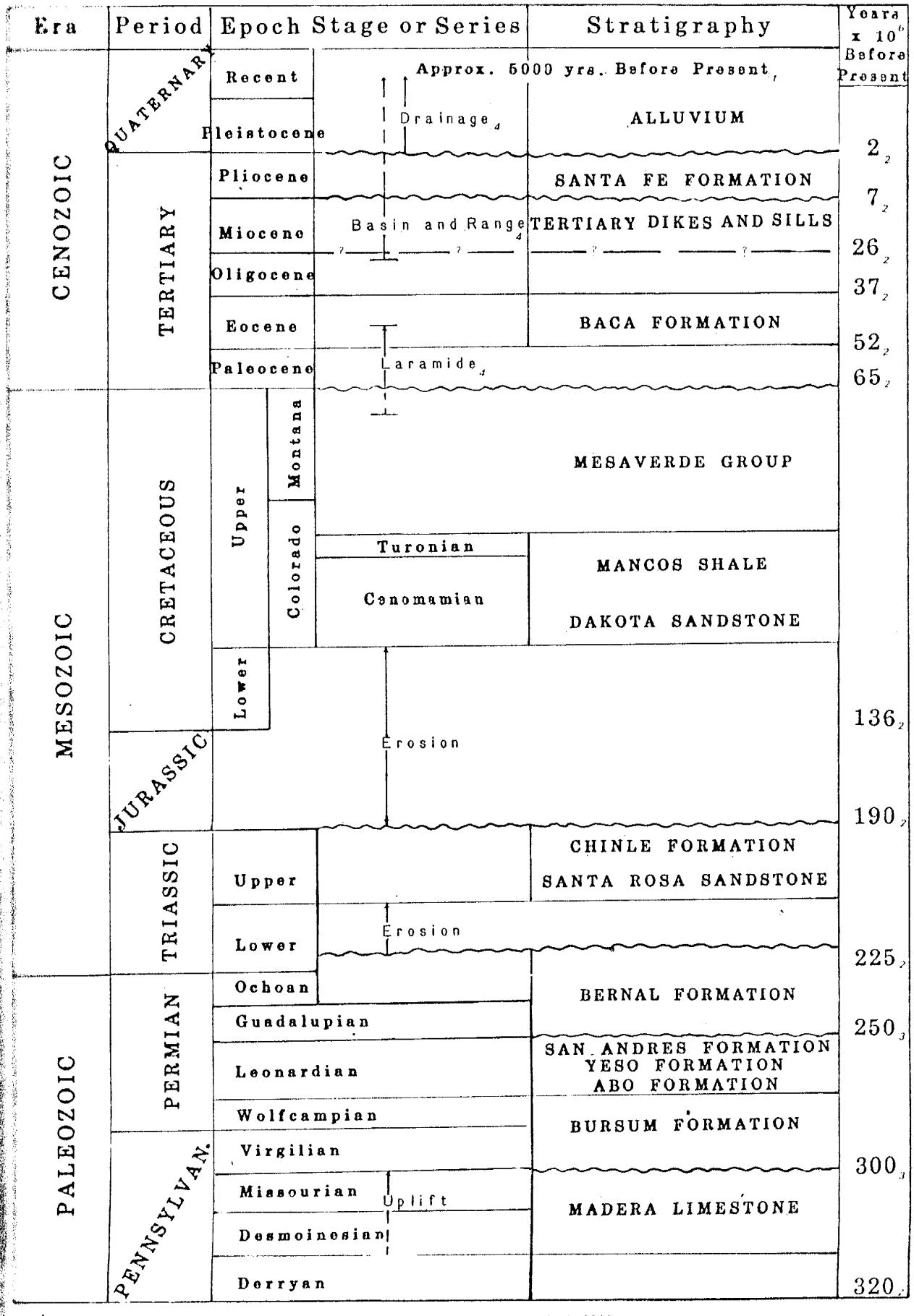


a) Cross section E-E', located on Plate I.

b) Reconstructed cross section of E-E', normal faults and folds have been removed.

PLATE 5



Geologic time scale of rocks exposed in the Cerro del Viboro area.
Ages after: 1 Condie, 1976, 2 Harland and others, 1964, 3 Baars, 1979,

This thesis is accepted on behalf of the faculty of the Institute by the following committee:

Adviser

May 17, 1982

Date