

# **Preliminary Geologic Map of the Bull Gap Quadrangle, Lincoln County, New Mexico**

By

**Kate E. Zeigler and Bruce D. Allen**

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*Open-file Digital Geologic Map OF-GM 210***

Scale 1:24,000

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

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# **Preliminary Geology of the Bull Gap Quadrangle, Lincoln County, New Mexico**

**<sup>1</sup>Kate E. Zeigler and <sup>2</sup>Bruce D. Allen**

<sup>1</sup>Zeigler Geologic Consulting, Albuquerque, NM 87123

<sup>2</sup>New Mexico Bureau of Geology and Mineral Resources, Albuquerque, NM 87131

## **INTRODUCTION**

The Bull Gap Quadrangle is located in the northern Tularosa Basin, south of Carrizozo and north of Oscuro, New Mexico. The topography is primarily low, rolling country with a long hogback of Cretaceous strata trending north-south in the center of the map, and the Carrizozo lava flow trending northeast-southwest across the quadrangle. Exposure of Permian and Cretaceous strata occurs in the center of the map area, though large tracts of modern alluvium and older fan deposits from the Sacramento Mountains to the east cover the bedrock geology in many areas. In addition, Cenozoic igneous intrusions, in the form of dikes and sills, can be found throughout the map area, though they are more common in the southeastern part of the map area. Most of the land is owned by the state of New Mexico or by the Bureau of Land Management, with smaller private holdings.



**Figure 1. Sinkhole in Permian San Andres Formation. Sierra Blanca is in the background.**

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## GEOLOGY

### **Stratigraphy**

#### *Quaternary Units*

The two most extensive Quaternary units on Bull Gap quadrangle are Qac (alluvium/colluvium) and Qes (reworked eolian sheet deposits). Reworked eolian deposits covers most of the eastern map area, such that bedrock exposures occur only in deeply incised arroyos or along hogbacks and local higher topography. Qac, a more generalized unit that can encompass Qes includes thin deposits of unconsolidated alluvial, colluvial, and eolian deposits on hillslopes and along drainages. Older deposits within Qac may exhibit accumulations of pedogenic gypsum and calcium carbonate. The western one third of the quadrangle lies to the north, south, and east of bedrock uplands and because of this relationship, surficial clastic sediments in this area are classified as "piedmont" deposits (Qp) with two distinct age designations (young and intermediate). Undivided valley-bottom deposits are designated Qa and modern alluvium (Qal) is confined to active to semi-active stream channels. Colluvium occurs primarily along the steep slopes of the Cretaceous hogback and around the edges of the Permian strata exposed in low hills in the central map area.

The Carrizozo lava flow cuts from southwest to northeast across much of the quadrangle. Dunbar et al. (1999) dated the flow to ~ 5 ka. The basalt is aphanitic with rare, small

olivine crystals and is vesicular. Textures include both a'a and pahoehoe, as well as elongated vesicles (see Elston, 1991).



**Figure 2. Collapse feature in Carrizozo lava flow. View is to the south.**



**Figure 3. Pahoehoe texture, Carrizozo lava flow.**

Reworked/redeposited gypsum is also a common constituent of modern or very young deposits in the Bull Gap area. This material occurs as low mounds of massive gypsum or as thick gypsum coatings on the sides of outcrops. The probable source for this younger

gypsum is reworked material from the Permian Yeso Formation that is deposited by eolian deposition into protected areas, hardened through repeated anhydrite/gypsum conversions and eventually left high on the modern landscape by erosional processes. Quaternary gravel deposits occur as long, low, flat-topped mounds dominated by cobbles and boulder of Sierra Blanca volcanics. These were deposited prior to exposure of Mesozoic bedrock because they contain no sedimentary rock clasts, only volcanic material.

### *Tertiary Units*

Units assigned a Tertiary age in the Bull Gap area include a cobble conglomerate (Tg) and a variety of igneous intrusions. The conglomerate is locally incised into underlying Cretaceous strata and its base is an angular unconformity with the older strata. It also is observed in the bottoms of deeply incised arroyos, though it is difficult to establish a clear outcrop pattern. Crossbed dip azimuths indicate a southeasterly flow direction. The igneous intrusives occur as both sills and dikes and are presumably related to the Oligocene volcanic activity of the Sierra Blanca volcanic field. Sills observed in the field area range from aphanitic to aphanitic porphyritic to phaneritic. The aphanitic sills, primarily found in the east-central part of the field area are pale pink or olive green in color and too fine grained to determine precise composition, though they are presumed to be felsic to intermediate based on their color. Aphanitic porphyritic sills were observed in the southeast corner of the map area and are intermediate in composition. The most prominent of these pyroxene phenocryst-rich sills caps a relatively tall hill in the very southeast corner of the map area and is up to 4 m thick. A phaneritic syenite sill was observed in the central part of the map area and was intruded into the Permian San Andres Formation. Samples of this sill were collected for radiometric dating (results pending) because the sill is offset by one of the numerous strike-slip faults in the area and we hope to better constrain the timing of this faulting.

Dikes in the map area are oriented east-west to southeast-northwest and tend to be short in length (less than 0.75 km maximum). They are dark green in color and are pervasively altered. Phenocrysts are very small pyroxenes, and three of these dikes were identified as syenogabbros by S. Kelley.

### *Cretaceous Units*

The oldest Cretaceous unit in the map area is the Dakota Sandstone, a quartz arenite to quartzite that forms the distinctive hogback trending north-south through the center of the map area. The Dakota Sandstone interfingers with the overlying Mancos Shale, a thick package of shale with limestone beds (Bridge Creek beds) and sandstones (Tres Hermanos Formation). The lower Mancos shale consists of interbedded thin sandstone beds and dark gray shale with multiple white to gray-white bentonite beds in the lower part. Up-section, there are no sandstone beds and fewer bentonite layers. The Bridge Creek Beds include three limestone units, each of which consists of a single limestone bed that is never more than 0.5 m thick. The Tres Hermanos Formation of the Mancos Shale usually is divided into three parts, the lowest unit being the Atarque Sandstone, the middle unit the Carthage Member and the upper unit the Fite Ranch Member. In the Bull Gap area, only the lower unit is recognized. The lower Tres Hermanos contains numerous invertebrate fossils, including large ammonites, pelecypods and oysters.



**Figure 4. Partial ammonite from Cretaceous Tres Hermanos Formation, Mancos Group.**

The D Cross Tongue of the Mancos Shale is only exposed locally in deeply incised arroyos or where partially armored by Quaternary fan deposits. The D Cross Tongue of the Mancos Shale interfingers with the overlying Gallup Sandstone, a yellow sandstone that locally contains abundant fossils, including oysters and the bivalve *Cardium* sp. The

Gallup Sandstone is marine and is differentiated from the overlying Crevasse Canyon Formation by differences in sedimentary structures and a lack of marine fossils in the Crevasse Canyon Formation. The Crevasse Canyon Formation also includes several shale horizons that are rich in organic material, though no true coal beds were observed in the field area.



**Figure 5. Crossbedding in Cretaceous Crevasse Canyon Formation.**

### *Triassic Unit*

The only Triassic unit in the Bull Gap area is the Moenkopi Formation, which is Early to Middle Triassic in age. The Moenkopi Formation is distinguished from the underlying Grayburg Formation (Early Permian: Artesia Group) by its gray-purple color and coarse-grained sandstones and conglomerates. Clasts in the conglomeratic units are predominantly quartzite, with lesser chert, and are very well rounded. Sandstones are hematite-stained quartz arenites.



**Figure 6. Conglomerate in Lower Triassic Moenkopi Formation. Clasts are quartzite and mud rip-ups.**

### *Permian Units*

The Yeso Formation is only exposed in the north-central part of the map area and consists primarily of gypsum with rare limestone/dolomite beds. Contrary to similar exposures on the southeastern flank of the Sacramento Mountains, no sandstone or mudstone beds were observed in the Yeso Formation. The Rio Bonito Member of the San Andres is present in low hills throughout the central part of the map area. Only the lower, dolomitic third of the unit is present, as compared to more complete sections in the southeastern Sacramento Mountains. Above the San Andres Formation is the Grayburg Formation of the Artesia Group. This unit is orange-red in color with green reduction mottles and is pervasively bioturbated, such that very few original sedimentary structures are present. The Grayburg Formation outcrops only in a few places and generally only where it is partially armored by Quaternary fan deposits.





**Figure 7. Outcrop of Permian Grayburg Formation (Artesia Group). View is to the north.**



**Figure 8. Gypsum in the uppermost Yeso Formation. View is to the north.**

## **Faults**

Faults in the Bull Gap quadrangle are primarily oblique-slip faults that are oriented northwest-southeast to east-west. Offset along these structures is most evident in the Dakota hogback along the center of the map. Some of these faults have only a few meters of throw and/or slip, but others have generated more substantial motion, resulting in offset of the hogback by tens of meters. Both right lateral and left lateral strike slip motion is evident in this group of faults. Slickenside lineations were observed at only a few localities and are steeply inclined.

A few faults trend north-south to northeast-southwest and appear to be primarily normal faults, although a lack of competent outcrop makes determination of any strike-slip motion on these faults impossible. These faults are primarily down to the west and bring younger units, such as the Middle Triassic Moenkopi Formation next to older units, such as the Early Permian San Andres Formation. These faults are presumably part of the basin-forming structural fabric.

In general, offset of igneous features (sills and dikes) was not observed in the Bull Gap area, except in a single case where a syenite sill was offset down and to the left by one of the dip-slip faults.

## **References**

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## Map Units

### Quaternary Deposits

- Qal Alluvium:** modern alluvium in perennially flowing streams and arroyo bottoms. Contains cobbles and pebbles of Permian and Cretaceous strata, as well as abundant material from the Sierra Blanca volcanic field.
- Qes Eolian Sheet Deposits:** Very fine grained sand to silt deposited by wind and subsequently reworked by sheet flow across the surface. Ranges in thickness from less than 0.5 m to over 2 m and can include pebbles of local bedrock, as well as of Sierra Blanca volcanic material.
- Qac Undivided alluvium and colluvium.** Holocene to Middle Pleistocene (?). Silt, sand, gravel and clay in various proportions, generally unconsolidated, deposited in a variety of depositional settings. Includes relatively thin accumulations of unconsolidated alluvial, colluvial, and eolian deposits on hillslopes, drainages, and dip-slopes underlain by bedrock; interfingers with differentiated alluvium (e.g., Qp and Qa) along valley floors. Older deposits may exhibit accumulation of pedogenic gypsum and calcium carbonate. Unit also includes areas of unmapped bedrock and differentiated alluvium. Up to a few meters thick.
- Qa Alluvium of valley floors and adjacent lowlands.** Holocene to Upper Pleistocene (?). Fine-grained (silt, sand, and clay) alluvium and small channels of poorly to moderately sorted pebbly sand. Relief between channels and surrounding alluvium is generally less than 1 m, but locally exceeds 4 m in larger arroyo cuts. Deposits are generally structureless, very pale brown to light reddish brown, and exhibit little to no soil development. May be up to 3 m thick or more.

**Qpy Younger piedmont alluvium.** Holocene to Upper Pleistocene (?). Silt, sand and clay with locally abundant pebble to boulder gravel. Coarse-grained clasts (gravel and boulders) are more common in areas proximal to surrounding bedrock uplands. Over most of the map area, unit is generally structureless, pale reddish brown, and fine grained (silt, sand, and clay), exhibits little soil development, and contains thin, discontinuous beds of clast-supported, angular to subrounded gravels. In the northwestern part of the map area, unit is divided into older piedmont alluvium (Qpy), which is commonly capped with a moderately developed desert pavement, and younger, inset, deposits (Qpy2) that display little to no pavement development. Up to several meters thick.

**Qpy2 Younger piedmont alluvium** in northwestern part of map area. Holocene. Silt, sand, and clay with local accumulations (lenses) of pebbly sand. Generally structureless, with little evidence of soil development. Inset below older piedmont alluvium (Qpy and Qpi) or buries older deposits in distal piedmont areas. Up to a few meters thick.

**Qpi Intermediate piedmont alluvium.** Lower Holocene (?) to Middle (?) Pleistocene. Pebbly to cobbly sand, silt, and clay, with abundant boulders of Paleozoic bedrock in northwestern map area. Upper surfaces of unit are commonly gravelly lags (desert pavements), and range up to several meters above active drainages. Deposits are weakly dissected to extensively stripped, depending on locality. Unit commonly exhibits pedogenic accumulation of gypsum a few decimeters below the surface. In areas where the deposit has been stripped, pedogenic gypsum horizons have been exposed and weathered to form a hard gypsum crust at the surface. Up to 5 m thick or more.

**Qgo Old Gravel Deposits:** Long, low mounds with flat tops that sit on the modern land surface and consist primarily of cobbles to boulders of Sierra Blanca volcanic material. Presumed to be the erosional remnants of material shed off the

western escarpment of the northern Sacramento Mountains. Mounds have no internal stratification and no evidence of older bedrock. Up to 2 m thick.

### **Quaternary Extrusives**

**Qb Carrizozo Basalt Flow:** Alkalic to transitional olivine basalt. Black to dark gray aphanitic vesicular basalt with rarely visible phenocrysts of olivine. Texture is predominantly pahoehoe, but locally a'a textures prevail. Dated at ~5000 years old (Dunbar, 1999).

### **Tertiary Deposits**

**Tg Gravel:** Well-cemented cobble to boulder conglomerate. Clasts are Sierra Blanca volcanic fragments, as well as occasional siltstone and sandstone fragments, all of which are subrounded to well rounded. Matrix is a very coarse sandstone that is subrounded to subangular, poorly sorted with high proportion of silt and clay and more than 80% lithics. Unit is locally incised into underlying Cretaceous strata and usually buried beneath modern deposits. Basal contact is locally an angular unconformity with Cretaceous strata.

### **Tertiary Intrusives**

**Tidm Intermediate Dikes:** Vertically oriented intrusions that are andesitic in composition with equigranular matrix and phenocrysts of pyroxene and occasionally feldspar. Phenocrysts are 2-5% of the rock and range in length from 1-2 mm to 1 cm. In one dike, pyroxenes are up to 6 cm in length and are 10% of the rock.

**Tidf Fine Grained Intermediate Dikes:** Green to dark green syenogabbros with pyroxene phenocrysts usually less than 1 cm in length and comprising up to 2% of

the rock. Outcrop exposures tend to be short in length, never exceeding 0.75 km and usually much shorter. Also usually pervasively altered.

**Tita Trachyandesite Dike:** Comprised of zoned feldspar in a matrix of feldspar and pyroxene. Phenocrysts are plagioclase feldspar and are up to 3 mm across.

**Tiss Syenite Sill:** Reddish brown sill with plagioclase and potassium feldspar. No quartz was observed. Phaneritic texture, 2-3 m in thickness.

**Tisf Fine Grained Intermediate Sills:** pinkish brown or pale green aphanitic with very rare phenocrysts of pyroxene or feldspar. Occasionally platy in appearance and less than 1 m in thickness.

**Tism Megacrystic Sills:** Andesitic in composition with equigranular matrix and phenocrysts of pyroxene. Phenocrysts are 2-5% of the rock and range in length from 1-2 mm to 1 cm.

### **Cretaceous Strata**

**Kcc Crevasse Canyon Formation:** Fine to medium grained, well rounded, well sorted with up to 20% lithic fragments that include chert grains. These sandstone contain relatively abundant clay matrix and thus are classified in general as lithic wackes. The dominant sedimentary structures are trough crossbeds, though planar tabular bedding and massive beds are also present. Color of the sandstone varies from brown to pale green to yellow, though most are yellow. Muscovite mica is a common component of the shales, which are yellow-gray and contain siderite nodules and can be carbonaceous.

**Kg Gallup Sandstone:** Yellow quartz arenite/wacke that is relatively poorly cemented. The sandstone is fine to medium grained, subrounded, moderately well

sorted, though some beds are well sorted, well rounded quartz arenites. Trough crossbedding is the dominant sedimentary structure and fossils found in this unit include “razor oysters” and the bivalve *Cardium* sp. In the lower third of the unit, medium to thick bedded sandstones are interbedded with thin shale intervals that occasionally include large, orange siderite concretions.

**Kmd D Cross Tongue, Mancos Shale:** Dark yellowish gray shale with common siderite concretions that are up to 0.5 m in diameter. Occasional sandstone concretions with shell fragments are also present. In the upper third of the unit, very thin laminar or massive fine grained sandstone lenses may occur, reflecting the gradational contact between the upper Mancos and the overlying Gallup Sandstone.

**Kmt Tres Hermanos Formation, Mancos Shale:** Series of interbedded poorly cemented pale yellow crossbedded sandstones and much more indurated dark brown lithic arenites that contain shell debris and chert fragments. The yellow sandstones are trough crossbedded quartz to lithic wackes that are medium grained, moderately well sorted and with subrounded grains. The dark brown sandstones are medium to coarse grained, subrounded, moderately sorted with up to 30% chert and 70% quartz. These beds are 0.5 m in thickness and either planar tabular bedded or massive. In places, lenses of bioturbated yellow brown sandstone occur that often include dense lenses of oyster and bivalve fragments, as well as ammonites that range in size from 10 cm in diameter to over 0.3 m in diameter.

**Kmm Mancos Shale:** Lower Mancos shale consists of interbedded thin sandstone beds and dark gray shale with multiple white to gray-white bentonite beds in the lower part. Up-section, there are no sandstone beds and fewer bentonite layers. The Bridge Creek Beds include three limestone units, each of which consists of a single limestone bed that is never more than 0.5 m thick. Each limestone bed is separated from the one above by less than a meter of gray shale. The lower unit is

a dark gray (fresh), densely crystalline micrite with that is nodular and weathers dark yellow. Locally this unit is fossiliferous, though the majority of the material is broken shell fragments. Recently, a rare specimen of *Picnodonte newberryi* was collected from this area. The second limestone is laminated dark gray micrite and the third limestone is similar to the first, though does not appear to contain fossils. Above the Bridge Creek Beds is gray shale.

**Kd Dakota Formation:** Quartz arenite to quartzite that ranges in color from white to yellow to pale purple. It is medium grained, well sorted and has well rounded grains with little to no matrix. Beds are usually massive, though occasionally display trough crossbedding. The lower part of the unit is thick bedded, though bed thickness becomes more variable in the upper part where the sandstone interfingers with thin dark gray shale layers. Locally, significant accumulations of manganese have collected on bedding planes and joint surfaces, turned large parts of the outcrop a dark metallic purple color and include small accumulations of ?boernite.

## **Triassic Strata**

**Trm Moenkopi Formation:** purple-gray and consists of interbedded pebble conglomerates and very coarse to fine sandstones. Sandstones are usually coarse to very coarse grained, but thin beds of very fine grained sandstone are also present. Composition varies between lithic arenite and quartz arenite with lithic fragments including chert. Dominant sedimentary structures in sandstone beds are planar tabular and tabular crossbedded. Rarely, high angle trough crossbedding was observed. Grains are well rounded and range from poorly sorted to well sorted. Conglomerates are primarily matrix supported quartzite and chert pebble conglomerates that often have faint planar crossbeds. Both sandstone and conglomerate beds frequently contain red, purple or yellow mud rip-up clasts that are well rounded.



## Permian Strata

**Pag Grayburg Formation, Artesia Group:** Red-orange, very fine to fine grained quartz arenite/wacke with well sorted, well rounded grains. Heavily bioturbated such that most original sedimentary features were obliterated though laminations and ripple laminations can be observed in places. Common to abundant pale green reduction mottles and streaks. Locally beds are bleached nearly white.

**Psr Rio Bonito Member, San Andres Formation:** Thin beds of dolomite with rare medium beds of dark gray micrite. No fossils are preserved. Locally the unit is heavily brecciated, probably by later karsting. Modern karst features include large sinkholes developing along the tops of the ridges that are up to 15 m in diameter. Represents only the lower third of the Rio Bonito Member, as no medium bedded, dark gray wacke-packstone beds were observed.

**Py Yeso Formation:** Very pale reddish brown to light brown. Predominantly gypsum with minor limestone/dolomite. No sandstone or mudstone beds were observed. Gypsum is faintly laminated in places, though bedding is usually contorted. Very rarely, near-alabaster quality gypsum was observed. Limestone beds are less than 0.3 m thick, are dark brown gray in color and appear to be intensely bioturbated, though no fossils are preserved (suggesting partial dolomitization of these units).