

# Geologic Map of the Tularosa Quadrangle, Otero County, New Mexico.

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**May 2008**

**New Mexico Bureau of Geology and Mineral Resources**  
*Open-file Digital Geologic Map OF-GM 179*

**Scale 1:24,000**

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# **GEOLOGIC MAP OF THE TULAROSA 7.5-MINUTE QUADRANGLE, OTERO COUNTY, NEW MEXICO**

BY

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# INTRODUCTION

Here we present descriptions for geologic map units depicted in the Tularosa 7.5-minute quadrangle, New Mexico. The Tularosa quadrangle generally consists of west-sloping alluvial fan deposits that grade westward into more gently sloping basin floor deposits. Alluvial fan sediment consists primarily of silty sand, with common gravel near the mountain-front and clay becoming abundant in the west. Basin floor deposits generally consist of clayey very fine- to fine-grained sand, clay, and gypsum beds. Locally minor gravel beds may be present in basin-floor deposits on this quadrangle. The extreme northeast corner of the quadrangle catches the base of the northeast-trending Sacramento Mountains (i.e., the Coyote Hills at the foot of this mountain range). Rocks exposed in the mountain-front on this quadrangle consist of intercalated: 1) fluvial sediment of overbank reddish shale together with channel-fill sandstone and pebbly sandstone, and 2) shallow marine limestone beds. These strata belong to the Bursum Formation (Permian), which has also been called the Laborcita Formation (Otte, 1959). Locally, the Bursum Formation has been intruded by Eocene-age syenites. The area mapped by the respective authors is shown in **Figure 1**. **Figure 2** depicts the age relations of the units described below, and stratigraphic relations are demonstrated in **Figure 3**. **Table 1** presents a descriptive summary of the major map units and lists potential land uses. **Table 2** lists C-14-related data for charcoal sampled from alluvial fan sediment here and to the south.

## DESCRIPTION OF MAP UNITS

### QUATERNARY UNIT DESCRIPTIONS

The Quaternary units on this quadrangle are found in two topographic positions: 1) on the gently westward-sloping basin floor in the southwestern and western parts of the quadrangle, and 2) on steeper alluvial fans emanating from the Sacramento Mountains in the north-central and eastern parts of the quadrangle. The laterally gradational contact between the basin-floor and alluvial fans is drawn based on a variety of factors: increase in clay, lessening of slope from  $\sim 0.7^\circ$  to  $0.3\text{-}0.6^\circ$ , and farthest eastern extent of gypsum deposits. We categorize the map units according to these topographic positions below.

These units were mapped by field traverses and aerial photography (White Sands Missile Range project, December and November of 1985; BLM, 1975). Initial work consisted of mapping representative parts of the alluvial fan and basin-floor sediment with a hand-held GPS unit and using the 10-ft contours on the published topographic map. This preliminary map was then utilized in identifying and mapping units using aerial photography. Mapping from aerial photographs using the PG-2 plotter at the U.S. Geological Survey in Denver produces relatively precise lines (contacts) separating the map units. Line work from the aerial photographic-based mapping was then field-checked during subsequent field visits to the quadrangle. Not all air photographic-based mapping could be field-checked because of access restrictions for the White Sands Missile Range and private property near Tularosa. In the areas we did field-check, we

found that there was an approximate 5-10% error in map unit identification using the aerial photographs. Consequently, the user should assume that there is a potential 5-10% error in the identification of the Quaternary map units (probably more error in the White Sands Missile Range). Some areas of the alluvial fan have two or more units that cannot be practically differentiated at a scale of 1:24000. In such cases, we use nomenclature reflecting a combination of units (e.g., Qf3am). Otherwise, we interpret  $\leq 10\%$  of other units present within a single-named unit. For example, in a map unit labeled “Qf1” we interpret  $\leq 10\%$  of other map units, such as Qf2 or Qf3, within that mapped polygon.

A brief discussion is warranted on the difference between lithostratigraphic and allostratigraphic units. For the alluvial fan depositional environments, we separate units based on unconformable contacts (representing inferred time gaps between overlying and underlying deposits) or by inset relations. For example, unit Qf2 unconformably overlies unit Qf1, and both are inset and back-filled by Qf3. However, it so happens that these three alluvial fan units have lithostratigraphic differences as well, that is, one can use sedimentological criteria to recognize these units. In addition, surface processes dependent on age -- such as desert pavement development, clast varnishing, gypsum accumulation, and eradication of original bar-and-swale topography -- can be used to differentiate the alluvial fan deposits.

We have subdivided the basin-floor deposits into a younger (Qbfy) and older (Qbfo) unit, which probably temporally correlate to alluvial fan units Qf3 and Qf2 (for Qbfy) and Qf1 (for Qbfo). Although there may be an unconformity separating Qbfy and Qbfo, such a contact is not obvious in the field. Instead, Qbf3 and Qbf1 are differentiated based on lithostratigraphic criteria: Qbfo consists largely of clayey sand and clay with minor gravelly channel-fills, and Qbfy consists of intercalated sand, pebbly sand, and clayey-silty sand. Another prominent basin-floor deposits, Qgy, is readily recognizable because it consists predominately of gypsum.

Grain sizes follow the Udden-Wentworth scale for clastic sediments (Udden, 1914; Wentworth, 1922) and are based on field estimates. Pebbles are subdivided as shown in Compton (1985). The term “clast(s)” refers to the grain size fraction greater than 2 mm in diameter. Descriptions of bedding thickness follow Ingram (1954). Colors of sediment are based on visual comparison of dry samples to the Munsell Soil Color Charts (Munsell Color, 1994). Soil horizon designations and descriptive terms follow those of the Soil Survey Staff (1992), Birkeland et al. (1991), and Birkeland (1999). Stages of pedogenic calcium carbonate morphology follow those of Gile et al. (1966) and Birkeland (1999). Because both calcic and gypsum often accumulate together in a given soil horizon on this quadrangle, we may use the term “apparent carbonate morphology” to indicate that gypsum accumulation is influencing the determination of the carbonate stage. Discussion of a unit’s age control is presented in the accompanying report.

**Unless otherwise noted below, Quaternary gravel on this quadrangle consists of limestone and possible dolomite with 1-10% sandstone and siltstone clasts, and trace to 5% Tertiary igneous rocks (unit Ti). Sand is subrounded to subangular. Medium to very coarse sand has a composition consistent with a litharenite, whereas very fine- to fine-grained sand is more arkosic (as inferred using a hand lens).**

## SLOPEWASH

**Qgysw Gypsiferous slopewash (late Holocene)** – gypsum and gypsiferous silt and very fine to fine sand reworked from locally adjacent, topographically higher basin-floor deposits (i.e., **Qgy** and **Qbfy**). Because these deposits lie below the inferred 1-2 ka maximum depositional surface (see discussion in report), they are inferred to post-date 2 ka. In the valleys cut into gypsum in the western quadrangle, these slopewash deposits are lumped with unit **Qbfvf** and **Qah**. Estimated thickness of 2-5 m.

## ARTIFICIAL FILL AND EXCAVATIONS

**ae Artificial excavation (modern)** – Pit, quarry, or reservoir; the base of these excavations have generally been filled by >10 cm-thick deposits of clay, silt, sand, and gravel carried into the pit by mass-wasting or slopewash processes.

**af Artificial fill (modern)** – Compacted silt, clay, and very fine to medium sand (minor coarse to very coarse sand and pebbles) under highways and railroads; also found in berms surrounding pits, quarries, or reservoirs. In the case of railroads and mounds in the White Sands Missile Range, very coarse pebbles and cobbles drape compacted fill.

## DEPOSITS SPANNING THE ALLUVIAL FAN AND BASIN FLOOR

**Qam Sand, silt, gravel, and clay associated with modern drainages on alluvial fans and the basin-floor (0-50 yrs old)** – Sand, silt, and clay in various proportions at the mouths of small, discontinuous gullies. Sand and gravel dominate in the channel of Tularosa Creek. The surface of this unit exhibits fresh-appearing bar and swale topography (up to 30 cm relief). Sand is generally pink (5-7.5YR 7/3) to light reddish brown (5YR 6/3), very fine- to very coarse-grained, and poorly to well sorted. In the distal alluvial fans, this unit supports a moderate to dense cover of grass and mesquite. Bar and swale topography may be absent on distal alluvial fans. However, topography may still be present because of fine sediment (i.e., clay, silt, and very fine- to fine-grained sand) accumulating around dense vegetation, such as grass clumps and creosote bushes. Loose. Generally less than 2 m-thick.

**Qah Historical deposition of sand and silt at the mouths of discontinuous drainages (50-200 yrs)** – Light brown (7.5YR 6/4) silt and very fine- to fine-grained sand that is distinctly planar-laminated, low-angle cross-laminated (<0.5 cm-thick), or wavy laminated. Surface exhibits subtle scouring or possible bar forms. No observable soil development, desert pavement or clast varnish. Unit is generally less than 20 cm-thick

and overlies unit **Qf3**. Only mapped where fluvial morphology can be seen on surface using aerial photographs. However, field investigations indicate that unit **Qf3** may be locally overlain by 10-20 cm of this deposit, even though surface fluvial morphology was not apparent. This unit was deposited by sheet flood processes. 10-30(?) cm-thick.

**Qamh** A composite unit consisting of **Qam** (mostly) and **Qah** (0-200 years) – See descriptions of **Qam** and **Qf3y** above.

**Qahm** A composite unit consisting of **Qf3y** (mostly) and **Qam** (0-200 years) – See descriptions of **Qam** and **Qf3y** above.

## ALLUVIAL FAN DEPOSITS

### **Qf3** Silty-clayey sand, sand, and subordinate gravelly sand and clay (upper Holocene) –

This unit underlies the majority of alluvial fan surfaces in the study area, and coincides with both agricultural and urban areas. Sediment color generally ranges from light reddish brown (5YR 6/3-4), reddish brown (5YR 5/3-4), brown to light brown to pink (7.5YR 5/4, 6/3-4, and 7/4), and pinkish gray (7.5YR 6/2) to light gray (10YR 7/2). Sediment consists of a clayey-silty very fine- to medium-grained sand that is moderately sorted. The fine sediment is typically massive or in thick, vague beds that may be bioturbated (minor planar-laminations). Locally, coarse to very coarse-grained sand is present and minor pebbles may be scattered in a sandy matrix. There are also minor coarse channel-fills consisting of pebbly sand to sandy pebbles. These coarse channel fills are in thin to medium beds that are broadly lenticular to lenticular. Pebbles are very fine to very coarse with 1-5% fine cobbles, subrounded, and poorly sorted. Sand in coarse channel-fills is dark reddish gray to reddish brown (5YR 4/2-5/3), very fine- to very coarse-grained, and poorly sorted. The overall less gravelly texture helps in differentiating this unit from gravelly **Qf2** deposits. The surface is generally not as bouldery and cobbly as that associated with **Qf2**, but yet commonly has a pebble to fine cobble gravel lag in the medial and proximal fan areas that indicates erosion of the surface (see **Qf3c** description below). The surface has slight bar and swale relief of 10-30 cm. Its desert pavement has weak to no clast armor and no to slight varnish. Soil development is characterized by gypsum accumulations as filaments or disseminated (comparable to a stage I in a calcic soil horizon). **Qf3** unconformably overlies **Qf1** (see **Figure 3**), and appears to interfinger laterally into unit **Qgy** (the transitional zone was mapped as **Qbgy**). Unit generally corresponds to **Qf3m** and **Qf3L** of Koning (1999) and Koning et al. (2002), and to **Qf3** of Koning et al. (2007). Unit correlates to the Organ alluvium in the Desert Project, which have been assigned an age of 7-1 ka (Gile et al., 1981). A **Qf3** deposit on the Mule Canyon alluvial fan south of Alamogordo consisting of an in-filled swale returned a C-14 age of  $1980 \pm 50$  yrs (Koning, 1999, and Koning et al., 2002). On the distal alluvial an southeast of this quadrangle, a C-14 date from charcoal returned an age of  $5140 \pm 10$  (radiocarbon years; **Table 2**). Generally less than

2 m-thick, but locally as much as 3-4 m (particularly in the medial and proximal parts of the fan).

**Qf3am** **Comination unit of Qf3 and Qam (upper Holocene to modern)** – See descriptions of **Qf3** and **Qam** above.

**Qf3c** **Gravelly sand and gravelly sand (upper Holocene)** – Sediment color generally ranges from light reddish brown (5YR 6/3-4), reddish brown (5YR 5/3-4), brown to light brown to pink (7.5YR 5/4, 6/3-4, and 7/4), and dark reddish gray (5YR 4/2). This unit consists of silty-clayey sand intercalated coarse channel-fills. This sediment is similar to unit **Qf3** (see above), but has slightly more coarse channel-fills of pebbly sand to sandy pebbles. Beds are thin to medium and broadly lenticular to lenticular (locally cross-stratified). Pebbles are very fine to very coarse with 1-5% fine cobbles, subrounded, poorly sorted, and composed of limestone with very minor clasts of Paleozoic sandstone-siltstone and Tertiary intrusives. Sand is very fine- to very coarse-grained and poorly sorted. Because of the general lack of exposures, this unit was mapped via aerial photographs for deposits underlying surfaces with more than 10-20% surface gravel coverage. Surface has slight bar and swale relief of 10-30 cm. Its desert pavement has weak to no clast armor and no to slight varnish. Surface soils characterized by gypsum accumulation (for comparative purposes, similar in amount to a stage I to II in a calcic soil). Commonly has a pebble to fine cobble gravel lag in the medial and proximal fan areas that indicates erosion of the surface; however, the surface has less coarse gravel compared to the surface of **Qf2**. Unit unconformably overlies **Qf1** (see Tu-154 stratigraphic section in **Figure 3**). Like unit **Qf3**, this unit correlates to the Organ alluvium of the Desert Project by Las Cruces and ranges in age from 7 to 1 ka (Gile et al., 1981); most deposits are probably 5-2 ka. Weakly consolidated and 1-4 m-thick.

**Qf3s** **Sand and silty sand (middle to upper Holocene)** – Pink to reddish brown (7.5YR 7/4 to 5YR 5/4) silty very fine- to fine-grained sand with minor medium- to very coarse-grained sand. Sand is moderately to well sorted and contains minor pebble beds. Mapped immediately north of Tularosa Creek for an area that is tanner and sandier than sediment found near the northern border of the quadrangle. This unit probably extends south of Tularosa Creek, but its extent there is obscured by agricultural activity. Unit is also differentiated in the southeastern quadrangle near the railroad tracks. Base of unit not observed in field, but presumably it probably overlies **Qf1**. Probably 1-3 m-thick.

**Qf3sh** **Sandy distal alluvial fan deposits forming topographic highs (middle to upper Holocene)** – Sand and minor pebbly sand forming slight topographic highs near the basin-floor alluvial fan transition. Only mapped in the south-central portion of the quadrangle. Sand is light brown (7.5YR 6/3-4), very fine- to medium-grained, moderately sorted, and contains minor silt. Has <15% patches of strong gypsum accumulation exposed on its surface, but generally gypsum accumulation in the soil is probably similar to that of unit **Qf3**. Base of unit not observed in field, but presumably it

overlies **Qbfo**, **Qf3**, or **Qf1**. Unit supports moderate creosote and grass vegetation. Probably 1-2 m-thick.

**Qf3gh Gravel-capped, slightly high-standing ridges of Qf3 (middle to upper Holocene)** – This is a subunit of **Qf3** which is differentiated because of its gravelly texture, slightly older surface (and associated higher gypsum content), and its topographically high nature. Unit consists of a reddish brown (5YR 5/4) pebbly sand. Sand is very fine- to very coarse-grained. Pebbles are very fine- to very coarse and locally includes 5% fine cobbles. Pebbles are subrounded to subangular, dominated by limestone, and form a weak to moderate pavement (generally greater than 10% clast surface cover). Clasts are weakly to moderately varnished. Surface lacks original bar- and swale relief and generally has <15% patches of strong gypsum accumulation. Surface gravel may overlie pink (7.5YR 7/3), internally massive, silty-clayey very fine- to fine-grained sand, with minor medium to very coarse sand; sediment contains 5% gypsum filaments (equivalent to a stage I in a calcic soil). The clast armor allows preservation of broad but yet elongated, relatively flat surfaces that stand 20-120 cm above surrounding, eroded low areas. Surface supports a moderate cover of creosote (mostly) and other shrubs (about 3 plants per 5 m<sup>2</sup>). The **Qf3gh** surface is probably about 12 ka, assuming a regional incision event starting about that time (see accompanying report). The deposit underlying the surface is probably slightly older (2-4 ka). Base of unit not observed in field, but presumably it overlies **Qbfo**, **Qf3**, or **Qf1**. Unit is approximately 1-2 m-thick and includes the lower, gravelly channel-fills immediately under any silty-clayey fine sand mantles.

**Qf3cl Clay in the distal alluvial fan (middle to upper Holocene)** – Reddish brown (5YR 5/4) clay and sandy clay. Generally internally massive and hard. Sand is very fine- to medium-grained and moderately sorted. Estimate 20% gypsum filaments throughout exposed profiles, with 30-40% gypsum filaments in the upper 10-20 cm. Unit grades laterally eastward into **Qf3s** or **Qf3**. Probably 2-3 m-thick.

**Qf2 Sandy gravel and gravelly sand (lower(?) to middle Holocene)** – This unit is only preserved in relatively small areas adjacent to the mountain front, where it is distinguished by its gravelly surface that is both less varnished than the **Qf1** surface and higher topographically than the **Qf3** surface. This quadrangle offers no good exposure of the unit. Surface descriptions suggest that the sediment is a pebbly sand to sandy pebble-cobble; the sandy matrix is a light brown (7.5YR 6/4), silty-clayey, very fine to very coarse sand (mostly very fine- to medium-grained), and poorly to moderately sorted. Surface mantled (>50% clast density) by very fine to very coarse pebbles and minor fine to coarse cobbles. These clasts are non- to moderately varnished. Surface clasts generally lack calcium carbonate coats, are poorly sorted, subangular to subrounded, and composed of limestone with an estimated 3-5% arkosic sandstone and granite clasts (trace quartzite clasts). Pavement is moderately to well-developed and has minor underlying Av peds. Less than 10% strong gypsum accumulation is apparent on the



surface. Surface lacks bar and swale topography and is undissected. The surface of **Qf3** is lower (by ~ 1 m) or level with this surface. The gravel of **Qf2** is commonly draped over **Qf1**. Estimate about 1 m-thickness on this quadrangle.

**Qf1 Sandy gravel, gravelly sand, and silty-clayey fine sand (upper middle(?) to upper Pleistocene)** – Although common near the mountain-front, this reddish alluvium is generally not well-exposed. It is recognized by its topographically high, smooth surface dissected by gullies (0.5-1.0 m-deep) that have been partly back-filled by **Qf3** deposits. This surface is smooth and lacks original bar and swale topography. This surface is slightly reddish in color, has a weak to moderate pavement of well-varnished clasts (up to 65% clast coverage), and has much indications of high gypsum accumulation (equivalent to a stage III in a calcic soil). Shallow gullies cut into **Qf1** reveal a reddish brown (2.5YR 5/4) silty-clayey very fine- to medium-grained sand (minor medium- to very coarse-grained) that is moderately sorted. Surface gravel include very fine to very coarse pebbles and 8-10% fine cobbles. In the distal alluvial fans, exposures indicate intercalated channel-fill gravel and overbank fine sediment. The gravel beds are >1 m-thick and consist of clast-supported, imbricated pebbles and cobbles. Overbank sediment consists of clay, silt, and very fine- to fine-grained sand; calcium carbonate nodules may be present in the clayey soils. The topsoil of this unit appears to lack a calcic horizon because of the high gypsum input. To the south, this unit characteristically exhibits multiple buried soils consisting of reddish horizons possessing illuviated clay and/or ped structure that overlie whitish calcic-gypsic horizons. Correlates to the Jornada II alluvium in the Desert Project, which is inferred to be upper middle to upper Pleistocene in age (Gile et al., 1981, table 9). This age range is consistent with a possibly finite radiocarbon age of  $41,320 \pm 1000$  ka from charcoal collected from fine-grained sediment correlated to **Qf1** located 1.5 km southeast of the International Space Hall of Fame (UTM coordinates of  $414,580 \pm 60$  m E,  $3,641,500 \pm 60$  m N; fig. 9 of Koning et al., 2002). Base of unit not defined, but alluvial fan sediment filling the basin here is several hundred meters thick. Greater than 8 m-thick.

**Qf1sc Silty clayey fine sand with subordinate sandy gravel and gravelly sand; deposited by fluvial, slopewash, and colluvial processes near the mountain front (upper middle(?) to upper Pleistocene)** – Temporally equivalent to **Qf1**, this deposit is located on the footwall of the Alamogordo fault, immediately adjacent to the mountain front, and has received much detritus from slopewash and colluvial processes. Sediment is light brown to pink (7.5YR 6/4-7/3) sand with very minor pebbles. Sand is a silty-clayey, very fine- to fine-grained, subangular, and poorly sorted. The high gypsum content is consistent with high eolian input, probably reworked slightly by slopewash or colluvial processes. Sediment is massive, bioturbated, and has strong gypsum accumulations near the surface (equivalent to a stage III morphology in a calcic soil). At least 3 m-thick.

## **BASIN FLOOR DEPOSITS**

- Qbfy** **Younger basin-floor deposits of intercalated clayey sand, fine sand, silt, and gypsum (middle to upper Holocene)** – Only mapped locally in the northwestern part of the quadrangle. Not exposed, but surface sediment seems similar to that of unit Qf3, with the exception of more gypsum accumulation. Probably 1-2 m-thick were mapped..
- Qgy** **Gypsum accumulation (middle(?) Holocene)** – Yellowish white to pink (7.5YR 7/4) to very pale brown (10YR 7/4) gypsum that has been subjected to multiple dissolution and precipitation events. These processes have formed a hard crust >10 cm-thick on the surface of this deposit. Underneath, gypsum is generally moderately consolidated, massive or in tabular beds (up to 40 cm-thick), and consists of silt and very fine- to coarse-grained sand-size, platy crystals (mostly very fine to fine-grained) that are subangular to angular and well-sorted. Locally, this gypsum sand is planar-laminated to low-angle cross-laminated. Very thin cross-beds, with 30 cm-thick foresets, seen at one locality near base of the deposit. Gypsum sand may include subordinate plagioclase and quartz, and when dry has a “fluffy” feel. Surface of unit may have microkarst topography where exposed on slope shoulders. Flat surfaces are commonly overlain by pale brown (10YR 6/3) silt and very fine- to fine-grained sand a few 10s of meters thick. Interpreted to be a relict of an eastward expansion of the White Sands dune field in the middle Holocene. Deposit thickens westward and is inferred to interfinger eastward with unit **Qf3** (this transitional zone was mapped as **Qbfgy**). Deposit overlies **Qbfo**, probably over an unconformity. Lower meter of deposit commonly grades into more siliclastic sand that is clean, fine- to coarse-grained, and planar-laminated to very thinly bedded (included in **Qgy**). In the western and southwestern parts of the quadrangle, the surface of this unit is marked by minor to abundant sinkholes and similar collapse features, whose locations and extents are shown on the map. These are probably due to dissolution of gypsum beds several meters below the surface (in underlying **Qbfo**). Up to 4 m-thick.
- Qbfgy** **Gradation-interfingering between gypsum and younger basin-floor deposits (middle to upper Holocene)** – This gradational unit contains about 1/3-2/3 gypsum to 2/3-1/3 fine-grained, basin-floor sediment of unit **Qbfy**. Surface sediment commonly consists of pinkish, gypsiferous silt and very fine- to medium-grained sand. Mapped where unit **Qgy** transitions eastward into unit **Qf3**. Probably 1-3 m-thick.
- Qgyes** **Gypsum sand sheet (middle to uppermost Holocene)** – Light-colored gypsum sand that lacks dune forms. Probably eolian. Not described in detail because of access restrictions in the White Sands Missile Range.
- Qgyh** **Hardpan gypsum accumulation (uppermost Holocene)** – Gypsum, as described in **Qgy**, that is found in low areas and forms a hardpan. Probably accumulated by repeated evaporation of ponded water during the late Holocene. Less than 1 m-thick.

**Qbfvf Combined basin-floor and undifferentiated uppermost Holocene deposits (upper Pleistocene to uppermost Holocene)** – This unit occupies the floors of valleys of drainages that incised below unit **Qgy**. Lack of exposure and similar erosion patterns commonly presented difficulty in recognizing thin, discontinuous latest Holocene to modern deposits (**Qam** and **Qah**) versus older basin-floor deposits (unit **Qbfo**). Thus, these units were generally combined on these valley floors. Latest Holocene sediment is light yellowish brown (2.5Y 6/3), internally massive, well-sorted, subangular, and consists of silty sand composed of gypsum, calcite, quartz(?), and plagioclase).

**Qbfo Older basin-fill deposits of intercalated intercalated clay, sand, silt, gypsum, and calcium carbonate (middle Pleistocene to Holocene)** – Intercalated clayey fine sand, clay, silt, very fine- to fine-grained sand, and gypsum; colors range from reddish brown to light reddish brown (5YR 4-6/4) to pink (5YR 7/3 to 7.5YR 7/4) to reddish yellow (7.5YR 6/6) and yellowish red (5YR 4/6). Very thin to thick, tabular beds that are internally massive and commonly hard; locally planar-laminated. Local calcium carbonate nodules and thin to thick beds. Sand is very fine- to coarse-grained (mostly very fine- to medium-grained), moderately to well sorted, subrounded to subangular, and consists of various proportions of quartz, calcite, gypsum, feldspar, and minor lithic grains (including granite). Locally, there are minor, meter-scale-thick, sandy pebble to cobble beds interbedded in the typically fine sediment of this unit. Radiocarbon age of 27,010 +/- 160 obtained from gastropod shells from the upper part of this deposit (silt and clay beds), 1.1-1.3 below **Qgy** (**Table 2**). Base of unit not defined. Unit is exposed or underlies units **Qgy** or **Qbfy**. Total basin-floor sediment thickness is several hundred meters thick before Paleozoic bedrock is encountered.

**Qbfu Undifferentiated basin-floor deposits (middle Pleistocene to Holocene)** – Undifferentiated units **Qbfo** and **Qbfy**. See the descriptions of these units above.

## **TERTIARY IGNEOUS ROCKS IN SACRAMENTO MOUNTAINS**

**Ti Igneous intrusive rocks, probably syenite (middle to upper Eocene)** – Light greenish gray (10T 8/1), very small igneous intrusive that intrudes the Bursum Formation (**Pb**) on the immediate footwall of the Alamogordo fault in the northeast corner of the quadrangle. This intrusive is greenish, at least in part, because of hydrothermal alteration. The rock contains 25% phenocrysts of plagioclase and 7-10% pyroxene that are 0.1-3.0 mm in length. Intrusive rocks to the east have been characterized as nepheline normative trachybasalts, basaltic trachyandesites, trachyandesites, and dacites by McManus and McMillan (2002) and as diorite (minor camptonite) by Asquith (1974). However, we call this rock a syenite, consistent with mapping of these intrusive rocks to the northeast on the Cat Mountain quadrangle (Shari Kelly, written communication, 2008). <sup>40</sup>Ar/<sup>39</sup>Ar

ages of 44-36 Ma have been obtained on the aforementioned intrusive rocks to the east (McManus and McMillan, 2002).

## **SEDIMENTARY ROCKS IN SACRAMENTO MOUNTAINS**

**Pb** **Bursum Formation (uppermost Pennsylvanian(?) to lowermost Permian)** – Subequal mudstone relative to sandstone and pebbly sandstone beds; these sediments are intercalated with 20-25% limestone beds. Mudstone consists of weak red, reddish gray, and dark reddish gray (2.5-5YR 4-5/2) mudstone and sandy claystone, where the minor sand is very fine- to coarse-grained and arkosic. Sandstone and pebbly sandstone occupy medium to thick, lenticular to tabular channel-fills; internal bedding is massive to planar-laminated or in very thin to medium, planar to lenticular beds. Channel-fill sediment is pinkish gray to reddish gray (5YR 5-6/2) to pinkish gray (7.5YR 6/2). Sand is fine- to very coarse-grained, angular to subangular (mostly) to subrounded, moderately sorted, and an arkose to lithic arkose. Pebbles are very fine to very coarse (mostly very fine to medium) and consists of poorly sorted subangular to subrounded granite with various proportions of subrounded to rounded quartzite. One conglomerate bed on the northern quadrangle boundary consists of imbricated, subrounded to rounded, very fine to very coarse pebbles and fine cobbles (up to 10 cm-long) of quartzite and granite; estimate a 60:40 ratio of granite to quartzite and clast imbrication is to the west. Limestone beds occupy medium to thick (mostly thick), tabular beds and are gray to light gray (2.5-5Y 5-7/1) and commonly micritic (at least in the quadrangle area). Very thick limestone beds (~2 m-thick) that cap the ridge top contain intraformational conglomerate of locally transported limestone clasts (probably transported only a few meters); these weather to form a knobby outcrop. Strata are well-cemented. Unit called the Laborcita Formation by Otte (1959), but we favor retaining the Bursum Formation here (see Lucas and Krainer, 2004). Exposed thickness on quadrangle is 40 m-thick. Age control obtained from fusulinids indicate a general lower to middle(?) Wolfcampian age (~299-290 Ma); this would be equivalent to earliest Permian given that the Wolfcampian is included in the Permian at the time of writing. Total thickness of this formation in the vicinity was estimated at 300 m (1000 ft) by Otte, 1959), considerably thicker than the 100 m (340-350 ft) reported by Pray (1961).

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## CAPTIONS

- Figure 1.** Index map of the Tularosa quadrangle that shows areas mapped by the respective authors.
- Figure 2.** Time-stratigraphic correlation of map units.
- Figure 3.** Fence diagram correlating three stratigraphic sections in the northern quadrangle.
- Table 1.** Summary of characteristic features of the major map units on this quadrangle and societal implications (e.g., land use, and hazards).

## Comments to map users

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map are based on reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

The map has not been reviewed according to New Mexico Bureau of Mines and Mineral Resources standards. Revision of the map is likely because of the on-going nature of work in the region. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Mines and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government. Cross-sections are constructed based upon the interpretations of the authors made from geologic mapping, and available geophysical (regional gravity and aeromagnetic surveys), and subsurface (drillhole) data.

Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.