Preliminary Geologic Map of the Capitan Peak Quadrangle, Lincoln County, New Mexico

By

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Introduction

The Capitan Pass and Capitan Peak quadrangles lie between about 25 to 37 miles east of Carrizozo and about 45 to 60 miles west of Roswell, New Mexico on the northeast side of the Sacramento Mountains. Elevations range from about 5,800 feet in the southeast corner of the Capitan Peak quadrangle to 10,083 feet at Capitan peak. The landscape exhibits at least three distinct types of vegetation cover. Much of the landscape in the southern parts of both quads (areas underlain by the San Andres Formation and younger units) is covered with grass and open woodlands composed of piñon pine and juniper (*Photos 1 and 2*). The broad alluvial slope in the central parts of both maps that separates the Capitan Mountains from the bedrock hills to the south is also mostly piñon pine and juniper but is commonly more densely vegetated (*Photo 3*). Some areas of this alluvial slope are rather free of trees and may have been artificially cleared. The vegetation in the Capitan Mountains changes with elevation and with the facing direction of the slope. The lower slopes are a transition from piñon and juniper to Spruce-fir forest. This transition occurs generally between 7,200 and 9,000 feet elevation (Martin, 1964). Above 9,000 feet the mountains are covered with spruce-fir forest and groves of aspen (*Photo 4)*. Pine trees (Ponderosa?) also preferentially grow along most of the major drainages that drain past the southern edge of the maps (*Photo 5*). .

Geologically, this area covers the northernmost end of the Pecos Slope, defined mostly by a very gentle, 1-2 degree eastward slope of the resistant cap of San Andres Formation. Where drainages have incised deeply, the underlying beds of the Permian Yeso Formation are exposed. These beds are in most places tightly folded and this represents the type locality for the Lincoln fold belt. The two quadrangles also straddle the area between the Mescalero arch on the west and the Tinnie-Dunken fold belt (or anticlinorium) on the east. West of the Mescalero arch bedding in the San Andres Formation dips gently westward. Here, recessive-weathering red-beds of the Permian Grayburg Formation and yellowish sandstone and conglomerate of the overlying Santa Rosa Sandstone overlie the San Andres. Rising prominently on the north, the Capitan Mountains were formed by the intrusion of felsic (fine-grained granitic) magma into shallow very shallow levels at about 26.5 Ma.

Rio Bonito, which slices through the southern part of the Capitan Pass quadrangle, has dissected about 800 feet with respect to the exposed top platform of the San Andres Formation. Rio Bonito probably has a long history of down-cutting that probably began when Mesozoic sediments still overlay the San Andres Formation. Some

of the larger tributaries show incised meanders with steep cliff walls and dry cut-off meanders. The modern stream valleys are filled with loosely to moderately consolidated alluvial deposits that occur as relatively flat-topped terraces in at least four distinct levels. These terraces record periodic fluctuations in the cycle of deposition and erosion that occured all over the Southwest and are thought to be in part controlled by variations in climate.

The cultural diversity of the region is a mix of mostly Spanish, Mexican, and American heritage. The region is famous/infamous today for the, albeit short, Lincoln County War, and as the stomping grounds of Billy the Kid. The myth that surrounds both originates from the competition to win the contract to provide beef to the Federal Government Army troops stationed at Fort Stanton, a few miles west of the Lincoln Quadrangle. A few of the Ranchers in the area relayed that they had parents or grandparents that were alive at that time and whose ranches have been passed down within the same families to the present.

Unfortunately, many areas along Rio Bonito were not mapped in great detail because of private property issues. Mapping in these areas was supplemented with black-and-white aerial photos dated 1936, which have a scale of approximately 1:50,000, and color photos dated 1994 with a scale of approximately 1:24,000. For clarity and completeness, structural symbols derived from these photos, as seen on the map, are different from those symbols obtained on the ground (see the map legend). Field work for both the Capitan Pass and Capitan Peak quadrangles was carried out between June and December, 2009. Very windy conditions were the norm.

Previous Work

Bachman (1954) produced a reconnaissance map of the area that was later incorporated into a geologic map and hydrologic report by Mourant (1963) of the water resources in the Hondo drainage basin. Kelly (1971) made some of the first detailed regional geologic and structural maps of the Sacramento Mountains-Pecos slope region, and subdivided the San Andres Formation into three members. Semmes (1920), Talmage (1935), and the Panhandle Geological Society (1939) examined these folds and made conclusions about their origin. Craddock (1960; and 1964) studied these folds in more detail and coined the term 'Lincoln fold system'. Foley (1964) examined some of the folds near Lincoln and made some conclusions about their possible origin, as did Yuras (1991) on a more regional scale. At least two New Mexico Geological Society field trips have ventured through this area between Ruidoso, Hondo, and Capitan (Ulvog and Thompson, 1964; and Cather et al., 1991). Lucas (1991) made detailed observations and measurements of Triassic strata overlying the San Andres Formation immediately west of the Capitan Pass quadrangle. Rawling (2004, 2006) mapped the geology in the neighboring Ruidoso Downs and Fort Stanton 7.5' quadrangles, respectively, to the southwest. Sidwell (1946), Patton (1951), Butler (1964), Kelly and Thompson (1964), Kelly (1971), Allen and Foord (1991), and Allen and McLemore (1991) all studied the Capitan pluton.

Yeso Formation

The Yeso Formation is not well exposed in the study area. The best exposures are along Rio Bonito in the Capitan Pass quadrangle. Unfortunately, because of private property these exposures were not examined in detail. Rather good exposures in Lincoln Canyon on the southeast side of the Capitan pass quadrangle show interbedded yellow red quartz siltstone, thin- to medium bedded dolomite, and minor bedded gypsum, all relatively tightly folded (*Photos 6, 7, and 8*). For a more thorough description of the Yeso Formation in the Lincoln area see Skotnicki (2009a).

Grayburg and Santa Rosa Formations

The Grayburg and Santa Rosa Formations are both poorly exposed on the west side of the Capitan Pass quadrangle where they generally form very gentle rounded slopes mantled by soil and grass cover (*Photo 9*). In fact, the locations of these units can generally be deduced from grass cover alone since the neighboring outcrops of the San Andres Formation are almost everywhere covered with piñon and juniper (*Photo 10 and Panorama 1*).

The Grayburg Formation is dominated by rusty red-colored fine sandstone and siltstone, with thin interbeds and disseminated granules of light gray gypsum. The best exposures are in the steeper ravines immediately below the capping deposits of **Qm** (*Photo 11 and Panorama 2*). The contact between the Grayburg and the overlying Santa Rosa Sandstone is not well exposed and its location was estimated based on the color change from red below to yellow above. The 220-foot thickness of the Grayburg Formation was calculated assuming a gentle westward dip of 5°.

The Santa Rosa Sandstone is also poorly exposed and lies above the Grayburg Formation. The lower parts of this unit are dominated by fine-grained pale yellow quartz sandstone and interbedded calcarenite and calcilutites (*Photos 12, 13, and 14*). Limy sandstone beds are commonly fragmental and are composed of subrounded sand-size to small pebble-size (1.5 cm) fragments of tan to gray fine-grained limestone (*Photos 15 and 16*). Cross-bedding is common in sets tens of centimeters thick that show erosional bases. Some beds locally show erosional bases and rip-up clasts of sandstone (*Photo 17*). Locally, the yellow sandstone beds contain chert-pebble conglomerate beds up to 1-2 meters thick that form chert lags down-slope (*Photos 18 and 19*). The upper part of the unit (as exposed) is composed of conglomerate containing angular to subrounded pebbles to boulders (1 m) of dark brown medium- to coarse-grained pebbly sandstone (*Photo 20*), gray limestone, and a variety of felsic intrusive rock that is darker gray and more platy than is Ti. All exposures are very poor and the best exposures are immediately below the capping deposits of **Qm**. As with the underlying Grayburg Formation, the unit's thickness of 590 feet was calculated assuming a gentle westward dip of 5°.

Quaternary Deposits

The Quaternary (Neogene) deposits within the study area display a range of ages. The older deposits are up higher in the landscape, are more deeply dissected, and typically contain better developed soils. The younger deposits are lower in the landscape progressively closer to the valley floors, are less deeply dissected, and contain less developed soils. The different levels that these deposits occupy probably reflect pulses of deposition and relative landscape stability, punctuated by periods of dissection and down-cutting. These cycles are thought to have been driven by changes in the rate of climate change (Mann and Meltzer, 2007, and references therein). The last relatively stable period of deposition during the Holocene is defined by the young deposits that cover the flat valley floors. Throughout much of the Southwest these Holocene deposits have been dissected by young, steep-walled arroyos that began their entrenchment apparently as recently as about 120 years ago.

All of the Quaternary deposits are composed of interbedded gravel, sand, silt, and less abundant clay, cemented to varying degrees. They fill portions of the modern valleys, which means that the current valleys were originally eroded to a greater depth, and have since been back-filled with material. Within the quadrangle they are assigned relative ages, but have also been interpreted to represent, from oldest to youngest, Early Pleistocene (**Qo**), Middle Pleistocene (**Qm**), Late Pleistocene (**Ql**), and Holocene deposits (**Qy**). Although the relative age designations are firm, the absolute age designations (Pleistocene and Holocene) are interpretations based on comparisons with similar deposits in other areas of the Southwest (Gile et al., 1981).

The oldest **Qo** deposits are only found on the west-central edge of the Capitan Pass quadrangle (*Photo 21 and Panorama 3*). Here they form two small terrace remnants probably less than 10 feet thick. As mapped, they actually form two different levels, with the easternmost remnant being about 10 feet lower in elevation than the western remnant, but they were here mapped as one unit. These tiny remnants likely represent all that is left of a much larger sheet that covered a vast erosion surface in the early Neogene. These deposits represent the elevation of the land surface at that time. Since that time, the modern drainages nearby have cut down more than 200 feet.

The **Qm** deposits are exposed mostly on the west side of the Capitan Pass map and the eastern side of the Capitan Peak quad. The top surfaces of these deposits are between about 30 and 50 feet above the level of the modern drainages (*Photo 22*). Where exposed **Qm** deposits typically contain very well developed dark brown organic-rich surface soils overlying material strongly cemented by pedogenic carbonate (*Photo 23*). Where these deposits overlie less resistant formations, they form a protective cap and exhibit steep sided borders. As noted below, these deposits also locally contain appreciable amounts of iron clasts. Some surfaces close to the mountain front contain large boulders, some of which appear to have fractured as a result of pedogenesis (*Photos 24 and 25*).

Deposits labeled **Ql** occur at elevations between about 10-30 feet above the level of the modern drainages. These deposits also contain gravel, sand, silt, and minor clay, but their soil zones are not as well developed and they do not contain as much calcium

carbonate cement as the **Qm** deposits (*Photo 26*). In some areas it was easy to distinguish **Ql** deposits from younger **Qy** deposits. In areas where the distinction was not obvious the unit label **Qyl** was used to denote that this unit may contain both **Ql** and **Qy** deposits (*Photo 27*).

Most widespread of all the Quaternary deposits are the Holocene deposits (**Qyl** and **Qy**). These form the relatively flat alluvial fans and valley floors (*Photos 28 through 32*) . Upon closer examination, some of these deposits are actually composed of two and locally three different terrace levels, which were not mapped separately. The broad apron of **Qyl** along the southern edge of the Capitan Mountains is comparatively smooth and, except for locally thick vegetation, is easy to walk across, except for areas closer to the mountain front where larger boulders dominate. This is in contrast to the older alluvial fan deposits south of the mountain front that are characterized by a gently sloping plain covered by boulders of all sizes and shapes overgrown by thick forest. From a distance, it looks like this gently sloping apron provides easy access to the mountain front but in fact these surfaces are very difficult to navigate even on foot (*Photo 33 and Panorama 4 and 5*).

It is interesting to observe that nearly all of the alluvial fan deposits along the south side of the Capitan Mountains are stabilized by forest and grass. Some distributary channels do exist on the fans, but most of the active alluvial activity is confined to the relatively narrow modern stream channels. The form of the fan deposits suggests that these alluvial fans were formerly active across their morphology. The ubiquitous presence of large boulders attests to the great power that the streams must have had in order to move these clasts up to several miles. These observations suggest that the sloping apron we see today must have looked much different during the Pleistocene, when most of the alluvial apron was probably bare and in a continual state of flux as material was being eroded from the Capitan Mountains and moved downhill across these fans. We can think of the apron we see today as a landscape that is temporarily 'frozen' with respect to alluvial fan deposition.

Variations in clast composition in terraces

With the exception of Rio Bonito and the drainages that do not drain southward from the Capitan mountains, the vast majority of alluvial deposits of all ages contain fine-grained granite (**Ti**) as by far the most abundant clast type. However, there are some notable exceptions on the western side of the Capitan Pass quadrangle. In this area the southernmost mapped polygons of **Qm** (north of Salado Creek), and including the **Qo** remnants, contain clasts that originated from outside of the map area. These deposits contain dark brown medium- to coarse-grained quartz sandstone, chert-pebble conglomerate, gray limestone, different varieties of plagioclase-bearing andesites (monzonite/syenite/porphyry?), greenish gray hypabyssal intrusive rock containing large conspicuous black hornblende up to 1 cm across (dikes?), a variety of **Ti** that is darker gray and more platy, and minor chert. These lithologies suggest that the source of these rocks was to the west, in the Sierra Blanca igneous complex (Moore et al., 1991)(*Photo*

34). It is possible that either **Qo** or **Qm** deposits may be roughly equivalent to QTg deposits as mapped by Rawling (2006).

Iron placers

The iron deposits exposed in actual bedrock north of Capitan magnetite occurs as fracture-fills and as whole-sale and disseminated replacement deposits (Sheridan, 1947; Cather et al., 1991). Locally, individual beds of San Andres Limestone have been replaced, while others have not been. The iron commonly occurs with calcite, and less abundant quartz and clay minerals. Kelly (1952) suggested that mineralization was related to fluids associated with the cooling and crystallization of the Capitan intrusive (Smith, C.L., *in* Cather et al., 1991, p. 42). For a good description of the geology of the ore deposits in the Capitan Mountains see McLemore and Phillips (1991).

Although no iron deposits were found in-place along the front of the Capitan Mountains, iron is actually quite abundant within the middle Pleistocene alluvial deposits (**Qm**). Interestingly, these are the *only* deposits in which appreciable amounts of iron are found. The iron occurs as dark gray to black angular to subrounded clasts, from pebble-size up to about 40 cm across. The iron is most abundant in deposits on the west half of the Capitan Pass quadrangle, indicating that the bulk of the original bedrock deposits were located in the western Capitan Mountains. Qm deposits further east show much fewer iron clasts, yet their presence there indicates that iron deposits once existed further east as well. The dark clasts of iron contrast vividly with the light tan-colored clasts of **Ti** that dominate these deposits and are easy to see even on eroded slopes. In fact, where **Qm** deposits have been most extensively eroded the iron clasts locally form diffuse to dense iron lag deposits—in effect placers (*Photos 35, 36, and 37*). These placers are quite striking as nowhere else in the area can one see alluvial deposits composed of nearly pure iron. More of these lag deposits are also visible on the north side of the range in the Capitan peak quad, where they rest on top of eroded deposits of the Yeso Formation.

Interestingly, iron clasts are almost completely missing from the younger Late Pleistocene and Holocene alluvial deposits (**Qyl** and **Qy**) that form the broad aprons shed off much of the south side of the Capitan Mountains. This relationship suggests that there were still bedrock exposures of iron in the Capitan Mountains up through the Middle Pleistocene, but that nearly all of the original bedrock iron deposits were eroded away by the end of the Middle Pleistocene. After that almost no iron deposits remained to shed material onto the younger alluvial fans.

Capitan Intrusion

As Allen and McLemore (1991) point out, the Capitan pluton is the largest exposed Tertiary intrusion in New Mexico, covering an area of approximately 280 km^2 and having an estimated volume of at least 300 km^2 (*Photos 38, 39, and 40 and Panorama 6*). Based on geochemical analysis, Allen and Foord (1991) described the Capitan pluton as granite. They interpret it to be a single-phase pluton that is texturally and compositionally zoned, where the core is fine-grained granite porphyry and the upper

'cap' is granophyre. In the field, these two variants are not easy to distinguish, and indeed most of the pluton appears, at least superficially, to be composed of fine-grained granite to granite porphyry (*Photo 41*). As a result, all of the intact granitic bedrock was mapped as simply as **Ti**. Allen (1988) reported an age for the Capitan pluton of 26.5 ± 1.2 Ma.

Because most of the periphery of the pluton is surrounded by an alluvial apron nearly all of the contact relationships within the field area are obscured. However, south of the mountain range in both quadrangles the Yeso Formation is exposed at the surface in many areas, and is very close to the surface in others. In the northeast corner of the Capitan Peak quad the Yeso Formation is in actual contact with Tertiary granite and dips between 20° and 40° to the north. These observations suggest that the Capitan pluton intruded up into at least the base of the Yeso Formation (and possibly higher into the formation) where it mushroomed outward within this rheologically weak layer to form a laccolith. Allen and McLemore (1991) observed that the Capitan pluton intruded up into the lowermost Rio Bonito member of the San Andres Formation on the western side of the range as well as within the Yeso Formation (northwest of the field area), suggesting that the pluton locally intruded discordantly to stratigraphy. Although Kelly and Thompson (1964) also made the interpretation that the intrusion is a laccolith, Allen and McLemore (1991) pointed out that since the base is nowhere exposed an intrusive stock cannot be ruled out. In any case, Allen and McLemore (1991) calculated that if the original sedimentary section included the Tertiary Cub Mountain Formation, then the overlying thickness of host rocks into which the pluton intruded was likely between 2.1 and 2.3 km thick.

Periglacial Features

As drawn on the maps, map unit **Tig** covers an area, mostly in the upper elevations of the Capitan Mountains, that is nearly devoid of intact rock outcrop. Instead, the landscape is very rounded, but with the rounded slopes covered with poorly sorted angular clasts of granite of all sizes. On steeper slopes this detritus forms large talus slopes (*Photo 42*). From a distance most of these slopes exhibit a dark gray coloration, and locally much lighter tan-colored streaks. The dark coloration is the result of a rather continuous but very thin coating of lichen, whereas the lighter tan streaks are areas that have undergone mass movement relatively recently. Because the vast majority of the talus slopes are covered with lichen it is likely that these slopes have been stable for a relatively long period of time—likely for at least several hundred years, based on the large size of some of the slow-growing lichen. It was curious to observe how fragile and mobile these slopes are, because individual blocks moved rather easily when walked across.

Blagbrough (1991, 1999) observed and studied in detail what he interpreted to be rock glaciers on both sides of the Capitan Mountains. These features are mostly tongue-like and in some cases extend longer than one mile down many of the steep valleys eroded into the flanks of the mountain range. They are composed of loose, porrly sorted, angular granitic debris. These features are characterized by steep flow fronts or heads (at the angle of repose) and rather linear or sinuous sides commonly surrounding a central spoon-shaped depression near the head. As Blagbrough described, rock glaciers form

where the mean annual air temperature is very close to freezing. The pore spaces between the rocks may contain ice ("ice-cemented") or the rock glacier may contain a central core of ice ("ice-cored"). The steep slopes, combined with repeated freezing and thawing, prompt the rock glaciers to move downhill. Frost-wedging at higher elevations supplies material to the back of the flow. If temperatures are too cold for too long, then the freeze-thaw cycle is suspended and motion slows down or stops.

The locations of the obvious rock glaciers are drawn on both maps. However, only the prominent ridges along the flow fronts and linear sides were recorded. Behind most of these flow fronts are spoon-shaped depressions, although several of these have been breached by subsequent stream erosion. Arrows on the map show the direction of flow. As shown, these flow fronts and sides strongly resemble the terminal and lateral moraines of glaciers. Although to not exactly analogous, the symbols drawn on the map may be interpreted as the terminal downhill extent of these features. Many of the rock glaciers show successive and regular curved ridges uphill that resemble compression ridges on glaciers. Some rock glaciers exhibit many tens of these features.

The canyons in the upper elevations of the Capitan Mountains are much wider than the narrow gorges common to the lower elevations. As mentioned above, they are also very smooth. It is possible that these smooth, wide valleys were created by actually glacial activity, where small glaciers carved out broader U-shaped valleys in the higher elevations. If this is true then the rock glaciers may be more recent overprints on older glacial valleys.

Although previous workers probably took this into consideration, caution should be exercised when collecting samples of granite in the 'periglacial zone' of the Capitan Mountains. Frost-wedging, talus movement, and rock glaciers appear to have moved a significant amount of material down-slope. The amount of movement may not be easy to quantify. Therefore, it may be difficult to certify that any particular sample of granite actually belongs to a specific location—except along the ridgelines—and was not transported there from some distance uphill.

Subsurface Information

There are no rocks older than the Yeso Formation exposed within the study area. The Yeso Formation is strongly deformed and it is therefore difficult to estimate the thickness of this unit. Two boreholes were drilled south of the study area, both of which in the central part of the Lincoln quadrangle (*Table 1*). The Muñoz Canyon AAN Fed. No. 1 well was drilled on what appeared to be a dome, on the Mescalero Arch at the head of Muñoz Canyon. This well was drilled to a depth of 2,800 feet. Another well, the Nosker 1-Y well, was supposedly drilled near the highway near Glencoe (near the meat seller; James Brannigan personal communication), but the cadastral location places it far from there and may be inaccurate. This information was obtained from the New Mexico Energy Library in Roswell, New Mexico. The thickness of the Yeso Formation and of underlying formations was estimated from these two wells and extrapolated both northward and eastward towards boreholes drilled east of the San Patricio quadrangle. Since the mechanism that created the tight folds within the Yeso Formation is still not clear, the extent to which pre-Yeso formations are deformed (if indeed they are) is also

uncertain. As a result, all of the formations in the subsurface are shown as relatively undeformed layers, as other researches have done. This is probably an oversimplification, but it is better to keep things simple than to invoke a complex structure where it is not understood. Based on the cross-section interpretation the greatest thickness of the San Andres Formation is about 800 feet. Based on the log of the Muñoz Canyon AAN Fed. No. 1 well the Yeso Formation is 1,685 feet thick, and the Abo Formation is 370 feet thick. Precambrian bedrock was encountered at a depth of 2,480 feet below the surface.

One other small-diameter well was observed in the field in the northwest side of the Capitan Pass quadrangle within T. 9 S., R. 15 E., Section 28. Its steel casing is about 6-inches in diameter and capped with a white PVC cap (*Photo 43*). Based on information obtained from New Mexico Tech the well name is Zamora, number H-707, has a Well ID number of 56019, and was drilled as a water well to a depth of 80 feet. Small, dark, angular cuttings around the well resemble limestone, which I interpret as San Andres Formation. However, a depth of 80 feet does not seem quite deep enough to have penetrated the San Andres Formation.

Structure

Dunken-Tinnie anticlinorium

The Tinnie-Dunken fold belt, or anticlinorium, is exposed only in the southeast corner of the Capitan Peak quadrangle (*Photos 44 and 45*). Here it is comprised of three rather abrupt kinks whose axes trend approximately N30°W. The easternmost kink shows locally vertical and overturned strata of the San Andres and Yeso Formations, while the others show dips in general less than 70°. The amount of folding seems to be greater in the east and less towards the west. In the Capitan Peak quad the fold belt is approximately 2 miles wide.

Bowsher (1991) interpreted the fold belt to be a Precambrian horst containing a series of north-trending strike-slip faults in the basement. He noted the presence of extensive north-trending shears in the tops of anticlines (presumably outside the map area) which suggested to him that the folds exposed within Permian strata are rejuvenated Precambrian features. While these may indeed be rejuvenated older structures, no evidence was seen for shearing (strike-slip motion) in the tops of any anticlines from the Capitan Mountains (this study) to Hondo (Skotnicki, 2009b), and as far south as Dunken (Skotnicki, 2008a and b).

Timing of folding relative to intrusion

Bedding within the Tinnie-Dunken fold belt exposed in the eastern part of the Capitan Peak quadrangle very consistently strikes to the northwest. Closer to the Capitan intrusion, however, the strikes slowly bend east-west until near the terminus of outcrops of the San Andres Formation nearly all strikes are east-west with bedding dipping between about 5 and 10 degrees south. This east-west orientation is nearly parallel to the orientation of the southern margin of the Capitan intrusion. These relationships suggest that folding within the Tinnie-Dunken fold belt occurred first, before intrusion of the

Capitan pluton. The orientation of these folds was later modified by the intrusion itself. This constrains the timing of most deformation in the Tinnie-Dunken fold belt to post Permian, but before about 26 Ma.

Capitan Pluton

Allen and McLemore (1991, their figures 6 and 7) show several apparently high-angle northeast-striking faults that cross the range. From their report it is not clear what evidence led to the identification of these faults. It is possible that the alignment of canyons suggested a fault lineation. Based on the current study, there is not enough evidence to support the existence of these structures.

Kelly and Thompson (1964) suggested that the pluton may be bounded on its north and south sides by faults. Although possible, as they and Allen and McLemore (1991) pointed out, the alluvial apron obscures nearly all of the bedrock exposures along both side of the range. However, based on the observation that beds of the San Andres and Yeso Formations on the north and south sides of the range (and on the east side, Allen, 1988) dip away from the intrusion, it is not necessary to invoke the existence of faults to explain the observed relief (see Allen and McLemore, 1991, figure 7).

Bonito Fault

Kelly (1971) mapped a northeast striking fault that projects along Salazar Canyon and along the course of Rio Bonito to the southwest. Although the alignment of the creek and the canyon suggests a structure, no obvious offset was observed on either side of Salazar Canyon or Rio Bonito. Rawling (2006) did not map any fault along Rio Bonito in the Fort Stanton quadrangle to the southwest. Kelly (1971) also mapped a smaller parallel fault within Priest and Lincoln Canyons. Mapping in Priest Canyon (Skotnicki, 2009a) and within Lincoln Canyon (this study) revealed no obvious offset of the Yeso/San Andres contact. Hence, there is no firm evidence for the existence of either of these structures.

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Unit Descriptions for the Capitan Pass
and Capitan Peak 7.5' Quadrangles

Anthropogenic Deposits

d   **Disturbed by man.** This unit was mapped only as the earthen dam in the southwest part of the Capitan pass quadrangle along Salado Creek.

Quaternary Deposits

Qy   **Holocene alluvial deposits.** These deposits were mapped separately from the remainder of the Quaternary surficial deposits because they are relatively easy to identify and are important because these are areas that may be prone to flooding. They are composed of weakly consolidated interbedded gravel, silt, and clay. They commonly form relatively flat deposits at the bottom of the wider drainages. They characteristically contain abundant dark brown, organic- and silt-rich soils at the surface. The deposits are commonly incised up to about 2-3 meters by the modern drainages, where vertical faces locally show older soil horizons. As mapped, this unit locally contains at least two and possibly three separate terrace levels.

Qp   **Holocene playa deposits.** Mostly weakly consolidated silt and clay. These fill depressions within the San Andres Formation in the southern part of the Capitan Peak quadrangle where they are interpreted to be sink holes that have filled with sediment. The presence of small seasonal ponds within some of them suggests that water does not infiltrate within them very quickly.

Qyl   **Holocene and Late Pleistocene alluvial deposits, undivided.** Dominated by sand to boulders of fine-grained granite. As mapped, this unit contains both Late Pleistocene deposits with elevations about 10-30 feet above the level of the modern drainages. Holocene deposits form one or more terrace levels below the level of **Ql** deposits. The two ages are very difficult to distinguish on the broad alluvial apron on the south side of the Capitan Mountains.

Ql   **Late Pleistocene alluvial deposits.** These deposits consist of poorly sorted sand, gravel, and boulders of dominantly **Ti**. They are poorly exposed, but commonly form terrace remnants less than about 20 feet above the **Qyl** deposits.

Qm   **Middle Pleistocene alluvial deposits.** Composed of poorly sorted subangular to subrounded pebbles to large boulders, the vast majority are composed of fine-grained granite (**Ti**). Some deposits contain a significant amount of angular to subrounded dark gray to black iron clasts (magnetite and hematite) from small pebbles up to about 40 cm across. Where **Qm** deposits have been significantly eroded the iron clasts locally form a lag placer. Although poorly exposed, these

deposits locally contain a well developed horizon of laminar caliche. These deposits are higher in the landscape than **Ql** deposits have been dissected by deeper drainages. Commonly less than 40 feet thick.

Qo   **Early Pleistocene alluvial deposits.** This unit forms only two small terraces on the far west side of the Capitan pass quadrangle where they reside about 200 feet above the modern drainage. They are comprised of far-traveled sand to small boulders composed of brown quartz sandstone, gray limestone, chert, andesite (or monzonite/syenite) and a darker gray platy granitic intrusive rock.

Tertiary Rocks

Tig   **Fine-grained granite, areas subjected to periglacial activity.** This unit contains the areas of the Capitan pluton that were subjected to glacial or periglacial processes. There is almost no intact outcrop, yet nearly all of the surface rubble is composed of fine-grained granite. As mapped, this unit also contains talus and rock glacier deposits which contain material that has moved down-slope. Since it was not practical with the time available to distinguish the different types of slope deposits, it made sense to lump them into this one unit.

Ti   **Fine-grained granite.** Overall the mineralogy of this rock is very bland and non-descript. The rock is characteristically fine-grained and tan-colored, exhibiting phenocrysts of subhedral to euhedral K-feldspar up to about 4 mm across, and anhedral muscovite and/or biotite from 1-2 mm across. The rock commonly weathers a light rusty tan color and commonly exhibits either a smooth or slightly granular texture. Commonly forms large subangular to rounded boulders.

Triassic Rocks

Trs   **Santa Rosa Sandstone.** Sandstone, siltstone, and minor conglomerate. The lower parts of this unit are dominated by pale yellow quartz sandstone and interbedded calcarenite and calcilutites. Limy sandstone beds are commonly fragmental and are composed of subrounded sand-size to small pebble-size (1.5 cm) fragments of tan to gray fine-grained limestone. Cross-bedding is common in sets tens of centimeters thick that show erosional bases. Even pebbly beds are cross-bedded and locally show erosional bases and rip-up clasts of sandstone. Locally, the yellow sandstone beds contain chert-pebble conglomerate beds up to 1-2 meters thick that form chert lags down-slope. The upper parts (as exposed) is composed of conglomerate containing angular to subrounded pebbles to boulders (1 m) of dark brown medium- to coarse-grained sandstone, gray limestone, and a variety of felsic intrusive rock that is darker gray and more platy than is Ti. All exposures are very poor and most exposures form gentle slopes covered with soil and grasses. Thickness is at least 590 feet.

Permian Rocks

Pgr **Grayburg Formation.** Red siltstone, fine-grained sandstone, and minor gypsum. This unit is characteristically dominated by rusty red quartz siltstone and fine-grained sandstone. Since exposure is poor, it was distinguished from the overlying Santa Rosa Sandstone mostly on the basis of color. Thickness is about 220 feet.

Ps **San Andres Formation.** Medium- to thick-bedded dolomite and limestone. Dolomite beds are typically light gray-colored, whereas limestone beds are commonly darker gray. Many beds contain sand-sized broken fossil debris surrounded by a matrix composed of micrite and more commonly microspar. Some beds contain faint, parallel laminae parallel to bedding. Other beds are massive and appear bioturbated. Orange-weathering chert is minor but widespread and is composed of granular microcrystalline quartz. The chert commonly forms irregularly shaped masses up to several tens of centimeters across that is both discordant and concordant to bedding. Common larger fossils include coiled gastropods up to about 5 cm across and less abundant nautiloids up to about 10 cm. Smaller recognizable fossils include crinoid stem segments, disarticulated brachiopods (commonly up to 2 cm and replaced by chert), and sparse fussilinids. The carbonate beds are interbedded with well sorted, fine- to medium-grained quartz sandstone from 1-10 meters thick, which probably represent intertonguing Glorietta Sandstone. Maximum thickness of the San Andres Formation is about 800 feet.

Pg **Glorieta Sandstone.** Well sorted, fine- to medium-grained quartz sandstone from 1-10 meters thick. The sandstone beds appear to occur within a few hundred feet of the base of the San Andres Formation. Sandstone beds typically weather light orange to brown and in most outcrops contain abundant calcite-cemented BB-size concretions up to 2-3 mm across. Maximum thickness is about 30 feet.

Py **Yeso Formation.** Interbedded fine-grained quartz sandstone, siltstone, dolomite, and bedded gypsum. Siltstone is commonly rusty red and pale yellow. Dolomite beds are locally fossiliferous and contain silicified brachiopod and crinoid fragments, abundant coiled gastropods, aminods, and possibly cephalopods. Dolomite beds locally contain moldic porosity with some pores still filled with gypsum. Gypsum beds are typically sub-horizontally banded and are locally thicker than 10 meters. Exposures are poor and typically mantled by regolith. The thickness obtained from the log of the Muñoz Canyon AAN Fed. No.1 well is 1,685 feet.

Pa **Abo Formation (in cross-section only).** Shown only in the cross-sections. The thickness obtained from the log of the Muñoz Canyon AAN Fed. No.1 well is 370 feet.

1. This view looking north-northeast towards the Capitan Mountains shows rounded foreground hills composed of the Yeso and San Andres Formations covered with typical piñon-juniper vegetation. Capitan Peak is the highest point visible in the distance. Photo taken from near UTM 475000, 3709000.

2. This grassland landscape is typical of many of the areas underlain by the Grayburg Formation and Santa Rosa Sandstone.

3. The sloping alluvial apron surrounding the Capitan Mountains is commonly thickly vegetated.

4. Some of the highest elevations on the Capitan Mountains contain groves of aspen trees.

5. Most of the major drainages contain abundant large pine trees.

6. View looking south-southwest down Lincoln Canyon towards Priest canyon across Rio Bonito from approximately UTM 464000, 3708000. The lower half of the hills are composed of the folded Yeso Formation, while the upper parts of the mesas are composed of the nearly flat-lying San Andres Formation. The snow-covered Sierra Blanca is in the distance.

7. This view looking northwest was taken immediately west and downhill from Photo 6, and shows steeply dipping and folded dolomite beds of the Yeso Formation overlain by a mesa of nearly flat-lying San Andres Formation.

8. Tightly folded dolomite and siltstone beds are exposed along Lincoln Canyon.

9. Much of the Santa Rosa Sandstone is recessive-weathering and forms gentle slopes covered with soil and grass. Looking north from just south of UTM 456000, 3715000.

10. View from the very western end of the Capitan Mountains, taken from northeast of UTM 457000, 3719000, looking southwest toward the Town of Capitan and Sierra Blanca on the skyline. The grass-covered plains are mostly underlain by the Santa Rosa Sandstone and locally capped by alluvial fan deposits (Qm). The darker tree-covered ridge in the center of the photo is underlain by Cretaceous Dakota Sandstone.

11. Red siltstone and fine-grained sandstone of the Grayburg Formation are best-exposed beneath caps of Qm. View is looking northeast from near UTM 454000, 3711000.

12. Planar cross-bedding within pale yellow quartz sandstone beds of the Santa Rosa Sandstone near UTM 455800, 3715500.

13. A typical good outcrop of the Santa Rosa Sandstone near UTM 455800, 3715500. Note iron clasts weathering out of overlying Qm deposits.


14. Close-up of cross-bedding in Santa Rosa Sandstone exposed immediately below Qo deposits near UTM 454000, 3713000. Pencil is about 15 cm long.

15. Close-up of calcarenite and calcilutite beds containing abundant small limestone clasts. Pencil is about 15 cm long. Photo taken near UTM 455800, 3715500.

16. A closer view of small limestone clasts within Santa Rosa Sandstone near UTM 455800, 3715500. Note the fine-grained yellow quartz sandstone matrix.
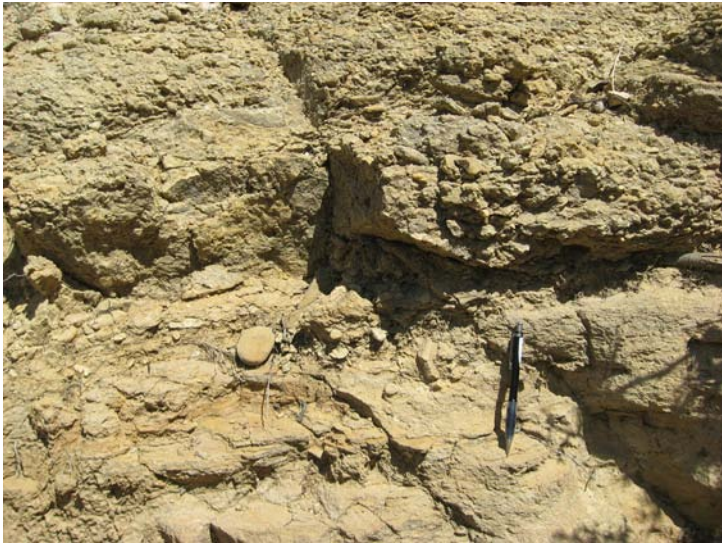
17. Outcrop view of the Santa Rosa Sandstone near UTM 455800, 3715500. The finer-grained beds below contain limy quartz sandstone and intercalated calcarentite. The nodular beds above contain up to pebble-size subangular to subrounded limestone clasts in a limey sandstone matrix. Note erosional channel and rip-up clasts immediately left of the pencil. Pencil is about 15 cm long.

18. Intercalated quartz sandstone and chert-pebble conglomerate within the Santa Rosa Sandstone exposed near UTM 455700, 3714900. View is to the north.

19. Close-up of chert-pebble conglomerate at the same location as Photo 18. Most clasts are chert, and some appear to be quartzite and vein quartz. Pencil is about 15 cm long.

20. Close-up of a large boulder exposed in conglomerate in the upper portions of the Santa Rosa Sandstone near 455700, 3716900. Pencil is about 15 cm long.

21. This photo was taken from the top of the highest Qo terrace looking southeast near 453100, 3713300. Grass-covered plains are underlain by Santa Rosa Sandstone and the Grayburg Formation. The darker, tree-covered slopes in the distance are underlain by the San Andres Formation. The Mescalero arch forms the skyline to the left.

22. The grass-covered mesa is underlain by a thin cap of Qm deposits. Note how this surface is at a higher elevation. It is a remnant of a much more extensive surface that has subsequently been dissected and eroded. View is looking northwest from near UTM 463600, 3710900.

23. Road-cut exposure of Qm near UTM 454500, 3717600, showing extensively developed pedogenic carbonate cement. Almost all clasts are fine-grained granite (Ti). Note thin, dark brown organic-rich soil on top surface.

24. Large boulder rests within a thin deposit of Qm on the north side of the Capitan Mountains near UTM 473500, 3720200. View is to the southeast toward Capitan Peak on the skyline.

25. This boulder within the same Qm deposit as Photo 24 shows fracturing possibly caused by prolonged exposure and pedogenic processes.

26. Stream-cut exposure of Ql deposits on the eastern side of the Capitan Peak quadrangle near UTM 476600, 3710700. Note the absence of extensive carbonate cement and the presence of accumulated reddish clays.

27. Stream-cut exposure of Qyl deposits. Note the similarity of soil development as compared to the Ql deposits in Photo 27.

28. Deposits of Qy exposed in a ravine near UTM 475600, 3710500. This exposure is typical of Qy deposits in the area, where coarse gravel deposits are overlain by 1-2 meters of fine, predominantly silty material.

29. The material in the active channels is typically coarse cobbles and boulders in most areas composed of clasts of fine-grained granite (Ti). View is upstream near UTM 475300, 3710300.

30. Close-up of material in the active channel in the same location as Photo 29.

31. An arroyo within Qy deposits near UTM 454400, 3712700 shows mostly fine silty material interbedded with a layer of coarser sand and gravel.

32. Close-up of the same arroyo wall in Photo 31.

33. The gently sloping alluvial apron in the south side of the Capitan Mountains looks deceptively easy to navigate across, but is commonly covered with boulders and dense vegetation. View is to the east-northeast from near UTM 463300, 3710400. Foreground hills are composed of the San Andres Formation.

34. The snow-capped Sierra Blanca igneous complex, looking southwest from near UTM 464500, 3709400.

35. Iron-rich lag placer deposits are common within and below eroded Qm deposits on Santa Rosa Sandstone. New UTM 456600, 3715800. Pencil is about 15 cm long.

36. Close-up of iron placer deposits in the same location as Photo 35. Pencil is about 15 cm long.

37. A well developed iron lag placer on Santa Rosa Sandstone near UTM 456400, 3715400. Pencil is about 15 cm long.

38. Fine-grained granite forms giant monoliths on the eastern end of the Capitan Mountains. View is to the northeast of the mountains just beyond the eastern edge of the Capitan Peak quadrangle.

39. View looking west from the top of Capitan Peak.

40. View looking east-southeast down-slope from the east side of Capitan Peak.

41. Close-up of the Capitan granite on a boulder downstream on the east side of Capitan Peak.

42. Talus deposits mantle much of the higher elevations of the Capitan Mountains. Although they are relatively loose and move when walked across, they are mostly covered with lichen (as in this photo) indicating that that have been stable for quite some time.

43. This 6-inch-diameter water well is located near UTM 455000, 3716000. View is to the north.

44. Looking northeast across the Tinnie-Dunken fold belt from near UTM 475200, 3708400.

45. View looking south across the Tinnie-Dunken fold belt from near the top of Capitan peak.