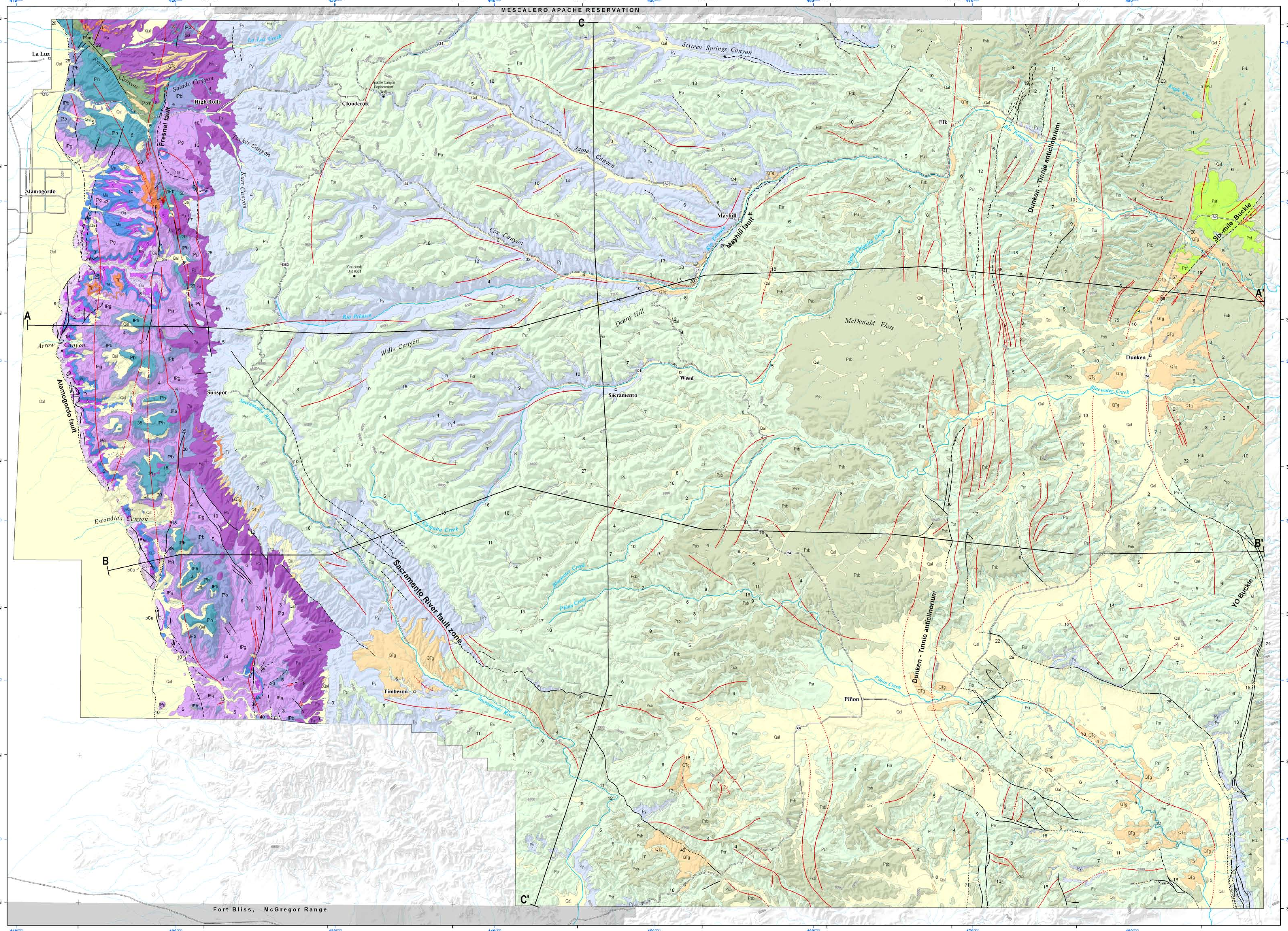

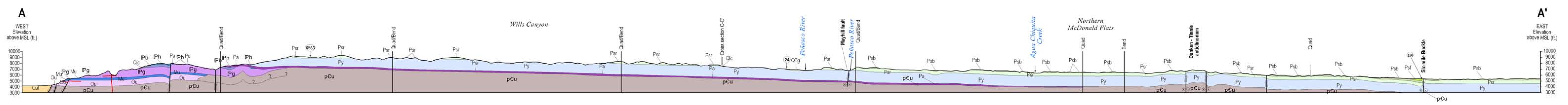

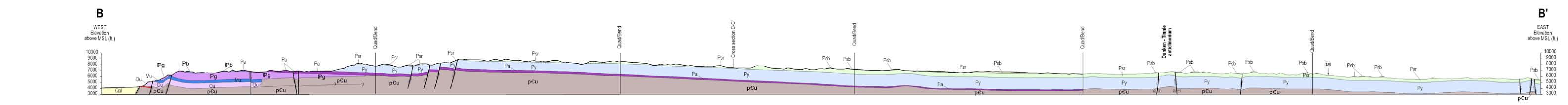

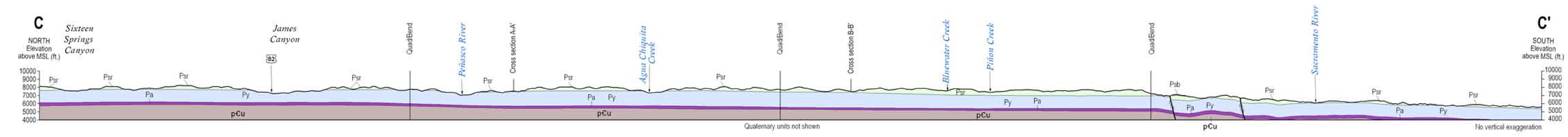

MAP EXPLANATION

Geologic contact
Cross section line

Faults
Fault, exposed
Fault, intermittent-obscured
Fault, concealed
Ball on downthrown side
Strike slip fault, dextral

Folds
Anticline, exposed
Anticline, concealed
Syncline, exposed
Syncline, concealed
Monocline, exposed
Monocline, concealed

Planar Features
Horizontal bedding
Inclined bedding

Introduction

This geologic compilation map was produced as part of a regional hydrogeologic study of the Southern Sacramento Mountains. New geologic mapping was limited to the area east of the crest of the Sacramento Mountains, where the San Andres and Yeso Formations are exposed. Work was begun in late 2005 and completed in early 2009. Compilation of map data sets, cartography and editing were completed in early 2012 . The new mapping was compiled together with the mapping of Pray (1961) of the western escarpment of the range and some northern portions of the map of Black (1973), as shown on the data source index map.

Methodology

In addition to standard geologic field mapping procedures, much geology, especially in the sparsely wooded eastern portion of the study area, was interpreted from aerial photographs. Subdivision of the members of the San Andres formation into its constituent members (as defined by Kelley, 1971) was performed in this way. These interpretations were locally field checked and compared to the regional map of Kelley (1971). In most places, the interpretations are similar.

Pray (1961) mapped the Yeso Formation to include the "Hondo Member" of the San Andres Formation, thus including with the Yeso Formation overlying basal limestone beds of the San Andres up to and including the distinctive tan quartz sandstones that are equivalent to the Glorieta Sandstone of northern New Mexico. This member ranges from 60 to 120 feet thick. Pray (1961) correctly observed that the tan sandstone beds form the only reliably mappable horizon above the Abo-Yeso contact. We chose to map the Yeso contact directly because of its hydrologic significance; we mapped the contact in the field by placing it 80 feet (two contour intervals) below the lowest appearance of the tan sandstone beds, and remapped Prays contact using this approach.

Cross-sections were drawn using subsurface data such as lithologic and geophysical logs from water and oil and gas wells. Numerous well cuttings in storage at the NMBGMR in Socorro were examined to aid in determining unit boundaries and to confirm unit boundaries picked on scout cards and geophysical logs.

Yeso and San Andres Formations

Geology on the map west of a roughly north-south through High Rolls (approximately following the West Side Road), is largely from Pray (1961). Aside from basic unit descriptions provided here, the reader is referred to his excellent discussion for details on the complex stratigraphy and structures of this area. From the aforementioned line to the crest of the range and east the exposed rocks are the Permian Yeso and San Andres Formations, which dip shallowly (2-3°) to the east. The new mapping presented here is largely concerned with these two units, so additional discussion is warranted.

Good natural exposures of the Yeso Formation are rare, as it is usually covered with colluvium from the overlying, more resistant San Andres Formation or by valley bottom alluvium. A complete section is not exposed east of the range crest. Pray (1961) measured a complete section 1239 feet thick on the west flank of Orendorf Peak three miles west of Timberon at the southwest corner of the present study area. Based on this section and the Southern Production Company # 1 oil test well between Cloudcroft and the Rio Peñasco, Pray (1961) estimated the Yeso Formation at 1200 to 1800 feet in the western Sacramento Mountains. The differences are probably due to initial stratigraphic variation and dissolution of evaporites.

The Yeso Formation in the Orendorf Peak section of Pray (1961) is composed of gray limestone with minor gray to tan dolomite (47%), gray, buff, and reddish shale (30%), and yellow to tan siltstone and fine sandstone (9%), with 95 feet of gypsum and mixed gypsum and shale (9%) at the base of the formation. The Village of Cloudcroft Apache replacement well was drilled in 2006 less than 2 miles east of Cloudcroft. It penetrated 1650 feet of the Yeso Formation and showed predominantly limestone and dolomite, with significant intervals of claystone and mudstone, and minor sandstone. Anhydrite and/or gypsum were first observed 1240 feet below the top of the Yeso Formation in this well. Anhydrite and minor halite were observed below 940 feet below the top of the Yeso Formation in the Southern Production Company #1 oil test well, but at 260 feet depth in the surface section of Pray (1961). No evaporites have been observed in surface exposures in the study area. In the area encompassing this study, Kelley (1971) and Pray (1961) both noted that the gypsum content of the Yeso Formation increases to the north and the carbonate content increases to the south.

Soluble carbonate rocks – limestone, dolomite, and calcareous sedimentary rocks – are abundant in the stratigraphy of the upper Yeso Formation. Intraformational dissolution-collapse features and chaotic bedding dips are common in road-cut exposures of the upper Yeso Formation and solution-enlarged fractures are abundant in bedrock pavements exposed in stream channels (Walsh 2008). Due to initial stratigraphic heterogeneity and that caused by subsequent dissolution, individual beds are not traceable laterally for more than a few tens of meters in outcrops, and beds in general cannot be unambigously correlated between outcrops or wells. Zeigler (2010) examined cuttings from four water wells less than 4 miles apart in canyons tributary to James Canyon and showed that individual beds in the Yeso Formation could not be correlated at depth. However, reasonable correlations of transgressive and regressive intervals in the stratigraphy can be made based on the vertical groupings of gross lithologic characteristics rather than individual beds (Zeigler, 2010).

The San Andres Formation is composed of light to dark gray and bluish-gray carbonate rocks (limestone and dolomite). Freshly broken surfaces are darker gray than weathered surfaces and often fetid. Subdivision of the San Andres into the lower dominantly thick-bedded Rio Bonito Member and middle dominantly medium- to thin-bedded Bonney Canyon member (Kelley, 1971) was based largely on interpretation of aerial photographs. In most areas, the differences in the nature of the bedding are not reliably distinguishable on the ground. Kelley estimated thicknesses for the Rio Bonito Member at 250-350 feet and the Bonney Canyon Member at up to 300 feet. Based on our mapping, cross-sections, and well–log interpretations, the thicknesses are ~580 and 400 feet, respectively, in the vicinity of the regional cross section A. These differences are significant, but Kelley mapped at a much smaller scale (1:125000) using a mix of air photo and topographic bases, and presented no cross-sections or well control to constrain his thickness estimates. Thickness variations on the order of ± 100 feet are likely in both members across the mapped area.

A small area of the uppermost member of the San Andres Formation, the Four Mile Draw member, is present in the northeast corner of the mapped area. On aerial photographs it presents an even-textured, much less-prominently bedded, and slightly darker and more grayish-brown appearance than the underlying Bonney Canyon member. Although it contains abundant gypsum elsewhere (Kelley, 1971), in the mapped area it is composed of thin bedded, locally brecciated dolomite (Ziegler, personal communication, 2007). The total thickness is not exposed, but it is at least 100 feet.

For the purposes of this compilation, younger geologic units have been generalized into Quaternary undivided alluvium and Quaternary and Tertiary terraces and gravels. The undivided alluvium includes unconsolidated alluvium in modern drainages, areas of colluvium, aeolian sand sheets, travertine deposits around springs, and broad flat terraces and valley bottoms underlain by fine-grained sediment. The terrace and gravel unit includes coarse grained sediments and gravels that have been incised by modern drainages. Some of these gravels are well lithified and may be as old as Miocene.

Structural Geology

The generally shallowly east-dipping Yeso and San Andres beds are complicated by faulting and folding. The Sacramento River drainage extends southeast of Sunspot, through Timberon, and out of the mapped area. This drainage is structurally controlled as it follows a zone of west-side down normal faults and associated folds that form east-tilted structural blocks, or half-grabens. These faults are probably of Tertiary age and related to the uplift of the Sacramento Mountains.

The northeast–trending segment of the Rio Peñasco drainage that passes by Mayhill follows the Mayhill Fault, which has minor west-side down displacement. This fault and valley segment is aligned with the Border Buckle, one of several linear right-lateral strike-slip fault zones that extend for tens of miles to the northeast across the Pecos Slope (Kelley, 1971). The Mayhill Fault may be an extension of this regional structure and have some component of right-lateral slip. This fault appears to die out in the vicinity of Denny Hill north of Weed. There are several small folds extending to the southwest and northeast along the trend of this fault that are probably due to the distribution of displacement across a broad zone at the fault tip.

The southern end of the Dunken-Tinnie anticlinorium, or Dunken uplift, forms a linear north-south trend of ridges and low hills in the eastern third of the map area. This regional structure extends north to the eastern end of the Capitan Mountains (Kelley 1971), and dies out within the mapped area just northeast of Piñon. The anticlinorium is a complex structure of subparallel anticlines and synclines and discontinuous east- and west-side-down faults, but overall is a structural as well as topographic high, as the Rio Bonito member is uplifted along the ridgeline.

The complex zone of faulting and folding in the southeast corner of the map area near the southern termination of the anticlinorium may be partly due to the interaction of this structure with the Six-Mile and Y-O buckles, two more of the zones of right lateral strike slip faulting on the Pecos Slope (Kelley 1971). The Six-Mile buckle enters the mapped area in the northeast corner, within the outcrop area of the Four-Mile Draw member. Synclinal folding is associated with this buckle here, thus the Four-Mile Draw member is preserved on the surface. The Y-O buckle impinges on the mapped area about 15 miles to the south, where faults change trend form northwest-southeast to roughly north-south. Kelley (1971) and Black (1973) both interpreted the Dunken-Tinnie anticlinorium and the buckles as Laramide-age features. However, the deformation in the southeast corner of the mapped area may also be related to Rio Grande rift extension, as extensional faults with Tertiary movement are present to the west in the Sacramento River valley and to the south along the west face of the Guadalupe Mountains. There are no faults scarps in the Quaternary units.

Structural contours derived from elevation points along the mapped San Andres – Yeso geologic contact are illustrated in on the tectonic map in brown. The elevation of the surface defining the contact between these two units decreases from more than 9000 feet near the range crest to less than 7200 feet on the east side of the Yeso outcrop belt. The structure contours indicate that the strata dip gently to the east from a broad anticline at the range crest. Troughs in the contoured surface along major drainages are broad folds that probably influenced the formation of the drainages and likely continue to influence ground water flow directions.

Structural contours derived from elevation points along the mapped contact between the Rio Bonito and Bonney Canyon members of the San Andres Formation are illustrated on the tectonic map in blue. The western extent of these contours occurs where the vegetation becomes dense enough to prevent reliable mapping of these two units on aerial photographs. Tight anticline-syncline pairs and discontinuous faults define the north-south Dunken-Tinnie anticlinorium through the eastern third of the mapped area. Southeast- and north-south-trending faults of the Sacramento River valley and the northern Guadalupe escarpment are associated with very complex, though broad folding.

Carbonate rocks throughout the mapped area are deformed by joints. Most fractures in the Sacramento Mountains are probably joints. We measured 170 joints at 70 sites west of the Dunken-Tinnie anticlinorium (Walsh 2008). There are two predominant joint sets, NE-SW and NW-SE, consistently oriented throughout the high mountain area. Outcrops containing joints occur at roadcuts, bedrock stream channels and stream valley walls that are not covered with alluvium and/or vegetation. No consistent age relationship could be established between the joint sets.

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CORRELATION OF UNITS

Period	Units
Historic	daf
Quaternary	Qa, Qls, QTg
Tertiary	Ti
Permian	Psf, Psb, Psr, Py, Pa
Pennsylvanian	IPbm, IPh, IPb, IPg
Mississippian	Mu
Silurian/Devonian	SDu
Ordovician	Ou
Precambrian	p€u

- - - - - - major unconformities

DESCRIPTION OF UNITS

Qau Undivided valley stream alluvium, valley fill, and aeolian deposits (Quaternary)—Stream alluvium is composed of unlithified gravel and poorly to moderately sorted clay, silt, sand in active stream channels and ephemeral arroyos. Valley fill is composed of poorly to moderately sorted clay, silt, and sand, often distinctly stratified, and commonly with angular to subrounded cobbles of local bedrock. Matrix material is light to dark brown. Valley fill Grades into alluvial and colluvial fans on toes of hillslopes. Aeolian units are low relief snad sheets in the eastern portion of the map area. Anthropogenic disturbance is common in valley fill and aeolian deposits. Thickness: 0–40 ft.

Qls Slump blocks, landslide deposits, and associated colluvium (Quaternary and Tertiary(?))—Hummocky slope failure deposits and rotational landslide blocks in the central portion of the map area. Stabilized by vegetation and not active. Thickness: 0–120 (?) ft.

QTg Terrace gravels, alluvial fans, and upland deposits, undivided (Quaternary and Tertiary)—Generally coarse deposits composed largely of sand and gravel and incised by modern drainages. Extensive gravel terraces in the eastern and southern portions of map are well lithified, 10's of feet above modern drainages, and may be as old as Miocene. Thickness: 0–80(?) ft.

Ti Intrusive igneous rocks (Tertiary)—Sills and subordinate dikes of porphyritic andesite to latite. Thickness: dikes a few feet to tens of ft wide; sills up to 300 ft.

Psf Four-mile Draw member, San Andres Formation (Permian)—Thin bedded, locally brecciated grayish-brown dolomite. Distinctly darker on aerial photographs than underlying members. Contains abundant gypsum outside of the study area. Thickness: top of unit eroded, ≥100 ft.

Psb Bonney Canyon member, San Andres Formation (Permian)—Light to dark grey, bluish-grey, and tan thin- to medium-bedded dolomite and subordinate limestone. Thin bedding forms distinctive "birds-eye maple" pattern on aerial photos. Thickness: 200 – 400 ft.

Psr Rio Bonito Member, San Andres Formation (Permian)—Light to dark grey, bluish-grey, and tan medium- to thick-bedded dolomite and limestone. Distinctive Hondo Sandstone member 40 to 80 feet above base of unit is composed of brown to tan clean quartz sandstone with well-rounded, frosted grains and is equivalent to the Glorieta Sandstone of central and northern New Mexico. Thickness: 400–600 ft.

Py Yeso Formation (Permian)—Yellow to tan siltstone and fine sandstone, red to pink muddy siltstone and fine sandstone, and gray to tan, often silty, dolomite and subordinate limestone. Gypsum, anhydrite, and halite are present below ~1000 ft in deep test wells but have been removed by dissolution nearer to the ground surface, resulting in abundant collapse features and chaotic bedding. Thickness: highly variable, >1650 ft in deep well near Cloudcroft, thins to 0 at Pajarito Mountain on the Mescalero Reservation.

Pa Abo Formation (Permian)—Dark reddish-brown mudstone, arkosic sandstone, and local basal conglomerate; southward thickening tongue of thin-bedded limestone, dolomite and grey shale in southern portion of map area. Thickness: 200–500 ft.

IPbm Bursum Formation (Pennsylvanian)—Red and grey sandstone and shale, grey limestone, and limestone conglomerate. Red beds and conglomerate become more abundant to the south. Thickness: Thins from 350 to 0 ft, north to south, into an angular unconformity between Pennsylvanian strata and the overlying Abo Formation.

IPh Holder Formation (Pennsylvanian)—Cyclic grey limestones, grey and red calcareous shale, mudstone, sandstone and conglomerate. Massive cliff-forming bioherms and biostromal limestones present near base of unit. Thickness: 0–850 ft, changes due to both erosional truncation and depositional thinning.

IPb Beeman Formation (Pennsylvanian) —Brown, grey and green calcareous shale, thin-bedded argillaceous limestone, and green to gray feldspathic sandstone. Light colored pure limestone abundant locally. Thickness: 350–500 ft.

IPg Gobbler Formation (Pennsylvanian)—Basal coarse quartzose sansdstone and dark argillaceous silty and cherty limestone. These units are overlain by thick-bedded to massive cherty limestones of the Bug Scuffle limestone member, which grade and interfinger laterally to with equivalent detrial facies composed of interbedded sandstone, siltstone, shale and minor limestone. Thickness: 1200–1600 ft.

Mu Caballero, Lake Valley, Rancheria, and Helms Formations, undivided (Mississippian)—Grey and dark grey, locally cherty or silty, limestone, marl and argillaceous and calcareous shale. Bioherms up to 350 ft thick are prominent in the lower Lake Valley Formation. Thickness: 300–450 ft.

SDu Fusselman, Oñate, Sly Gap and Percha (?) Formations, undivided (Silurian and Devonian)—Dark grey, olive, and brownish-grey cherty dolomite, medium grey to brownish grey and olive silty dolomite, dolomitic quartz siltstone and sandstone, grey calcareous shale, nodular grey limestone, and dark grey to black shale. Thickness: 135–175 ft.

Ou Bliss Sandstone, El Paso and Montoya Formations, and Valmont Dolomite, undivided (Ordovician)—Tan quartz sandstone, thin- to medium-bedded light grey to olive-grey dolomite, dolomitic quartz sandstone and dark grey cherty dolomite, and light to very light grey, thin- to medium-bedded dolomite. Thickness: 740–915 ft.

p€u Precambrian rocks, undivided—Gray-green shale, siltstone, and minor quartz sandstone intruded by diabase. Thickness: at least 80 ft. exposed.

daf Disturbed land/artificial fill (Historic)—Heavily disturbed land and artificial fill for stock tanks and dams.

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 may be based on any of the following: 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.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, 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.

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.

24K QUAD INDEX MAP AND GEOLOGIC MAPPING CREDITS

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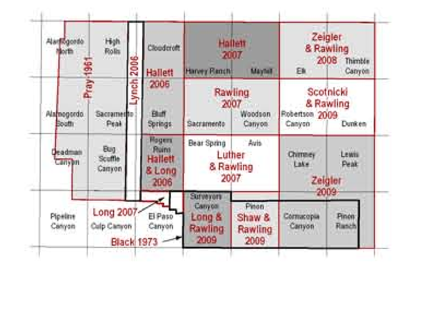
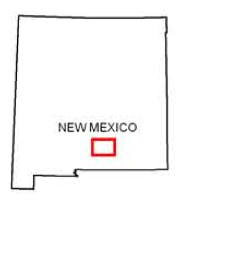
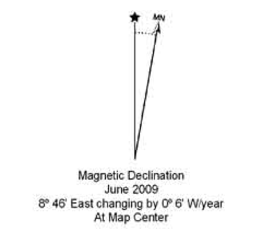


COMPILATION LOCATION





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CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

New Mexico Bureau of Geology and Mineral Resources
Open-file Report 537-Geologic Map, Sheet 1

Generalized Geologic Map of the Southern Sacramento Mountains, Otero and Chaves Counties, New Mexico

February, 2012

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