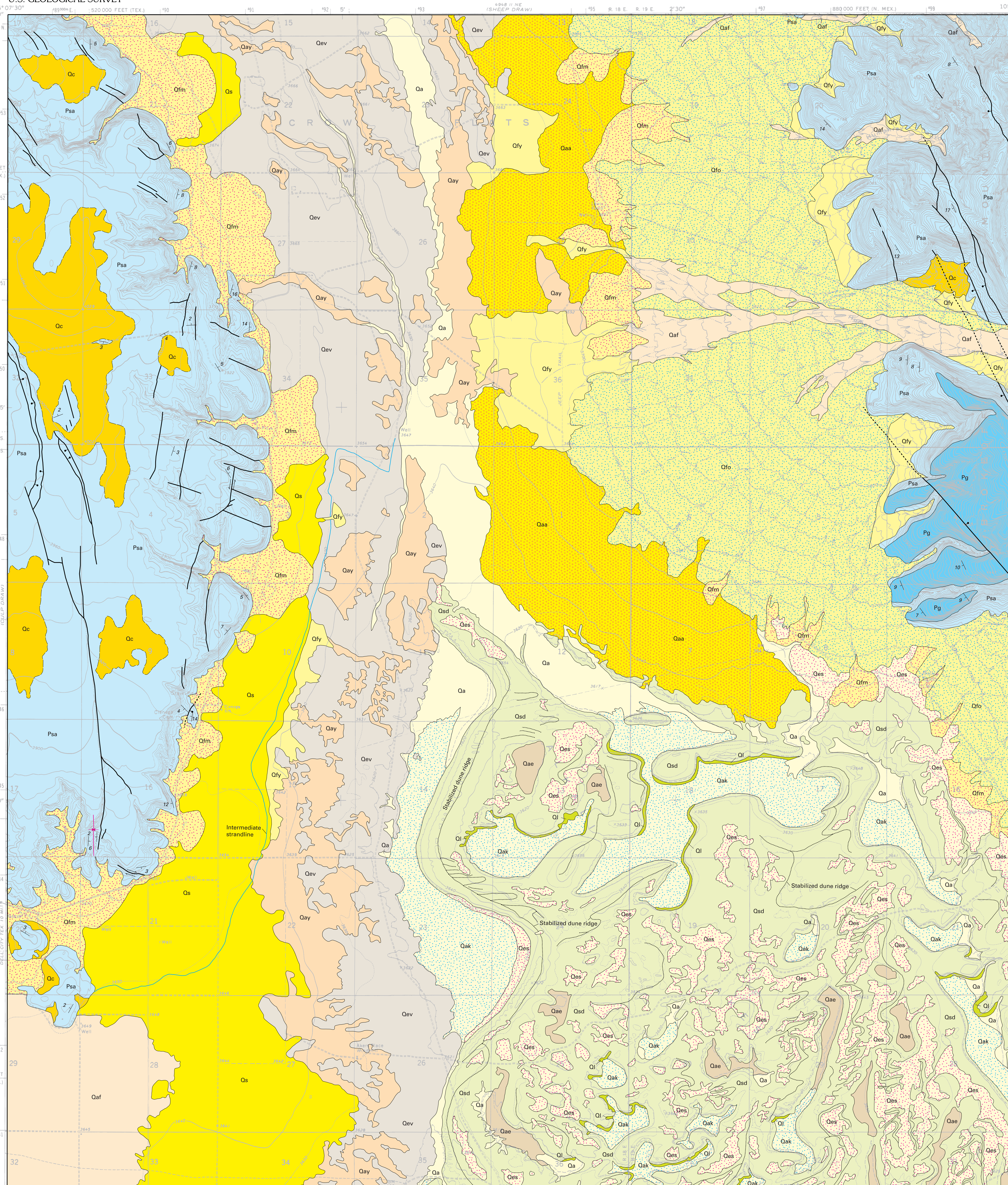


Base from U.S. Geological Survey, 1969
Polyconic projection. 1927 North American datum
10,000-foot grids based on New Mexico coordinate system, central zone, and Texas coordinate system, central zone
1,000-meter Universal Transverse Mercator grid ticks, zone 13

APPROXIMATE MEAN DECLINATION, 1998

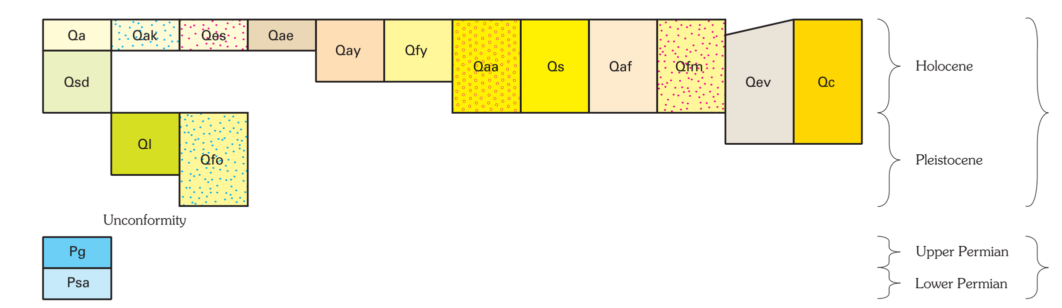
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology mapped October–November 1996
Geology digitized by Esther L. Castellano
Editing and digital cartography by Alessandro J. Donatich
Manuscript approved for publication February 9, 1998

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Most surficial deposits in the Cienega School quadrangle were deposited in the Salt Basin graben along the west side of the Guadalupe Mountains. In late Pleistocene time, this area was the site of a lake that extended southward into Texas. Almost all surficial deposits, with the notable exception of the highest, moderately dissected alluvial fans along the west side of the Brokeoff Mountains, were deposited within the confines of the now evaporated lake; the youngest surficial deposits are those deposited in the lowest, deepest parts of the pre-existing lake. Almost all alluvial and fluvial deposits were derived from the Permian San Andres and overlying Grayburg Formations]

Qa — **Stream alluvium (Holocene)**—Sand, silt, and clay deposited in (1) broad, open stream valleys, (2) confined, ephemeral stream channels, or (3) ephemeral alkali lake beds adjacent to inlet channels. Generally less than 6.5 ft (2 m) thick

Qak — **Alkali lake deposits (Holocene)**—Pale-olive-gray alkaline deposits in ephemeral lakes. Consist of very fine sand- and silt-size, euhedral crystals of gypsum and minor subrounded grains of reddish-orange quartz silt. Locally, minor calcite and (or) dolomite coats gypsum crystals. Thickness generally less than 20 in. (0.5 m)

Qes — **Eolian sand and silt (Holocene)**—Two types of contemporary eolian deposits are present in the quadrangle: (1) cream-white, gypsum sand dunes and thin, sheet-sand deposits are common along the eastern, leeward margins of alkali lake beds; dunes show maximum relief of about 3 ft (1 m) and cover areas ranging from several tens to several hundred square yards (meters); and (2) deposits of reddish-brown, sand- and silt-size grains that consist mainly of subhedral crystals of gypsum, anhedral grains of calcite, and minor reddish-brown, subrounded quartz silt. Most deposits fill depressions related to geomorphic forms of older stabilized dune deposits (Qsd). Mapped separately where windblown sheet sand is major component of young alluvial deposits along the east side of the alkali lakes. Maximum thickness of all contemporary windblown deposits is about 10 ft (3 m)

Qae — **Alkali lake deposits and windblown sand (Holocene)**—Alkali lake deposits (Qak) locally mixed with eolian sand and silt (Qes)

Qay — **Young alluvium (Holocene)**—Patchy deposits of sand, silt, and clay reworked mainly from adjacent alluvial fans and deposited as a thin, reddish-brown veneer on gypsum- and calcite-rich lake sediments (Qev). Maximum thickness less than 6.5 ft (2 m)

Qfy — **Young alluvial fan deposits (Holocene)**—Sand, silt, and clay deposited in higher parts of evaporated late Pleistocene lake bed and derived mainly from erosion of older alluvium (Qfm) and sheetwash deposits (Qs). Also includes small alluvial fans in narrow gullies and canyons in Brokeoff Mountains

Qaa — **Young alluvium and eolian sand, undivided (Holocene)**—Mixed deposits of sheetwash (Qs), young alluvium (Qay), and eolian sand and silt (Qes) along the east side of late Pleistocene lake

Qs — **Sheetwash alluvium (Holocene)**—Sand, silt, and clay deposited by unchanneled overland flow downslope of alluvial fan deposits (Qfm) and alluvial and fluvial deposits (Qaf). Generally less than 6.5 ft (2 m) thick

Qaf — **Alluvial and fluvial deposits (Holocene)**—Sand, silt, clay, and pebble to cobble gravel deposited (1) in southwest corner of quadrangle, derived mainly from Culp and Fourmile Draws to the west that drain bedrock exposures of San Andres Formation (Psa), and (2) in active arroyos that are incised into old alluvial fan deposits (Qfo) shed from the Brokeoff Mountains on the east. Generally less than 16 ft (5 m) thick

Qfm — **Alluvial fan deposits (Holocene)**—Poorly sorted silty sand and gravel deposited in small alluvial fans overlapping highest strandline of late Pleistocene lake; commonly overlies late Pleistocene lake deposits (Qev)

Qev — **Gypsum-calcite duricrust (Holocene and late Pleistocene)**—Cream-colored, sand- to granule-size evaporite minerals consisting mostly of calcite and gypsum; restricted to west side of quadrangle. Deposits are present at elevations below 3,685 ft (1,116 m) (highest strandline of late Pleistocene lake). Composition and character of crust are similar to those of duricrust formed on stabilized and mineralogically altered dune deposits (Qsd); probably represents diagenetically altered sediment of unit Ql formed by evaporation of near-surface brines within the Salt Basin graben. Maximum exposed thickness south of quadrangle is about 6.5 ft (2 m)

Qc — **Colluvium (Holocene and late Pleistocene)**—Residual deposits of silt, sand, and clay and angular pebbles and cobbles that are weakly to strongly cemented by calcium carbonate-bearing soil; most commonly mantles the San Andres Formation (Psa), which underlies eastern edge of Otero platform on west side of quadrangle. Thickness generally less than 15 in. (40 cm)

Qsd — **Stabilized dune deposits (Holocene)**—Deposits interpreted to be stabilized sand dunes, based mainly on morphology best seen in aerial photographs. Dune types include barchanoid, parabolic, and transverse and are best preserved directly south of quadrangle. In the Cienega School quadrangle, the dunes are mainly preserved as elongate, sinuous ridges of low to moderate relief that in places can be traced for distances of greater than 0.6 mi (1 km); also commonly form mounds of low to moderate relief composed of multiple, curvilinear ridges defining cuspate or colloform map patterns. Windblown gypsiferous sand and silt that originally composed the dunes are strongly altered and (or) replaced by minerals formed during evaporation of near-surface brines and the concomitant precipitation of evaporite minerals. The present surface of the dune deposits consists of medium- to light-gray, hard, vuggy duricrust composed of variable amounts of gypsum and dolomite, and ranges in thickness from 2–4 in. (5–10 cm) to more than 16 in. (40 cm). Underlying the duricrust is a friable, vuggy deposit of weakly cemented, sand- to granule-size crystals of gypsum and calcite that attains a maximum exposed thickness of about 10 ft (3 m); large, 4–6 in. (10–15 cm) long crystals of selenite are locally common and occur as single crystals, twins, and rosettes concentrated near base of friable zone. The duricrust and underlying friable zone do not display eolian cross bedding; the duricrust displays a strong vertical texture controlled by the alignment of selenite crystals, whereas the friable zone commonly displays a vague horizontal layering that becomes more distinct downward. Maximum relief on dune ridges is about 55 ft (17 m) in south-central part of map area adjacent to alkaline lake deposits (Qak); most ridges stand 6.5–13 ft (2–4 m) above adjacent depressions

Ql — **Lake sediments (late Pleistocene)**—Laminated, tan to light-olive-tan, fine-grained layers of late Pleistocene lake sediments; laminations range from 0.1 to 0.5 in. (mm to cm) thick. In outcrop the rock is soft and blocky and commonly interlayered with hard, platy, 0.5-in.-thick (cm-thick) beds. X-ray analysis shows the blocky sediment to consist of variable amounts of gypsum, halite, and calcite; trace amounts of clay and reddish-brown quartz are also present. Rock is very fine grained and porous; euhedral crystals of gypsum and associated calcite and (or) dolomite, less than 0.008 in. (0.2 mm) across, compose bulk of rock. Hard, resistant layers are composed of very fine grained halite and calcite and (or) dolomite. Maximum exposed thickness is less than about 10 ft (3 m)

Qfo — **Old alluvial fan deposits (Pleistocene)**—Poorly sorted silty sand and gravel deposited in large alluvial fans along the eastern margin of the late Pleistocene lake; fan deposits do not extend to elevations lower than about 3,670 ft (1,111 m). Fans are moderately dissected and no longer receive sediment because of incision due to evaporation of late Pleistocene pluvial lake in the Salt Basin graben

Pg — **Grayburg Formation (Upper Permian)**—Dolomite and calcareous dolomite; grayish orange to very light orange and gray, fine grained, and medium bedded; contains minor interbeds of light-orange, very fine grained, thin- to medium-bedded calcareous and dolomitic sandstone. Maximum thickness exposed in map area is about 300 ft (90 m); top not exposed

Psa — **San Andres Formation (Lower Permian)**—Dolomite and dolomitic limestone; medium gray to light olive gray, fine to medium grained, thin to medium bedded; contains medium-gray chert nodules. Unit grades upward into Grayburg Formation to the east in the Brokeoff Mountains. Maximum thickness exposed in map area is about 600 ft (180 m); base not exposed

Contact—Dashed where approximately located

Fault or prominent fracture zone—Dotted where concealed. Where relative movement known, ball and bar on downthrown side, and arrows indicate sense of horizontal displacement

7
Strike and dip of bedding

Syncline—Showing trace of axial plane

Dune ridge—Axis of stabilized dune ridge and zone of maximum accumulation of soluble minerals formed by evaporation

Strandline—Intermediate strandline of fluctuating late Pleistocene lake. Defined by subtle break in slope of lake sediments or overlying veneer of alluvium only along west side of late Pleistocene lake; break in slope is more or less coincident with the 3,660-ft (1,109 m) contour. Highest shore line (not shown) expressed only by maximum elevation of lake sediments, near 3,685 ft (1,116 m) in northwestern part of quadrangle

GEOLOGY

REGIONAL GEOLOGIC SETTING

The Cienega School 7.5-minute quadrangle is located in the easternmost part of the Basin and Range province of southern New Mexico (Woodward and others, 1975; Seager and Morgan, 1979; Goetz, 1985). Physiographically the area could be considered a part of the Rio Grande rift; however, the rift margin is generally drawn west of this area, near the western margin of the Otero platform and its counterpart in Texas, the Diablo platform (fig. 1). That part of Salt Basin graben within the quadrangle is thus separate from the main structures of the Rio Grande rift. The Salt Basin graben is the northernmost basin of four elongate, structurally integrated grabens that form a north-trending, narrow rifted zone that joins the Rio Grande rift about 200 mi (320 km) to the south, near Big Bend National Park (Goetz, 1985; Pearson, 1988). The Guadalupe Mountains of New Mexico and Texas stand as a formidable escarpment east of the graben, rising to elevations near 8,700 ft (2,610 m) in Guadalupe Mountains National Park. Rocks west of the escarpment have been downdropped along a series of Tertiary and Quaternary normal faults that define the eastern margin of the Salt Basin graben (fig. 1).

SEDIMENTARY ROCKS

The oldest rocks exposed in the area are Permian and represent a shelf-to-basin transition zone related to the formation of the Capitan reef complex; the reef marks the northern boundary of the Permian Delaware Basin of Texas and New Mexico. The western face of the Guadalupe Mountains displays the complete, uninterrupted sequence from shelf to back reef to reef to basin stratal transitions (fig. 2) and has been the focus of decades-long geologic research of marine basin margin geology (Pray, 1988). In this scheme of rapid stratal transitions, the Cienega School quadrangle lies on the Permian shelf margin; as such, only the back-reef and underlying bank-ramp shelf facies rocks were deposited here.

Permian sedimentary rocks exposed in the Cienega School quadrangle are the San Andres and overlying Grayburg Formations (Psa, Pg). The San Andres and Grayburg Formations are well exposed along the east margin of the quadrangle; only the San Andres is present on the west. The San Andres and Grayburg Formations in this area are the uppermost formations of the bank-ramp complex of the margin of the Permian shelf edge (fig. 2); the overlying back-reef deposits have been removed by erosion. Directly south of the Cienega School quadrangle, the San Andres intertongues with basinal sediments of the Delaware Basin. The overlying Grayburg also cannot be traced south of the Cienega School quadrangle, as it intertongues with, and is overlain by, the lower part of the main Capitan reef complex.

The remaining sedimentary rocks in the Cienega School quadrangle are Quaternary alluvial, fluvial, eolian, and lacustrine deposits of the Salt Basin graben. Total thickness of the basin fill has been estimated to be between 1,650 and 2,300 ft (500 and 700 m) (Friedman, 1966; Gates and others, 1980). In late Pleistocene time, a pluvial lake occupied much of the Salt Basin graben (King, 1948); the northernmost reaches of this lake, informally referred to as Lake King (Miller, 1981), extended into the Cienega School quadrangle. Alluvial fans (Qfo) flanking the adjacent Brokeoff Mountains were active while the lake occupied this part of the Salt Basin graben. Minor progradation of the older alluvial fans occurred during initital drop of the maximum lake level. With continued drop in lake level, the older fans became dissected and younger alluvial and fluvial deposits were shed onto the lake floor as it became subaerially exposed.

Lake sediments (Ql) are exposed locally in the central part of the graben and consist of two types: layered sedimentary deposits and gypsiferous evaporite deposits. Limited exposures of layered, locally laminated lake deposits are restricted to areas adjacent to contemporary, ephemeral alkali lakes, where they are overlain by younger eolian deposits. The lake deposits consist of laminated to thinly layered gypsiferous, saline, dolomitic and calcareous sediments (fig. 3). South of the quadrangle, these lacustrine deposits have been examined in shallow, subsurface cores as long as 9 ft (3 m) (Hussain and others, 1988). The cores contained laminated, varve-like, light- and dark-colored layers or couplets. Hussain and others (1988, p. 180) recognized three couplet types: (1) gypsum and algal laminae, (2) gypsum and organic matter-rich dolomicrite, and (3) dolomite and organic-rich dolomicrite. X-ray fluorescence analysis of lake sediments in the Cienega School quadrangle during this study revealed similar compositional layering. Radiocarbon ages from organic-rich layers in lake sediments exposed 25 mi (40 km) south of the quadrangle indicate that the lake sediments accumulated between about 22,600 and 17,200 years before present (Wilkins and Currey, 1997).

Gypsiferous evaporite lake deposits can be traced from north to south in the central and western parts of the quadrangle and indicate that the maximum elevation of the lake was near 3,685 ft (1,116 m). The deposits are not well exposed in this area; to the south, near Dell City, Texas, a pit excavated in these deposits exposed about 6 ft (1.8 m) of cream-colored, loosely compacted gypsum-rich basin fill capped by a well-developed gypcrete duricrust (Love and Hawley, 1993). The thickness of these evaporite deposits in the quadrangle is not known.

Resting above laminated, layered lake sediments is an immense, stabilized dune field that extends from the southern part of the Cienega School quadrangle southward at least 10 mi (16 km). The dunes (Qsd) are restricted to the eastern, leeward side of the former lake basin and consist of transverse dunes, barchanoid ridges, and large and small parabolic dunes. Like the evaporite lake deposits, the gypsiferous dune forms are lithified and capped by a hard, gypcrete duricrust that ranges in thickness from 4 to 16 in. (10 to 40 cm) (figs. 3 and 4). The dunes were originally interpreted as beach ridges by King (1948); that interpretation was subsequently accepted by Wilkins and Currey (1997).

Present day "lakes" within the graben are deflation basins formed by wind erosion of the Pleistocene lake beds (fig. 3). The extremely flat nature of the lake bottoms is a reflection of the local water table; at the water table, gypsum within the Pleistocene sediments periodically remains sufficiently wet and cohesive to resist wind erosion. Consequently, the planar surface of the water table determines the depth of wind erosion, which defines the bottom of the "lakes." Gypsum scoured by wind from at or above the water table presently accumulates in small, patchy dune fields and sheet sand deposits along the leeward sides of the "lakes" and on the older, stabilized dune forms.

STRUCTURAL GEOLOGY

Faults

The Salt Basin graben, which underlies the central part of the Cienega School quadrangle, formed in Tertiary and Quaternary time (King, 1948; Goetz, 1985). To the south, in Texas, clearly defined faults separate the graben from the Guadalupe Mountains on the east and the Diablo platform on the west (fig. 1). In southernmost New Mexico, the Guadalupe Mountains are separated from the main trace of the graben by the partly down-dropped and strongly faulted Brokeoff Mountains. In the Cienega School quadrangle, bounded on the east by the Brokeoff Mountains and on the west by the Otero platform, no graben-bounding faults are exposed. The broadly anticlinal nature of the Brokeoff-Guadalupe Mountains may control the position of the range margin; the west limb of the anticline dips gently to moderately beneath the Quaternary sediments that fill the graben. Permian rocks that underlie the Otero platform on the west are cut by faults of small displacement, none of which can be traced into Quaternary deposits of the graben. Although the eastern escarpment of the platform may be structurally controlled, as inferred by Black (1975) and Goetz (1985), it is possible that the break in slope is an erosional feature as well.

Major faults that cut the rocks of the Otero platform trend north-northwest and are associated with a second set of faults of smaller displacement and trace length that trend west-northwest. Slickenlines, where preserved on surfaces of north-northwest-trending normal faults, indicate a component of strike-slip displacement. In contrast to the through-going normal faults, the smaller, west-northwest-trending faults commonly show oblique reverse displacements. A well-exposed west-trending fault of small displacement, mapped at the southern end of the platform, dips 45° NE.; slickenlines plunge 5° NW. The observed displacements and overall map pattern of the smaller west-northwest-trending faults of the Otero platform suggest they represent secondary structures kinematically related to through-going north-northwest-trending faults. The west-northwesterly orientation of the smaller faults, coupled with evidence of reverse and strike slip displacement, indicate that they are contractional structures necessarily associated with an overall right-slip component on the major faults. These observations appear to support the interpretation of Goetz (1985) that the Salt Basin graben formed in response to right-transtensional displacement on north-northwest-trending normal faults.

Folds

Gentle undulations of sedimentary rocks of the Otero platform are common, subtle, and not mappable. The strata adjacent to some faults is gently warped; where mappable, the warps are defined as small folds subparallel to the trace of the adjacent fault.

The Brokeoff Mountains in the northeastern part of the quadrangle are the west limb of a large north-northwest-trending anticline that underlies the combined Brokoff-Guadalupe Mountains. The trace of the fold axis is located east of the quadrangle boundary.

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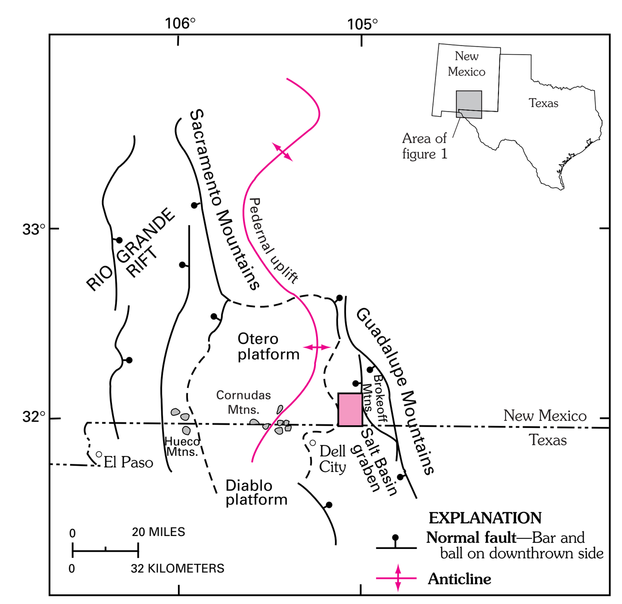

Figure 1. Index map showing regional physiographic setting of the Cienega School quadrangle (pink), south-central New Mexico and adjacent Texas.

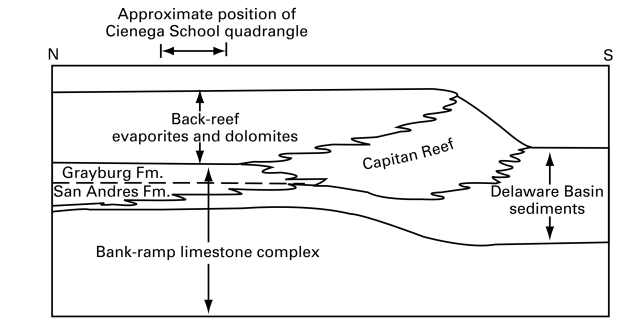

Figure 2. Diagrammatic section of Permian shelf margin stratigraphic complexes, Guadalupe Mountains, showing location of Cienega School quadrangle with respect to the known stratigraphic framework (modified from Pray, 1988).

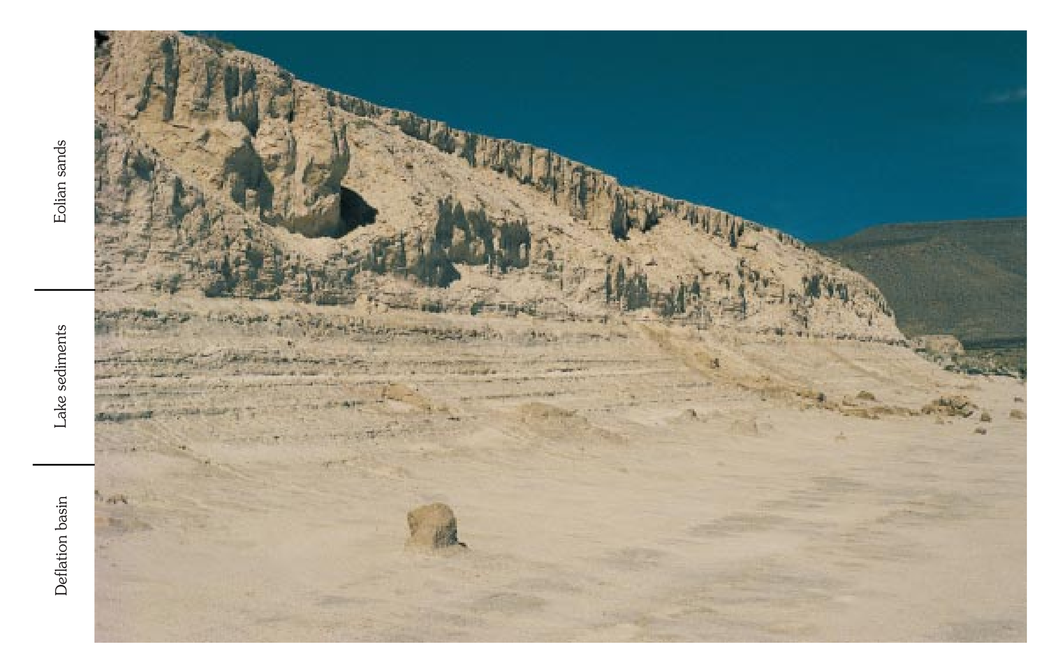

Figure 3. Margin of alkali lake deflation basin. Cliff is about 15 ft (5 m) high. Lower part exposes late Pleistocene laminated to thinly layered, gypsiferous, dolomitic to calcareous lake sediments; upper part is eolian sand that now contains abundant evaporite minerals. Contact between lake sediments and eolian sand is planar, abrupt, and commonly marked by large crystals of selenite. Note uppermost, cliff-forming gypcrete duricrust capping the stabilized eolian deposit.

Figure 4. Cross section through rounded crest of a large parabolic dune. Relief on dune is about 6 ft (2 m). Note thick gypcrete duricrust capping dune form.

GEOLOGIC MAP OF THE CIENEGA SCHOOL QUADRANGLE, OTERO COUNTY, NEW MEXICO, AND HUDSPETH COUNTY, TEXAS

By
J. Michael O'Neill
1998

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