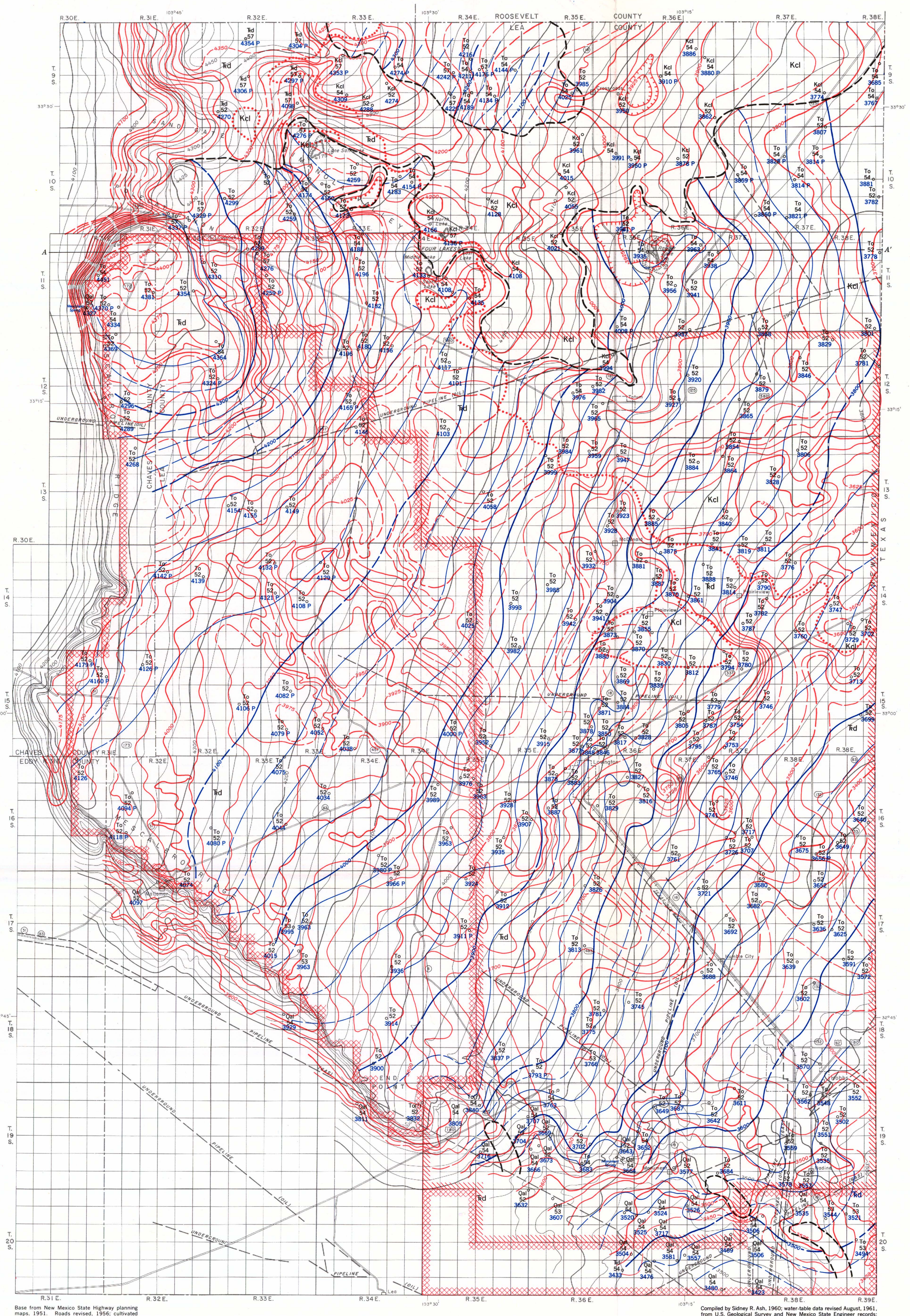
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE NEW MEXICO STATE ENGINEER

HYDROLOGIC INVESTIGATIONS
ATLAS HA-62 (SHEET 1 OF 2)



Base from New Mexico State Highway planning maps, 1951. Roads revised, 1956; cultivated acreage from inventory taken by H. O. Reeder and F. E. Busch, 1953; topography adapted from Hale and Nicholson, 1953

Compiled by Sidney R. Ash, 1960; water-table data revised August, 1961, from U.S. Geological Survey and New Mexico State Engineer records; control for post-Mesozoic erosional surface taken from shothole and water-well logs; boundaries of Lea County Underground Water Basin from New Mexico State Engineer; oil and gas development adapted from Dixon, Blatz, Stipp, and Bieberman, 1955, and Stipp and Haigler, 1956

FIGURE 2.—*Map showing the topography, contours on the water table and on the post-Mesozoic erosional surface in northern Lea County, New Mexico*

SCALE 1:250 000

1 0 1 2 3 4 5 6 7 8 9 10 MILES

1 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

EXPLANATION

AQUIFERS

Recent	**Qal** Alluvium *Sand and gravel; may include some redeposited material from Ogallala formation and the underlying Cretaceous and Triassic rocks*	QUATERNARY	CENOZOIC
Pliocene	**To** Ogallala formation *Irregularly-bedded sand, grit, and local gravel conglomerate cemented by lime or caliche, and local beds of sand, clay, and limestone; may include some redeposited material from the underlying Cretaceous and Triassic rocks*	TERTIARY	
Lower Cretaceous (?)	**Kcl** Clay and limestone *Yellow and blue clay with thin stringers of brown, and gray, limestone; probably equivalent to the Tucumcari shale*	CRETACEOUS	MESOZOIC
Upper Triassic	**Ꞧd** Dockum group, undivided *Maroon, red, and gray irregularly-bedded sandstone, bright- and dark-red shale and sandy shale, and purplish limestone pebble beds*	TRIASSIC	

GEOLOGIC UNITS DIRECTLY BELOW THE ROCKS OF CENOZOIC AGE

Lower Cretaceous (?)	**Kcl** Clay and limestone *Yellow and blue clay with thin stringers of brown and gray, limestone; probably equivalent to the Tucumcari shale*	CRETACEOUS	MESOZOIC
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o~ Spring

o Water well

Aquifer — To
Year sampled — 52
o
3494
Altitude of water level, in feet above mean sea level. Static-level measurement unless the figure is followed by the capital letter "P" which indicates that the measurement was made while the well was being pumped.

Data are grouped around the source-of-water symbol. Undetermined information is noted by the absence from the designated position in the group of data.

——— 4025 - - - - -

Contour drawn on the water table in the deposits of Cenozoic age as of November-December, 1952

Dashed where approximately located; contour interval 25 feet; datum is mean sea level

- - - - - - - - - - -

Approximate boundary of bedrock highs that interrupt the water table in the deposits of Cenozoic age

——— 4150 - - - - -

Contour drawn on the post-Mesozoic erosional surface

Dashed where approximately located; contour interval 25 feet; datum is mean sea level

....

Buried contact

▨ Area included in declared Underground Water Basin, prior to Oct. 1, 1952

▩ Area added to declared Basin on Oct. 1, 1952

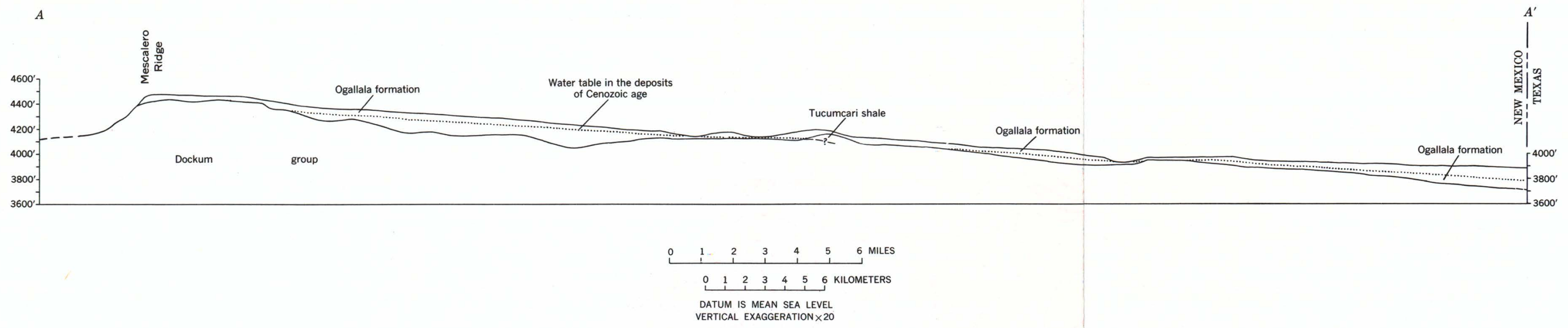

FIGURE 3.—SECTION ALONG A–A' FROM MESCALERO RIDGE TO THE NEW MEXICO—TEXAS STATE LINE IN NORTHERN LEA COUNTY, NEW MEXICO

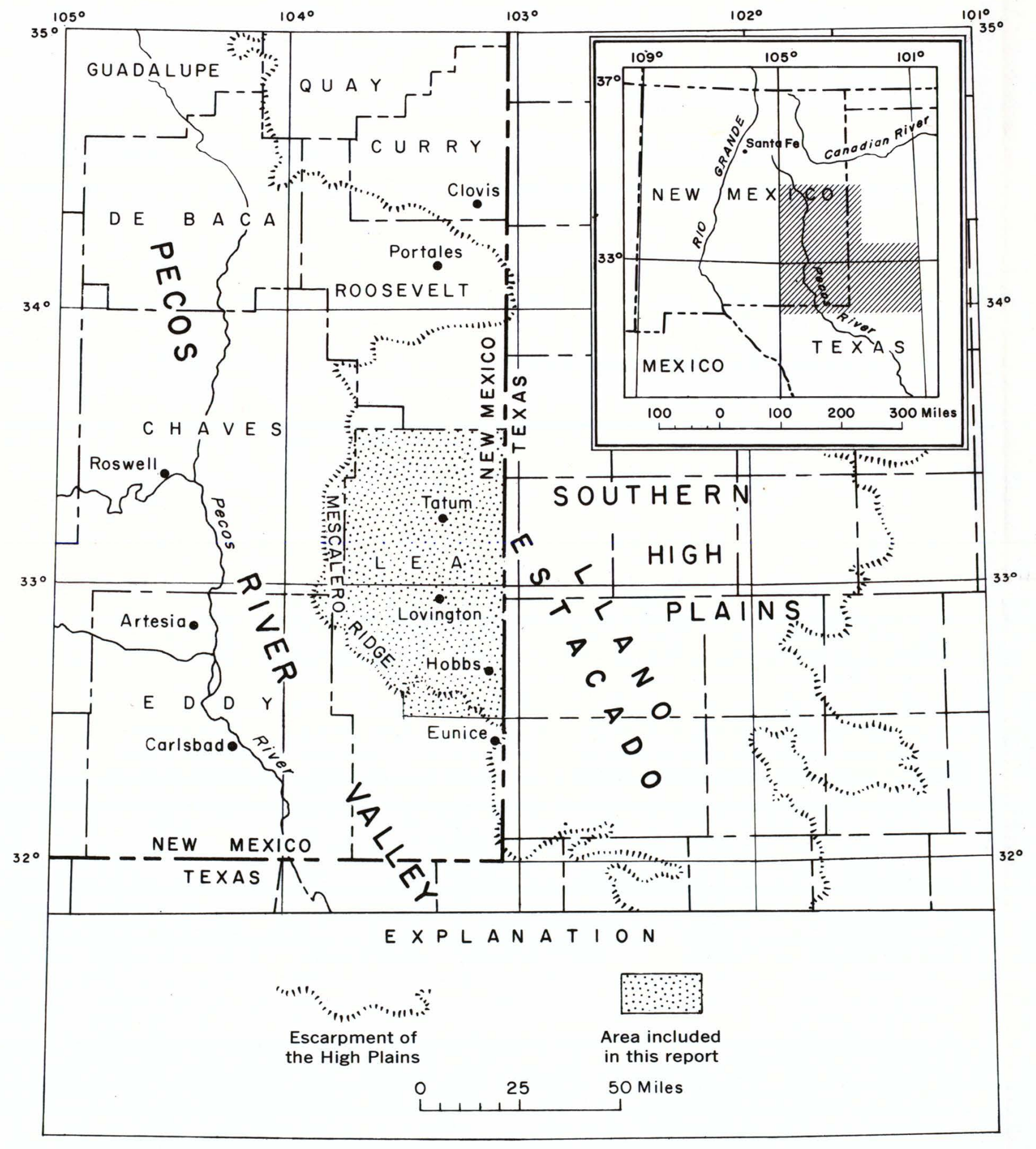

FIGURE 1.—INDEX MAP SHOWING THE LOCATION OF THE NORTHERN LEA COUNTY AREA AND ITS RELATION TO THE HIGH PLAINS AND THE PECOS RIVER VALLEY

INTRODUCTION

Northern Lea County, New Mexico, is dependent chiefly on ground water for its water supply. It also is one of many areas in New Mexico in which ground water is being mined; that is, more water is being withdrawn from the ground-water reservoir both by natural means and by pumping for irrigation, municipal, stock, and industrial use than is being recharged to the reservoir. The magnitude of the pumping and the volume of the water in storage are such that in places the depletion of the reservoir may be measured in a few tens of years on the basis of the rate of use of water in 1953.

The State Engineer of New Mexico declared the Lea County Underground Water Basin in 1931 subject to regulation of the development of water in this area. New Mexico water policy is based on the philosophy that the withdrawal of water from an area of ground-water mining should be limited to a rate that will permit amortization of the investment in farms irrigated with ground water over a period of 40 years (Reynolds, 1960, p. 233–234). In parts of northern Lea County, the ground-water supply is considered to be fully appropriated. In these areas the users of ground water for irrigation can expect about 40 years of supply at the rate of use in 1953 and extending from that date unless additional supplies are discovered in deeper water-bearing formations. Beyond such a period there will remain in storage sufficient water for stock and municipal use and, to some extent, water for industrial use for many years to come. In other parts of the declared basin water was still unappropriated in 1960.

PURPOSE AND SCOPE

The purpose of this atlas is to make available in convenient form information on the ground-water reservoir in northern Lea County, New Mexico, an area dependent chiefly on ground water for its water supply. The atlas shows by means of maps the saturated thickness of the principal ground-water reservoir and indirectly the volume of water in storage in northern Lea County. Other maps show the depth to water and areas in which water levels have declined in the past several years. The atlas was prepared as a part of the general program of ground-water investigations being made by the U. S. Geological Survey in cooperation with the State Engineer Office of New Mexico. The information contained in the atlas should lead to a better understanding of the availability of water in this important part of the State.

LOCATION AND EXTENT OF THE AREA

The area described contains about 2,900 square miles in southeastern New Mexico and includes northern Lea County, and small parts of Chaves and Eddy Counties (fig. 1). The area is bounded on the east by the New Mexico-Texas State line, on the north by the Chaves and Roosevelt County lines, and on the west and south by the Mescalero Ridge.

PREVIOUS WORK

Generalized reports on the geology of the area have been made in connection with regional investigations concerned primarily with the oil- and gas-producing formations of Paleozoic age; few data have been published on the younger rocks that contain potable ground water. Selected references pertaining to the geology and hydrology of Lea County are listed at the end of this text. A network of observation wells has been maintained on a continuing basis for a number of years by the Geological Survey in cooperation with the State Engineer Office Related data such as the amount of water withdrawn from the reservoir have also been collected and published in U. S. Geological Survey Water-Supply Papers and the Technical Report series of the New Mexico State Engineer Office.

ACKNOWLEDGEMENTS

This atlas is an outgrowth of work begun in 1952 to define the thickness of the zone of saturation in the water-bearing materials of the Ogallala formation, the principal aquifer in northern Lea County. Control for thickness of the Ogallala formation was obtained from logs of about 6,000 holes, most of which were shotholes drilled by various oil companies and geophysical companies in exploration for oil.

The author gratefully acknowledges the assistance given the Geological Survey by oil and exploration companies and by personnel of the State Engineer Office who tabulated most of the well logs.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Northern Lea County is on the west side of the Llano Estacado, which is the southern extension of the High Plains in southeastern New Mexico and western Texas (fig. 1) (Fenneman, 1931, p. 9). The Llano Estacado, or southern High Plains, is a plateau which stands about 100 to 300 feet above the surrounding region (fig. 2). The general surface of the Llano is smooth and slopes to the southeast at 10 to 20 feet per mile into Texas. The Mescalero Ridge (figs. 1 and 2) forms the western and southwestern boundary of the Llano Estacado and is the boundary between the High Plains and Pecos Valley sections of the Great Plains Province (Fenneman, 1931, p. 9). The name Mescalero Ridge is a misnomer as this feature actually is an escarpment that faces the Pecos Valley.

The steep front along the ridge from T. 9 S. to End Point in T. 19 S. is broken by broad reentrants, such as Sand Gate in the northwest part of the area, and narrow reentrants such as Polecat Canyon in the southern part of T. 10 S., R. 31 E., through which U. S. Highway 380 passes from the Pecos River Valley onto the Llano Estacado.

Shallow closed depressions, sometimes called buffalo wallows, are the most characteristic minor topographic features on the Llano Estacado. The floors of the depressions generally range in area from 1 to 150 acres; the average size is probably about 1 acre. The depth of the depressions generally ranges from 1 to 50 feet. Some of the depressions have been sealed or dammed by ranchers for use as tanks for watering livestock. Some of the depressions contain perennial lakes, but most of them contain water only during the summer rainy season.

The drainage on the Llano Estacado generally is not integrated; a few of the depressions, however, are connected by shallow and superficial drainage ways. Drainage into the depressions is mainly from the northwest. Much of the runoff from precipitation is caught in the depressions, where the water remains until it infiltrates, is lost by evaporation, or is consumed by plants. The only semblance of through drainage is a shallow broad swale called Simanola Valley, which originates east of Sand Gate and terminates a few miles northwest of Tatum.

Six perennial lakes occur in the northern part of the area. The two largest are Lane Salt Lake (T. 10 S., R. 33 E.) 7 miles northeast of Caprock, and Ranger Lake (T. 11 S., R. 36 E.) 8 miles north of Tatum. Four Lakes (T. 11 S., R. 34 E.) is the collective name for the four small lakes about 12 miles northwest of Tatum. For the purpose of this report, however, they will be referred to individually as North Lake, East Lake, Middle Lake, and South Lake (fig. 2).

Springs and seeps are present in the beds or on the margins of several of the lakes. North Lake has several islands on which seeps are found. Water in all the perennial lakes is brackish and is derived from both surface runoff and underground inflow.

SOILS

The soils in northern Lea County include loam, sandy loam, clay loam, and clay (Harper and Smith, 1935). The loam soils are the thickest and most productive soils. They generally occur in long, narrow, subparallel strips which vary in width and length but nearly always trend in a southeasterly direction. The loam strips are surrounded, in most places, by uncultivated scabland or by sand hills. The scabland is chiefly thin, rocky loam, and the sand hills are chiefly sandy loams. The sand hills, like the loams, occur in long narrow strips.

The northwest-southeast lineation of the soils and sand hills is well illustrated on the soil map of the area around Lovington (Harper and Smith, 1935). The cause of the lineation is unknown; however, the trend, thickness, and location of the soil strips suggest that the lineation may be related to streams of Tertiary age which originated to the west and flowed southeastward at the time the Ogallala formation was being deposited. The lineation may also be related to older sand-dune patterns developed from prevailing southwesterly winds.

Generally, only clay is found on the floors of the shallow closed depressions because the coarser materials are deposited at the margins as the water flows to the depressions; only very fine materials can be carried by the weak currents in the ephemeral lakes.

CLIMATE

The climate of northern Lea County is semiarid; the humidity is low, the rate of evaporation is high, and the mean annual temperature is about 60°F. The average annual precipitation at Tatum is 16.20 inches, at Lovington 14.82 inches, and at Hobbs 15.26 inches. More than two-thirds of the annual precipitation falls during the growing season, which lasts from April through September. At Hobbs and Lovington the average number of frost-free days per year is 206 and at Tatum is 193 days per year. The average date of the last killing frost at Lovington is April 11 and the first killing frost is November 3. Climatological data, from records of the United States Weather Bureau (1953–59) are summarized in the following table for three stations in northern Lea County:

Station	Average annual precipitation (inches)	Mean annual temperature (°F)	Mean annual maximum temperature (°F)	Mean annual minimum temperature (°F)	Average number of frost-free days per year
Hobbs	15.26	60.8	75.4	45.6	206
Lovington	14.82	59.9	76.7	43.6	206
Tatum	16.20	58.8	74.5	42.1	193

ECONOMY

The economy of northern Lea County has changed gradually in the period 1929–60 from one based predominantly on stock raising and dry farming to one based on irrigated farming and the production of oil and gas.

Prior to 1929 most of the farmers in northern Lea County relied on precipitation for their crops. The general use of ground water for irrigation began during the drought of the early thirties; however, until 1946, irrigation was limited principally to small tracts in the vicinity of Lovington and Hobbs. The amount of irrigated acreage began to increase rapidly in 1946 and by 1954 nearly 93,000 acres were under irrigation; after 1954 the expansion continued but at a much reduced rate.

Most of the irrigated acreage (fig. 2) is between Tatum on the north, Hobbs on the south, the Texas border on the east, and an irregular northward-trending line about 15 miles west of Tatum and Lovington. In 1954 about 66 percent of the irrigated land was used to grow cotton, sorghum, and alfalfa; about 31 percent was used to raise vegetables, fruits, berries, oats, and wheat; and about 3 percent was devoted to pasture.

The Lea County Underground Water Basin (fig. 2), as redefined by the New Mexico State Engineer in 1952, is included in the northern Lea County area. Drilling for water in the declared basin is controlled by the New Mexico State Engineer so that the ground water can be conserved and the rights of prior users will be preserved to the extent possible. If the State Engineer determines that additional wells may seriously deplete the supply of water, he can close part or all of the basin to further appropriation of water.

The basin was declared under regulation by order of the State Engineer in 1931, but the amount of water pumped in the basin remained so small that it was not closed to further appropriation of ground water until December 31, 1948. The State Engineer extended the area of the basin October 1, 1952. Some parts were reopened to further appropriation on December 31, 1952 and on February 2, 1953. At present the declared basin includes an area of about 2,180 square miles.

About two-thirds of the cattle and almost all the other livestock in Lea County are raised in northern Lea County. Between 1929 and 1949 the value of all livestock and livestock products sold annually more than doubled. Since 1949, however, sales have steadily declined. The decline has been attributed to the redirection of effort from grazing management to farming and to the production of petroleum products.

The oil and gas industry, expanding rapidly since 1944, has become the most important segment of the northern Lea County economy. Between 1926, when the first oil well in Lea County was drilled near Maljamar, and January 1, 1955 when about 3,000 wells were in operation, more than 568 million barrels of oil and more than 939 million cubic feet of natural gas has been produced. Local plants during 1954 produced about 1½ million barrels of butane and propane, 1½ million barrels of gasoline, and 22 million pounds of carbon black from natural gas produced in southeastern New Mexico.

GEOLOGY AND GROUND WATER

Rocks of Precambrian through Cenozoic age underlie northern Lea County; however, only rocks of Mesozoic and Cenozoic age crop out in the area and only they are known to contain potable ground water. The Ogallala formation is the principle source of ground water in northern Lea County. The deposits of Quaternary age and the underlying rocks of Cretaceous and Triassic age generally yield only small amounts of water. Most of the sediments of pre-Mesozoic age contain brackish and saline water.

ROCKS OF PRE-MESOZOIC AGE

Granite and volcanic rocks of Precambrian age underlie the area at depths which range from 11,000 feet in the northwestern part to about 14,000 feet in the southeastern part (Flawn, 1956, p. 68, pl. 2). Ground water has not been reported in the rocks of Precambrian age and probably little occurs in them.

The rocks of Precambrian age are overlain unconformably (Barnes, and others, 1959, p. 25–26) by approximately 3,000 to 6,000 feet of limestone, dolomite, shale, and sandstone of Early Ordovician through Pennsylvanian age. Overlying the Pennsylvanian rocks are 8,000 feet of Permian rocks—about 5,000 feet of dolomite and limestone containing a small proportion of shale and sandstone, and about 3,000 feet of salt and anhydrite. In general, water in the rocks of Paleozoic age contains a large amount of dissolved solids and occurs with oil and gas.

Water discharges from the formations of Paleozoic age in two ways—produced with oil and as subsurface flow out of the area. The amount of subsurface flow is unknown, but records (New Mexico Oil and Gas Engineering Committee, 1952, 1954, and 1955) show that the amount of water pumped with oil from these formations was about 1,900 acre-feet in 1952 and approximately 2,400 acre-feet in 1954. By the end of 1954 about 20,500 acre-feet of water had been produced from 2,800 wells drilled since the start of oil production. Some wells did not yield any water while others produced several times the annual average of 7.35 acre-feet of water per well.

A source of recharge is the brine pumped from wells in Lea County into other wells which are bottomed in rocks of pre-Mesozoic age. In some cases this type of recharge is used primarily to repressure oil pools which thereby increases the recovery of oil and gas from the reservoir. In other cases the primary consideration is the removal of the fresh-water contamination hazard. In Lea County only a small proportion of the oil-field brines is currently (1960) artificially recharged to the rocks of pre-Mesozoic age.

ROCKS OF MESOZOIC AGE

Rocks of Mesozoic age in northern Lea County range in thickness from 1,400 to 2,100 feet and consist of shale and sandstone of Triassic age and siltstone and limestone of Cretaceous age.

The amount of water produced from rocks of Triassic and Cretaceous ages is small, but the small production does not necessarily indicate that the quantity available is insignificant. The meager production may be due in part to the general lack of exploration and development. Rocks of Mesozoic age have been penetrated by only a few water wells most of which are in the northern third of the area where the Ogallala formation is relatively thin and contains little water.

Rocks of Triassic age.—Rocks of the Dockum group of Triassic age unconformably overlie rocks of Permian age and range in thicknes from 1,400 to 2,000 feet (Nye, 1930, p. 370). The Dockum group underlies the entire area, but it is exposed only along the escarpment of the Mescalero Ridge from the southern part of T. 10 S., R. 31 E., to the northern part of T. 14 S., R. 31 E.

The Dockum group in northern Lea County comprises an upper part and a lower part that are distinctive but which grade into one another. The lower part of the group has a maximum thickness of 600 feet and consists mostly of reddish sandstone but includes a relatively small proportion of variegated shale and limestone. The upper part of the group has a maximum thickness of about 1,200 feet. This part is predominantly a reddish shale but includes minor amounts of variegated shale, sandstone, conglomerate, and limestone (Adams, 1929, p. 1051; Nye, 1932, p. 237–238).

Approximately 165 feet of the Dockum group is exposed in the SW¼ sec. 3, T. 11 S., R. 31 E. (Nye, 1932, p. 236). The lower 40 feet of the exposure consists of light-greenish-gray to grayish-green shaly sandstone that contains thin beds of chocolate-colored and greenish-colored shale and grit made up of shale pellets. Overlying the shaly sandstone is 30 feet of light-green and chocolate-colored sandy shale that includes thin beds of micaceous shaly sandstone. The sandy shale is overlain by 90 feet of poorly exposed chocolate-colored to reddish-brown shale that contains some green shale.

Silicified wood is the only fossil material reported found in the Dockum group in this area (Nye, 1932, p. 237).

The rocks of Triassic age usually can be distinguished from rocks of Permian age by the difference in color—the shale of Triassic age is deep purplish to brownish red while that of Permian age is generally brick red—and by the presence of mica flakes in the rocks of Triassic age.

The rocks of Triassic age contain some water but they are not considered to highly productive aquifers. Seven wells in northern Lea County obtain water from the upper part of the Dockum group. Several wells in southern Lea County also tap the Dockum group and it is possible that more water could be developed in the rocks of Triassic age in northern Lea County.

Rocks of Cretaceous age.—The Tucumcari shale of Cretaceous age unconformably overlies the Dockum group in the northeastern part of Lea County. A few shot-hole logs from south of Lovington record gray, blue, yellow, and green shale which may be Cretaceous in age as reported by Bates (1942, p. 269).

The fossils listed below, which were collected at North Lake in sec. 32, T. 10 S., R. 34 E., were identified: *Serpula?* sp., *Gryphaea corrugata* Say, *Exogyra texana* Roemer, *Exogyra plexa* Cragin, *Pecten (Neithea) texanus* Roemer?, and *Plicatula* cf. *incongrua* Conrad. The fossils indicate that the enclosing rocks are of Early Cretaceous age and probably are equivalent to the Tucumcari shale.

The Tucumcari shale generally consists of fossiliferous dark gray siltstone and thin beds of brownish sandy limestone, grayish limestone and sandstone. In outcrops the siltstone beds weather to yellow and the sandy limestone beds usually have the appearance of yellowish sandstone because weathering dissolves the calcium carbonate from around the sand grains.

The Tucumcari shale is about 150 feet thick in the northeast corner of Lea County but it thins southwestward and pinches out along an irregular line extending from T. 9 S., R. 33 E., to T. 14 S., R. 38 E.

The Tucumcari shale crops out along the western and northern edges of North Lake, and, reportedly, along the eastern edge of Ranger Lake (Conover and Akin, 1942, p. 286) and along the northwestern part of Middle Lake (Dane and Bachman, 1958). The greatest observed thickness of the Tucumcari shale is in a gully on the west side of North Lake where a composite section approximately 17 feet thick was measured. The Tucumcari at the exposure consists of dark gray siltstone and thin interbedded stringers of limestone. Several of the stringers wedge out laterally into siltstone. In the lower part the stringers are light brown, sandy, crystalline limestone; in the upper part they are light gray and fine grained. Here the contact between the Tucumcari shale and the overlying alluvium is exposed and is unconformable. Fragments of Lower Cretaceous fossils and of the Tucumcari shale were noted in the alluvium at this outcrop.

Limited quantities of ground water occur in the Tucumcari shale. Beds of sandstone near the base of the formation constitute the principal aquifer.

Water is pumped from several wells which penetrate the rocks of Cretaceous age. At one time some of the water in these rocks was under sufficient artesian pressure to flow at land surface, but since 1940 all the artesian wells in the area have gradually ceased to flow. Well owners generally attribute the cessation of flow to the widespread drilling of shotholes for seismic surveys. The shotholes penetrated the water-bearing stratum and since the holes were not cased the artesian water leaked into the overlying Ogallala formation and dissipated the hydraulic pressure.

The characteristics of a well in the SW¼ sec. 20, T. 12 S., R. 37 E., which produces water from rocks of Cretaceous age have been studied by the U.S. Geological Survey (Conover and Akin, 1942). The well was completed in 1940 at a total depth of 185 feet. Sediments of Cretaceous age were penetrated from 25 feet below land surface to the bottom of the well, and artesian water was found in a bed of sand at a depth of 183 to 185 feet. The well flowed about 25 gpm (gallons per minute) when first drilled and had a static head of about 14 feet above land surface; reportedly, flow ceased about 1946.

DEPOSITS OF CENOZOIC AGE

Deposits of Cenozoic age in northern Lea County range in thickness from 0 to 350 feet and consist of continental deposits of Pliocene age and sand and alluvium of Pleistocene and Recent ages. The Cenozoic formations crop out over most of the area.

The erosional surface that underlies formations of Cenozoic age was cut on rocks of Mesozoic age. The slope of the surface is generally southeastward and the relief is moderate (figs. 2 and 3). Two cycles of erosion of the bedrock surface are indicated by the contour map. Stream channels found beneath the Ogallala formation of Pliocene age trend southeastward and probably were cut after the close of the Mesozoic era. Stream channels beneath the alluvium south of Mescalero Ridge trend in a southwestward direction and were cut during the Cenozoic era after the Ogallala formation had been removed by erosion.

The Ogallala formation of Pliocene age lies unconformably upon rocks of Mesozoic age. The formation underlies the Llano Estacado everywhere except for a few small areas where it has been removed by erosion.

The Ogallala ranges in thickness from 0 to about 350 feet and averages approximately 200 feet. It is thickest near the Mescalero Ridge in Tps. 14 and 15 S., Rs. 31 and 32 E. It ranges in thickness from about 75 to 225 feet in the vicinity of Lovington and McDonald where it averages about 150 feet. Most of the variation in thickness is due to irregularities of the surface of the Mesozoic rocks on which the Ogallala was deposited rather than to post-Ogallala erosion (Nye, 1930, p. 369).

The Ogallala consists mostly of fine to very-fine sand but includes minor quantities of clay, silt, coarse sand, and gravel. The lower one-third of the Ogallala contains a higher proportion of coarse sediments than the upper two-thirds. Usually the coarse sediments occur as lenticular beds in the finer material. Extensive beds of coarse sand and gravel are found in some of the buried stream channels cut into the Mesozoic bedrock.

Most of the formation is unconsolidated, although near the top and locally within it the sediments have been cemented by calcium carbonate to form beds of caliche. The degree of cementation of the caliche varies greatly. However, in general the Ogallala is most firmly cemented near the top of the formation and where the sediments are fine and contain much silt (Nye, 1932, p. 235).

The bed of caliche at the top of the formation forms topographic prominences because of its resistance to erosion. It generally occurs at the top of most plateaus in the southern High Plains and is usually called the cap rock. There is no sharp break between the caliche cap rock and the underlying sediments because the amount of cementation decreases gradually downward. In some places the cap rock is so dense that it breaks with a semiconchoidal fracture; elsewhere it may be soft and chalk like. Usually it is not stratified or bedded, but locally it is flaggy and is used as a building material. The partially cemented material beneath the cap rock is used extensively as road metal, particularly in the oil and gas fields. Sand and gravel from the Ogallala formation are used in construction and road building.

The following stratigraphic section, measured by the author and Alfred Clebsch, Jr., shows the general character of the upper part of the Ogallala formation:

Section of the Ogallala formation on the south side of U.S. Highway 31 in SE¼ sec. 11, T. 15 S., R. 30 E.

	Thickness (feet)
Tertiary:	
Ogallala formation:	
Caliche, hard, weathers to knobby slope	8
Sand, brown, fine-grained, locally well cemented with caliche. Forms vertical cliffs	20
Sand, brown, fine-grained, moderately cemented with caliche near top, grades into overlying unit, contains pendants of caliche. Forms bench	28
Sand, brown, fine-grained, poorly cemented	3.5
Sand, brown, fine-grained, well cemented, contains vertical joints filled with caliche. Forms ledge	10
Sand, brown, fine-grained, slightly cemented	3
Sand, brown, fine-grained, contains irregularly distributed blebs of caliche, massive	6.5
Sand, brown, fine-grained, contains vertical joints filled with caliche, massive	5.0
Sand, brown, fine-grained, poorly cemented, contains several thin discontinuous moderately cemented beds	5.0
Sand, brown, fine-grained, moderately cemented, case hardened on weathered suface. Forms ledge	0-1
Sand, brown, fine-grained, poorly cemented	3.5
Sand, brown, fine-grained, slightly cemented	0.1-1.5
Sand, brown, fine-grained, poorly cemented in lower half, moderately cemented in upper half	4
Sand, brown, fine-grained, poorly cemented	1
Base of section covered	
Total section exposed	100

Sand, soil, and alluvium of Pleistocene and Recent age unconformably overlie the Ogallala formation on the Llano Estacado and the Dockum group west and south of Mescalero Ridge. The thickness of the sediments ranges from 0 to about 30 feet on the Llano and from 0 to about 40 feet on rocks of the Dockum group. The material overlying the Ogallala formation is off-white to light brown and was derived from the Ogallala on the Llano; the material overlying the Dockum group is mostly red because it was derived from the red beds of Triassic age.

The Ogallala formation of Pliocene age and the alluvium, soil, and sand of Pleistocene and Recent ages form a single hydrologic unit and in this atlas their hydrologic characteristics will be discussed together.

Ground water in the formations of Cenozoic age is unconfined and occurs mainly in the unconsolidated or poorly consolidated sand and gravel of the Ogallala formation beneath the caliche cap rock. The water-bearing properties of the formation vary vertically and horizontally. The vertical variation is due chiefly to the amount of calcium carbonate cement in the Ogallala. As a rule, the amount of calcium carbonate cement decreases downward and is practically negligible at depths of 35 to 50 feet below the surface. The porosity and permeability increase downward as the cementation decreases. Lateral variations in the water-bearing properties of the sand and gravel below the zones of cementation are the result of variations in the coarseness and degree of sorting of the particles.

The yield of wells, or the amount of water pumped in gallons per minute, ranges widely throughout the area. The maximum yield recorded in normal operation of the pumps in 1953 was about 1,700 gpm. Some wells used for irrigation pump as little as 200 gpm but wells yielding less than about 300 gpm are generally considered unsatisfactory for irrigation use. The yields of wells differ greatly in relatively short distances and may be attributed to formation differences or differences in well construction. The low yield in some wells may be due in part to poor development or construction of these wells, inasmuch as wells of higher yield have been developed nearby.

Perched ground water is found in beds of caliche that have a honeycomb-like structure. These beds have bedding planes enlarged by solution and are locally referred to as "honeycombed rock" or "water rock" (Nye, 1930, p. 372). The quantity of ground water derived from this type of reservoir is small.

Irrigation wells tap the alluvium in the area south of the Mescalero Ridge in the vicinity of Nadine and Monument. Stock wells have been constructed in the alluvium at Sand Gate, but no large-production wells have been drilled, so the potential of the aquifer there is unknown. Generally the alluvium on the Llano is above the water table although perched ground water could occur in those places where the alluvium is relatively thick and overlies an impervious section of caliche.

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GROUND-WATER CONDITIONS IN NORTHERN LEA COUNTY, NEW MEXICO

By
Sidney R. Ash
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