BULLETIN 85

Stratigraphy and Petroleum Possibilities of Catron County, New Mexico

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Abstract

Most of Catron County is underlain by volcanics and sediments of Tertiary and Quaternary age. Outcrops of pre-Tertiary rocks are restricted to a strip, four townships wide, across the northern part of the county and to a few isolated exposures in the volcanic rocks. Data on pre-Mesozoic rocks are almost entirely restricted to a few deep oil tests drilled in the northern part of the county. These tests reveal that the lower Permian Abo Formation directly overlies the Precambrian in most of this area. Permian rocks consist of carbonates, evaporites, sandstones, and shales. They probably attain a maximum thickness of 3000 feet in the southeastern part of the county. Projection of control points from adjacent parts of New Mexico and Arizona suggests that approximately 2000 feet of Paleozoic rocks older than Permian underlie the volcanics of the southern half of Catron County.

Mesozoic rocks (Triassic and Cretaceous) have a maximum thickness of slightly more than 3000 feet in the northern part of the county, but Triassic strata thin rapidly to the south and are absent in southern Catron County. Cretaceous rocks beneath the southern two thirds of the county may attain a thickness of from 2000 to 3000 feet, but thinner sections are to be expected.

The most favorable stratigraphic intervals for petroleum exploration are Cretaceous sandstones, Permian carbonates and sandstones, and, where present, Pennsylvanian carbonates. Exploration is difficult in much of the area because favorable structures are concealed by volcanic rocks, and thicknesses of volcanic intervals are unknown. Areas where minimal sections of Tertiary rocks are present are pointed out.

Introduction

In 1933, the New Mexico Bureau of Mines and Mineral Resources published Bulletin 9, entitled *The Oil and Gas Resources of New Mexico,* by Dean E. Winchester. This bulletin was later revised by Robert L. Bates (1942) and published as Bulletin 18. Since 1942, the production of petroleum in New Mexico has more than tripled, oil and gas have been found in large quantities in rocks of pre-Permian age in the southeastern counties, and almost all discoveries and developments in the San Juan Basin have taken place. As a direct result of the thousands of wells drilled in the past twenty years, tremendous strides have been made in our knowledge of the stratigraphy of New Mexico. It would be virtually impossible now to condense all the geologic data accumulated since 1942 into one publication.

A revision of Bates' work is needed. A series of bulletins should be published covering the oil and gas resources of New Mexico by geographic areas in the nonproductive regions and by segments of the stratigraphic column in the productive regions. Publications such as that of the Roswell Geological Society's (1956) symposium on the oil and gas fields of southeastern New Mexico make it unnecessary to discuss each field in that area. Revisions should stress stratigraphy, structure, and possible areas of future production. To do this will require personal examination of numerous well samples and mechanical logs. The subsurface data from these sources are of immediate value to all individuals and companies involved in the extraction of the mineral wealth of New Mexico. For this reason, data from the well samples should be released in advance as they become available. Regional interpretations including isopach and facies maps should be published as reliable information is acquired.

This bulletin on Cation County is meant to be the first of such a series on the oil and gas resources of New Mexico.

PHYSIOGRAPHIC SETTING

Most of Catron County lies within the Mexican Highland section of the Basin and Range Province (Fenneman, 1931). A sharp demarcation with the Colorado Plateau Province to the north is lacking. As noted by Fenneman, ". . . the plateau character after continuing some distance (south of the Zuni Mountains) gives way to a disordered structure and mountainous surface assigned . . . to the Mexican Plateau section. . . . Generally speaking, the mountains on the east and south (of the San Agustin Plains), while in some cases increased in height by volcanic flows, are due primarily to deformation and hence have more in common with the Mexican Plateau than with the Colorado Plateau." The southern edge of the Colorado Plateau Province might thus be drawn along the north edge of the Gallinas, Datil, Horse, Tularosa, and San Francisco mountains.

ACKNOWLEDGMENTS

Many persons have assisted directly or indirectly in the preparation of this manuscript. Philip B. Luce, a graduate student at New Mexico Institute of Mining and Technology, aided in the field work and preparation of well samples. Dennis E. Williams, also a graduate student, drafted the figures. Frank E. Kottlowski, Robert H. Weber, and Teri Ray of the Bureau staff reviewed the manuscript and made many helpful suggestions. Informal discussions with various geologists, dating over several years, have also been of considerable benefit. The manuscript was typed by Lola White, Lois Devlin, and Helen Waxler.

Stratigraphy

Rocks varying from Pennsylvanian to Recent in age are exposed in Catron County, although the exposures are for the most part limited to Mesozoic and Cenozoic sediments and volcanics. Very few data are available concerning Paleozoic and Precambrian rocks and most of these are based on limited subsurface information. The following discussion of the stratigraphy of Catron County relies heavily on interpretation of well samples, brief field examinations, and a review of the literature.

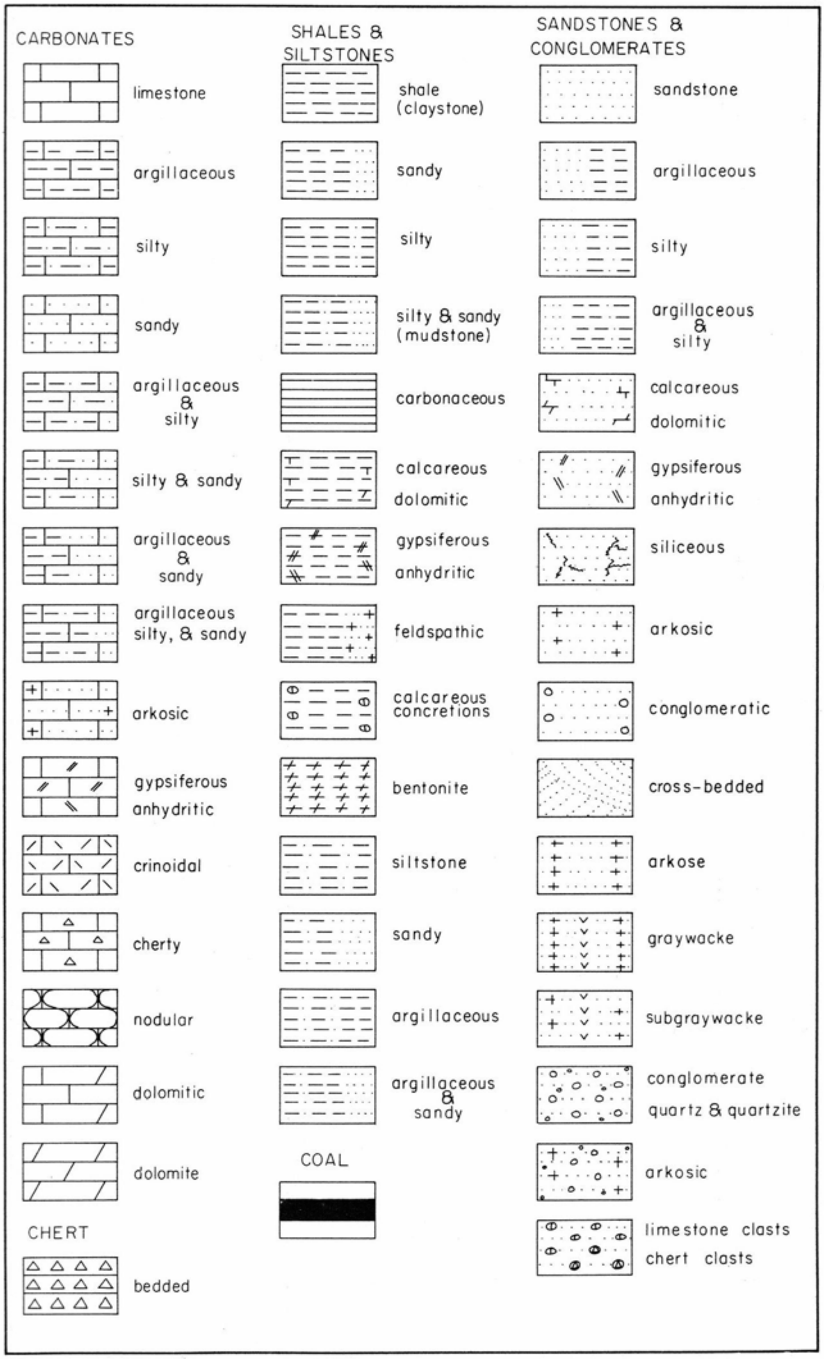
PRECAMBRIAN ROCKS

There are no known exposures of Precambrian rocks in Catron County, and thus far only three oil tests have been drilled to rocks of this age. These wells, the Huckleberry (fig. 1), deep Spanel (fig. 2), and the first Skelly stratigraphic test, are widely spaced near the northern edge of the county (pl. 1). The Precambrian encountered consists of red and gray, coarsely crystalline, biotite granite. Biotite in part is altered to chlorite, and the feldspars have been partly altered to clay. The Belcher well (fig. 3) in southeastern Apache County, Arizona, about two miles from the New Mexico line, bottomed in a weathered quartz-biotite schist. Regional stratigraphic studies of Paleozoic rocks and lithology leave little, if any, question regarding a Precambrian age designation for the lowest rocks drilled in these wells. (A key to the lithologic symbols used on the graphic logs is given on pages 5 and 6.)

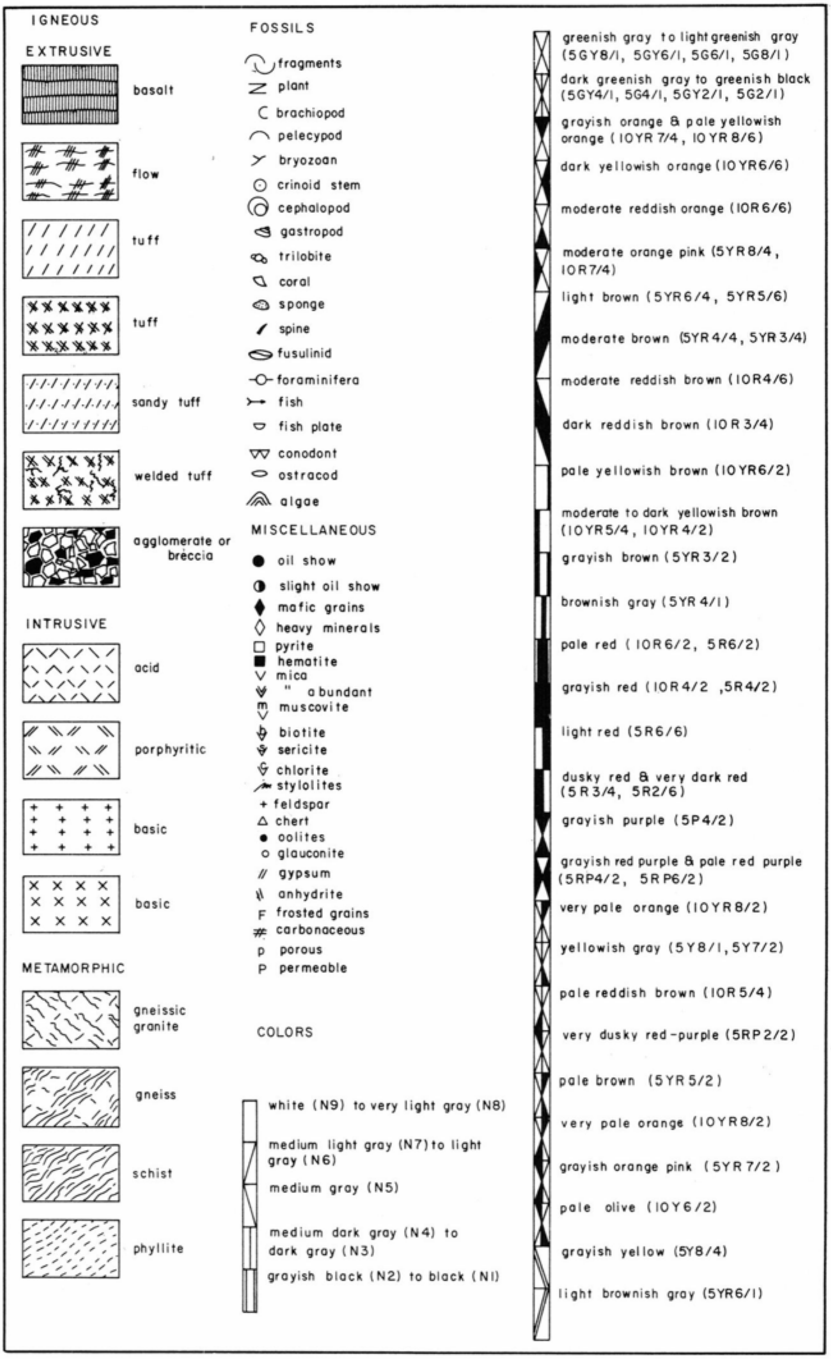
The altitudes of the Precambrian surface in the four wells noted above are all above sea level: 4278 feet in the Belcher well, 3801 feet in the Skelly test, 1633 feet in the Huckleberry well, and 2031 feet in the deep Spanel well. These meager data indicate an east slope on the Precambrian surface of about seventy feet to a mile between the Arizona line north of U.S. 60 and Quemado. Farther to the east this surface is apparently slightly higher. In most of southern Catron County, Precambrian rocks are probably at much greater depths. Estimated depth to the Precambrian in the San Agustin Plains east of Datil is 8500 feet.

PRE-PENNSYLVANIAN ROCKS

Paleozoic rocks older than Pennsylvanian are not known to be exposed in Catron County, and their possible presence in the subsurface can only be inferred by projecting sedimentary trends from adjacent parts of New Mexico and Arizona. Well data limit the northern extent of pre-Pennsylvanian strata, and the line on Plate 1 is drawn as a



Lithologic Symbols



LITHOLOGIC SYMBOLS (CONT.)

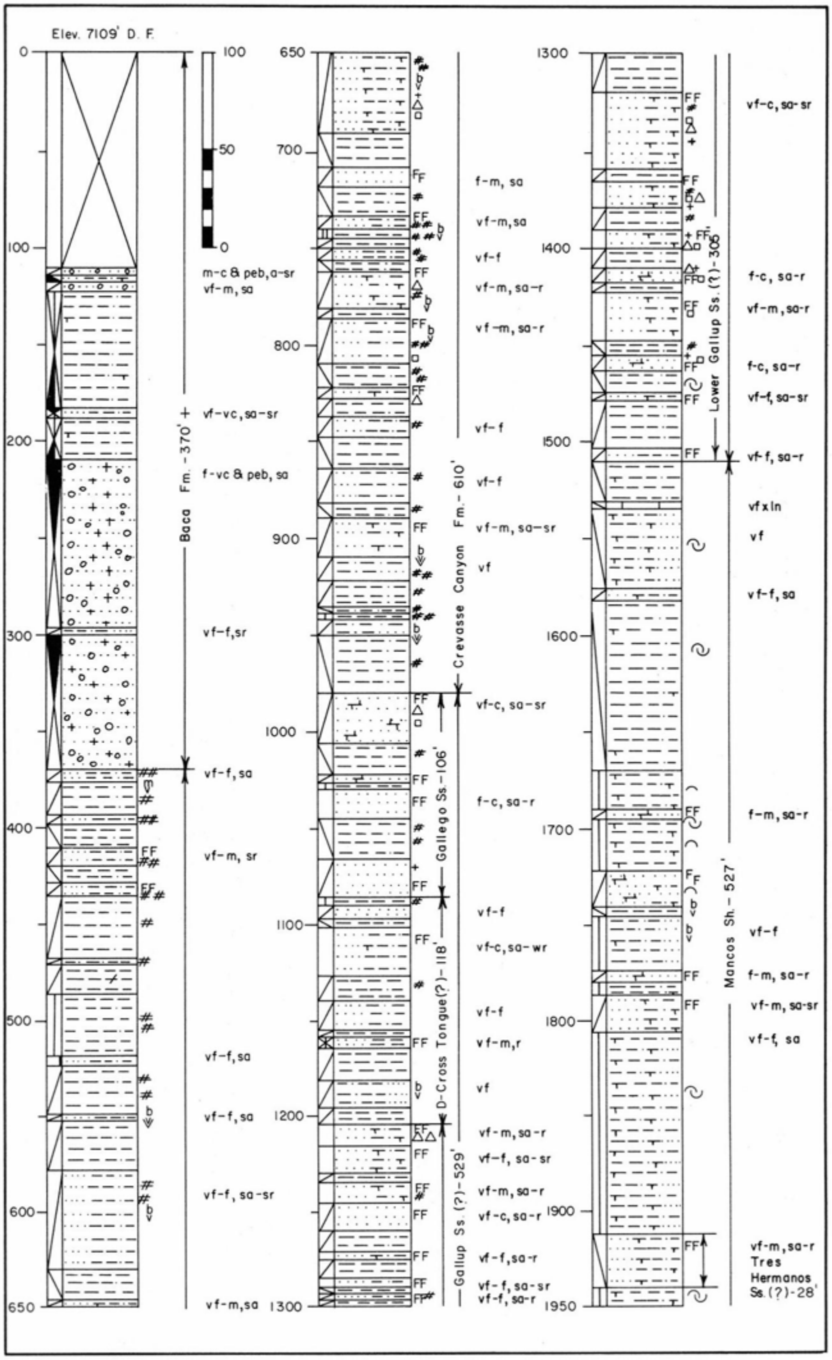


Figure 1

HUCKLEBERRY No. 1 FEDERAL

330N, 330E, sec. 11, T. 2 N., R. 16 W.

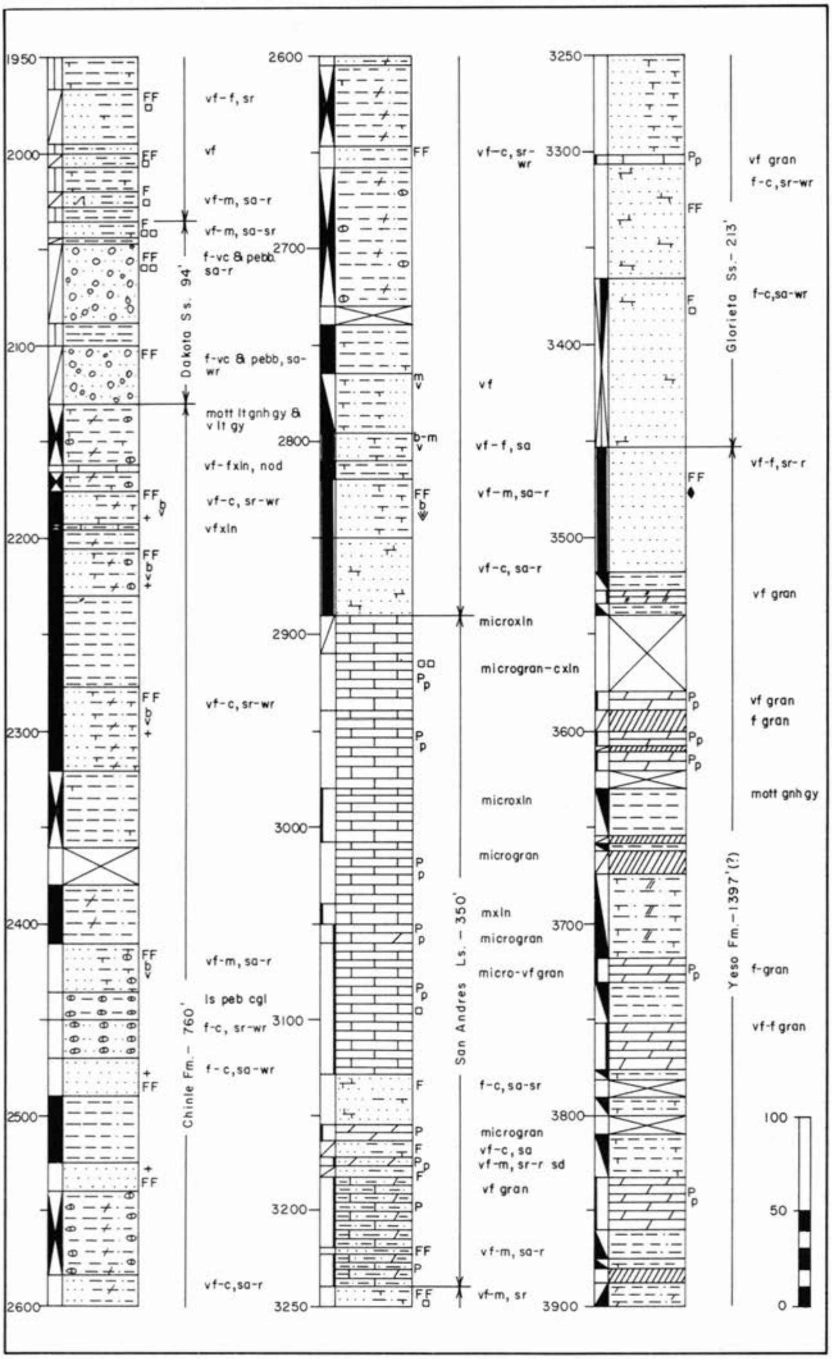


Figure 1
HUCKLEBERRY NO. 1 FEDERAL (CONT.)

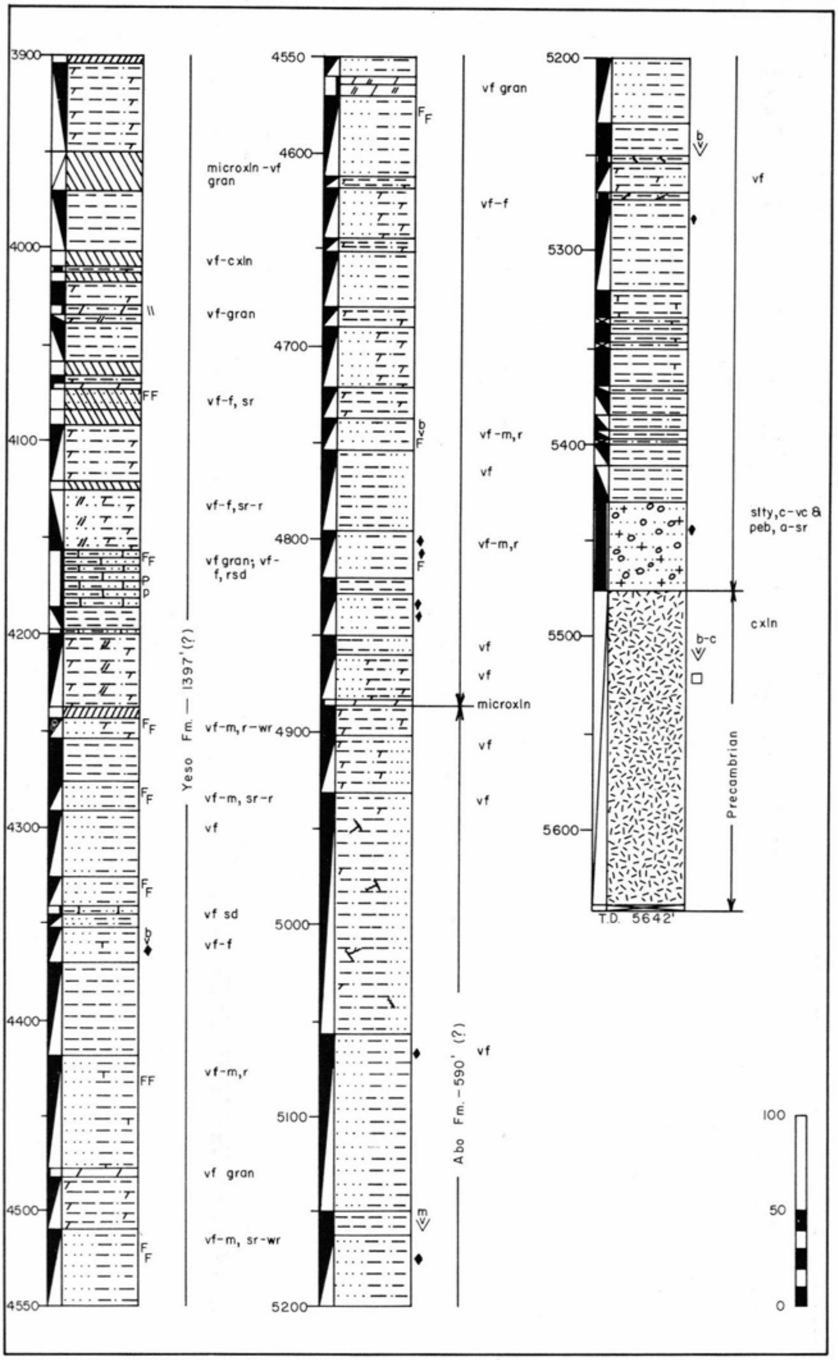


Figure 1
HUCKLEBERRY No. 1 FEDERAL (CONT.)

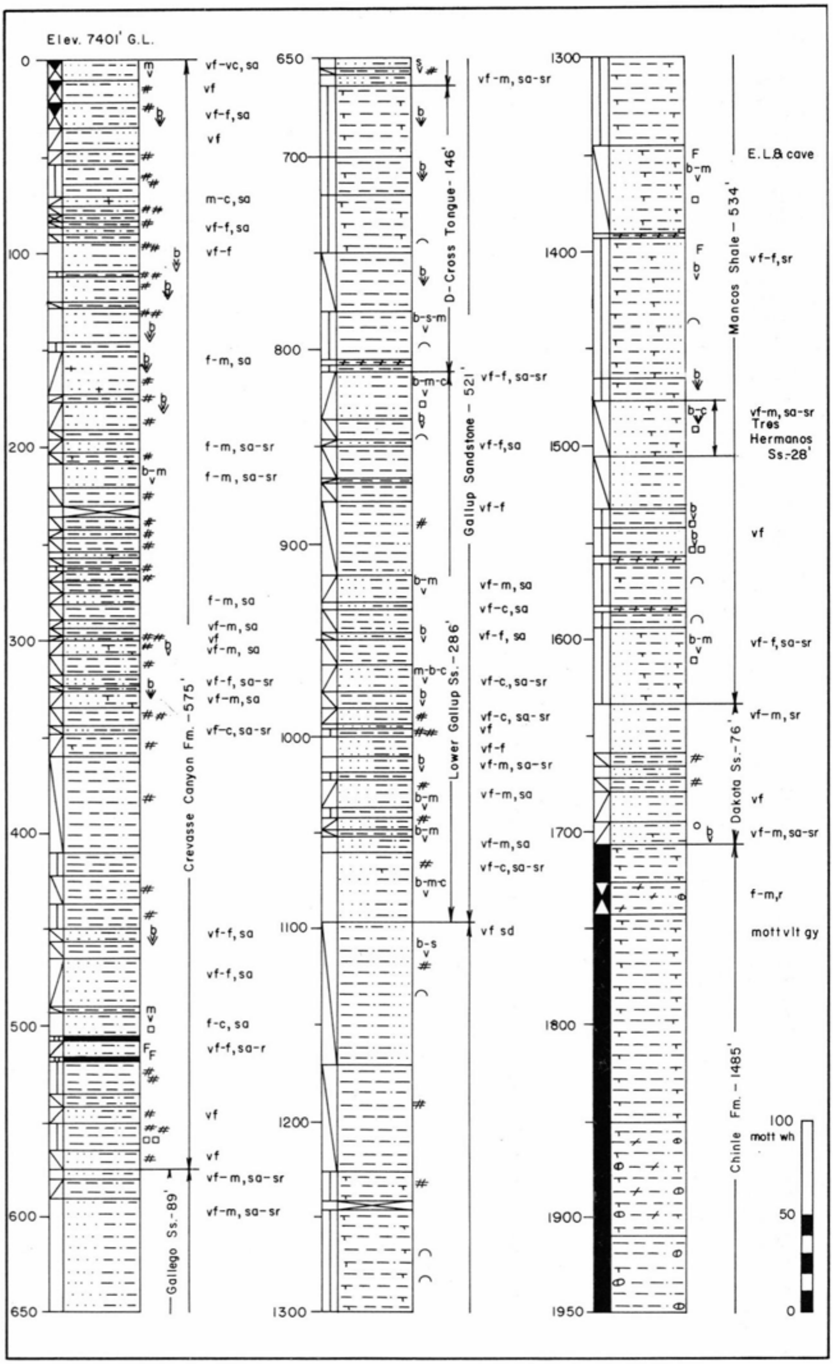


Figure 2

Spanel & Heinze No. 1—9617 Santa Fe Pacific Railroad

2080N, 560E, sec. 27, T. 4 N., R. 11 W.

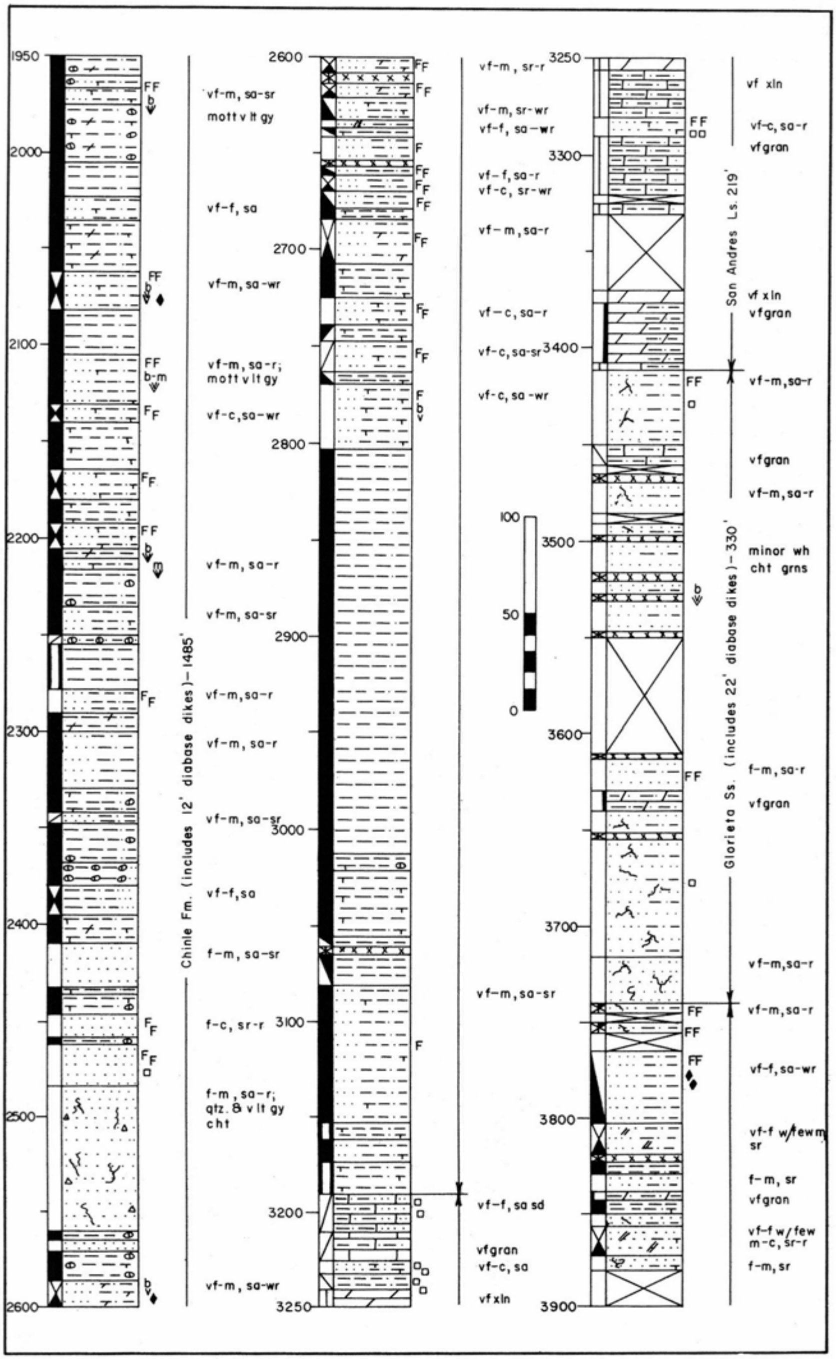


Figure 2
SPANEL & HEINZE NO. 1—9617 (CONT.)

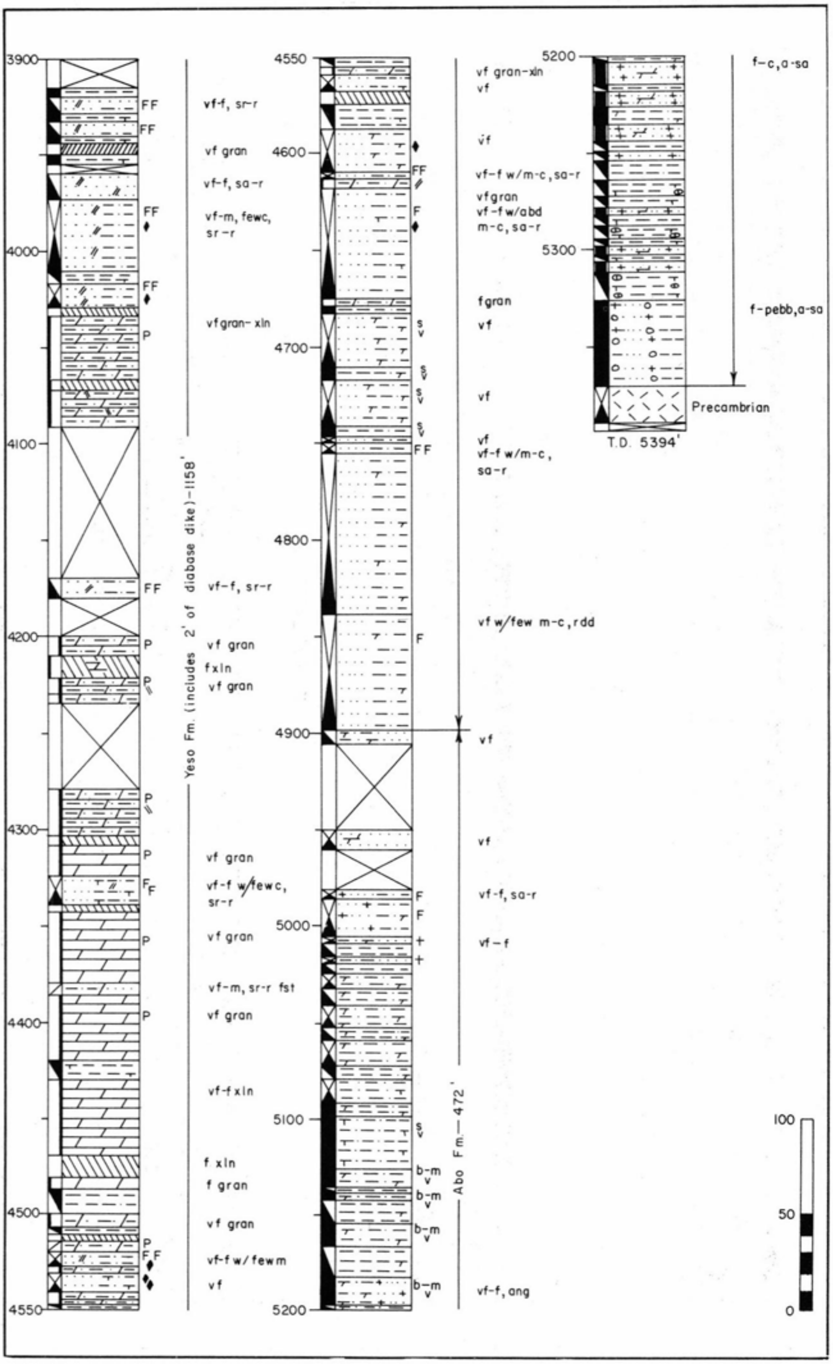


Figure 2

Spanel & Heinze No. 1—9617 (cont.)

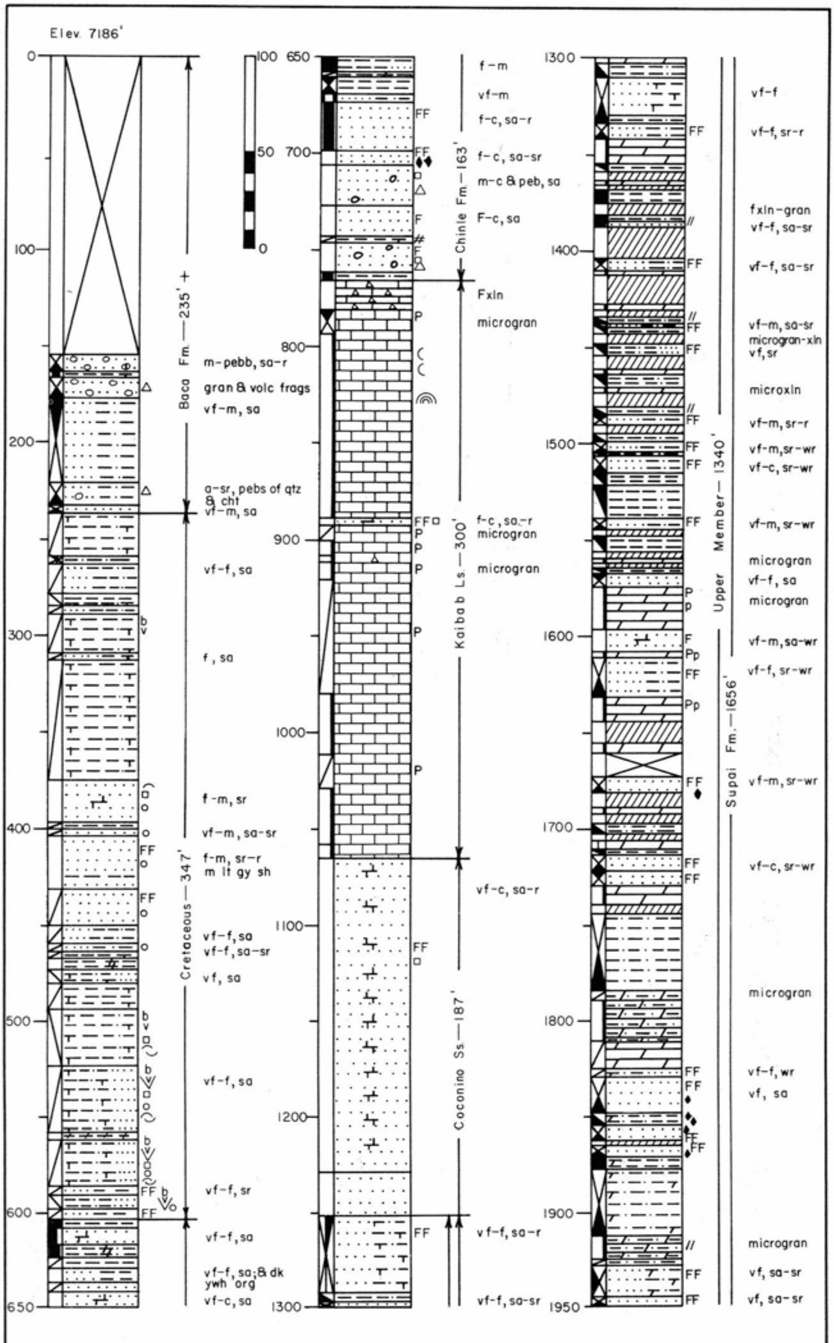


Figure 3
M. A. Belcher Trust No. 1 State
1980N, 1980W, sec. 20, T. 9 N., R. 31 E.
Apache County, Arizona

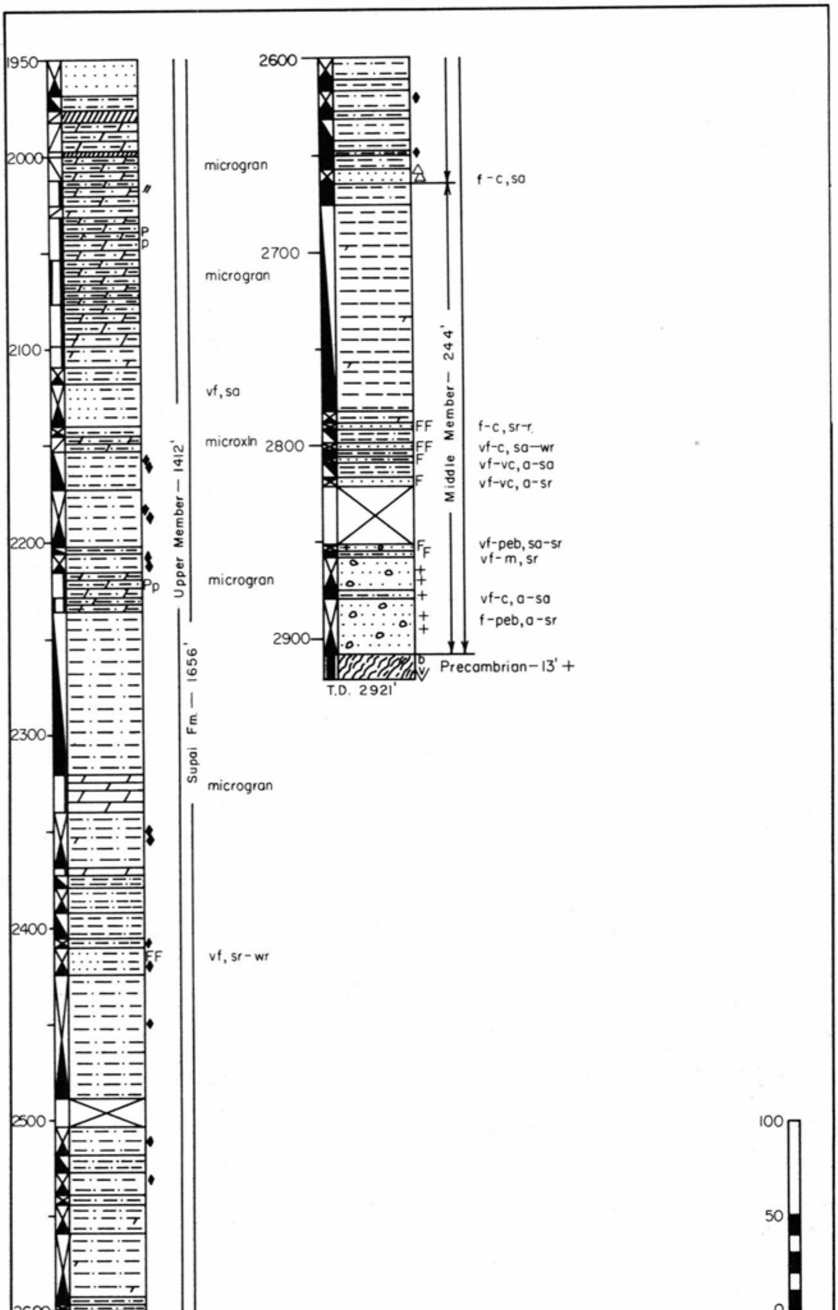


Figure 3
M. A. Belcher Trust No. 1 State (cont.)

straight line between zero points to the east and west. Kottlowski and Foster (1959) suggested that as much as 600 feet of these rocks may be present in parts of southern Catron County. If the same general pattern of south to north truncation exists beneath the Datil—Mogollon volcanic plateau as is present in the bordering uplifts to the east and west, the southern part of the county should be underlain by the Cambrian—Ordovician Bliss Sandstone, Lower Ordovician El Paso Limestone, Upper Ordovician Montoya Dolomite, and strata of Devonian and Mississippian ages. Silurian rocks are not present in adjacent parts of Arizona and their western extent into Catron County is doubtful. The possible presence of these rocks is complicated further by the unknown northward influence of the late Paleozoic-early Mesozoic Burro uplift that was stripped of sediments prior to Late Cretaceous time (Hewitt, 1959). Therefore, in at least parts of southwestern Catron County, Precambrian rocks may be directly overlain by Upper Cretaceous or Tertiary rocks. Tertiary volcanic cover also obscures any possible uplifts, faults, or intrusions associated with the Laramide orogeny.

Mississippian rocks occur as isolated remnants directly overlying the Precambrian in much of northern and central New Mexico. Outcrops of this type are known in the hills southwest of San Antonio and in the Magdalena, Lemitar, and Ladron mountains west and northwest of Socorro. Similar thin remnants may extend beyond the northern limit indicated on Plate 1. Armstrong (1962) suggests this possibility.

PENNSYLVANIAN SYSTEM

Two small outcrops of Pennsylvanian rocks were mapped recently by Robert H. Weber (Weber and Willard, 1959a) northwest of Luna. The larger of these occurs in secs. 3 and 10, T. 5 S., R. 21 W. and the smaller in sec. 27, T. 5 S., R. 21 W. Weber (personal communication, 1964) considers the smaller of the two exposures to be a rafted block. In this outcrop, Pennsylvanian strata are broken, silicified, and floored by andesites of the Datil Formation. Evidence for the nature of the larger exposure is inconclusive; the base of the section is not exposed and the southeast side is separated from andesites by a fault. Kottlowski (1960) examined and measured the larger of the two exposures. He reported a thickness of from 350 to 400 feet and fusulinids of probable Desmoinesian age. The exposed section consists mostly of calcarenite with some pink calcareous shale and brown, lenticular, arkosic sandstone near the top. Kottlowski postulated a thickness of 1100 feet or more for the Pennsylvanian in this area.

Across the state line in Arizona, a similar Pennsylvanian interval of from 50 to 100(?) feet was found by Chester T. Wrucke of the U.S. Geological Survey. These exposures occur on Escudilla Mountain in secs. 28 and 29, T. 7 N., R. 31 E. Fusulinids, identified by Wendell

Stewart of Texaco, Inc., suggest a Missourian and upper Desmoinesian age. Considerable faulting is present in this section.

Rocks of Pennsylvanian age were not found in the three basement tests drilled in Catron County or in the Belcher well in southeastern Apache County, Arizona. The Abo Formation of Permian age directly overlies the Precambrian in each of these tests. Kottlowski and Foster suggested that some of the basal Abo red beds in the subsurface of northern Catron County might be equivalent to the lower Supai red beds of Arizona that are in some places Pennsylvanian in age. Kottlowski (1960), in discussing the Huckleberry well, states, "Comparison of the electric log [of the Huckleberry well] with that of the Tidewater No. 1 Mariano test [north of the Zuni Mountains] suggests that from 70 to 200 feet of the basal Abo may be of Pennsylvanian age in the Huckleberry test. However, the Pennsylvanian in the Tidewater No. 1 Mariano well is interbedded red beds and thin fossiliferous limestones, whereas the basal Abo of the Huckleberry No. 1 Federal is entirely unfossiliferous red-bed clastic rocks." Recent detailed work on the Pennsylvanian and Permian rocks of west-central New Mexico by this writer indicates that the Huckleberry well was located on the buried ancestral Zuni uplift, and that Pennsylvanian rocks either were not deposited in this area or were removed prior to the beginning of Permian deposition. Lithologic features of the Abo Formation, discussed later, tend to support this conclusion. It might be added that there also remains considerable question regarding a Pennsylvanian designation for the interbedded red beds and limestones drilled in the lower part of the Tidewater No. 1 Mariano well.

As noted above, Pennsylvanian rocks are absent in the deep Spanel well in sec. 27, T. 4 N., R. 11 W. However, in the Mitchel No. 1 Red Lake test in sec. 2, T. 3 N., R. 8 W., Socorro County, there appear to be 570 feet of Pennsylvanian strata beneath Abo red beds. It would seem, therefore, that a thin marine Pennsylvanian section, possibly 200 to 400 feet in thickness, may be present in the northeastern part of Catron County (pl. 1). In western Catron County, the possible northern extent of Pennsylvanian rocks is based on exposures on Escudilla Mountain and the absence of Pennsylvanian in the Belcher well, located only 20 miles north of the Escudilla exposures. Projected thicknesses of Pennsylvanian rocks in the southern part of Catron County suggest as much as 1000 to 1200 feet of strata of this age. This estimate of thickness is subject to the same modifications (Laramide tectonic effects, Burro uplift) discussed under pre-Pennsylvanian rocks.

PERMIAN SYSTEM

The classic subdivision of the Permian rocks of western New Mexico, except for the southwestern part of the state, includes (in ascending order) the Abo Formation, Yeso Formation, Glorieta Sandstone, and San Andres Limestone. As applied to Arizona terminology, these units correspond respectively to the middle and upper members of the Supai Formation, Coconino Sandstone, and Kaibab Limestone. Farther to the east in New Mexico, there is a transition zone between Pennsylvanian and Permian rocks. This interval, for the most part Wolfcampian in age, is generally referred to the Bursum Formation. As far as is known, this unit does not occur in Catron County, although it may underlie areas where Pennsylvanian rocks are present.

OUTCROPS

The only known outcrop of Permian rocks in Catron County was discovered recently by Stearns (1962). It occurs in secs. 19 and 20, T. 4 S., R. 12 W. on the southwest side of Horse Mountain. The exposed section was measured by Foster and Kottlowski, and their description was published by Stearns. The lowest exposures consist of 201 feet of interbedded limestone, sandstone, dolomite, and possibly some gypsum that is considered to be part of the Yeso Formation. Above this are 95 feet of very light gray to white, medium-grained sandstones assigned to the Glorieta Sandstone and 417 feet of algal, oolitic, and fossiliferous limestone referred to the San Andres Limestone. The base of the section is not exposed and overlying beds consisting of red sandstones and conglomeratic sandstones may be of either Triassic or Tertiary age.

SUBSURFACE DATA

Complete sections of the Permian interval were penetrated in the deep Spanel, first Skelly, Huckleberry, and Belcher wells. Partial sections were drilled in the second and third Skelly tests and in the Cleary well (figs. 4, 5). The thickness of the Permian section is remarkably uniform over most of northern Catron County. Based on well samples and electric logs, thicknesses are 2155 feet in the deep Spanel well, 2146 feet in the Skelly test, and 2143 feet in the Belcher well. The Huckleberry well with 2586 feet of Permian rocks reflects the southward thickening previously reported by Foster (1957). The Permian also thickens east of Catron County to almost 3000 feet in western Socorro County. Permian beds are probably thin or absent in southernmost Catron County because of erosion following the uplift of the Burro positive element.

In the subsurface, the San Andres Limestone consists mostly of pale to moderate yellowish brown and light gray microgranular limestones and dolomitic limestones. In the lower part of the interval there are usually some interbeds of white, very fine to coarse, subangular-grained, quartz sandstones similar to those of the underlying Glorieta Sandstone. In the deep Spanel well, the carbonates contain considerable

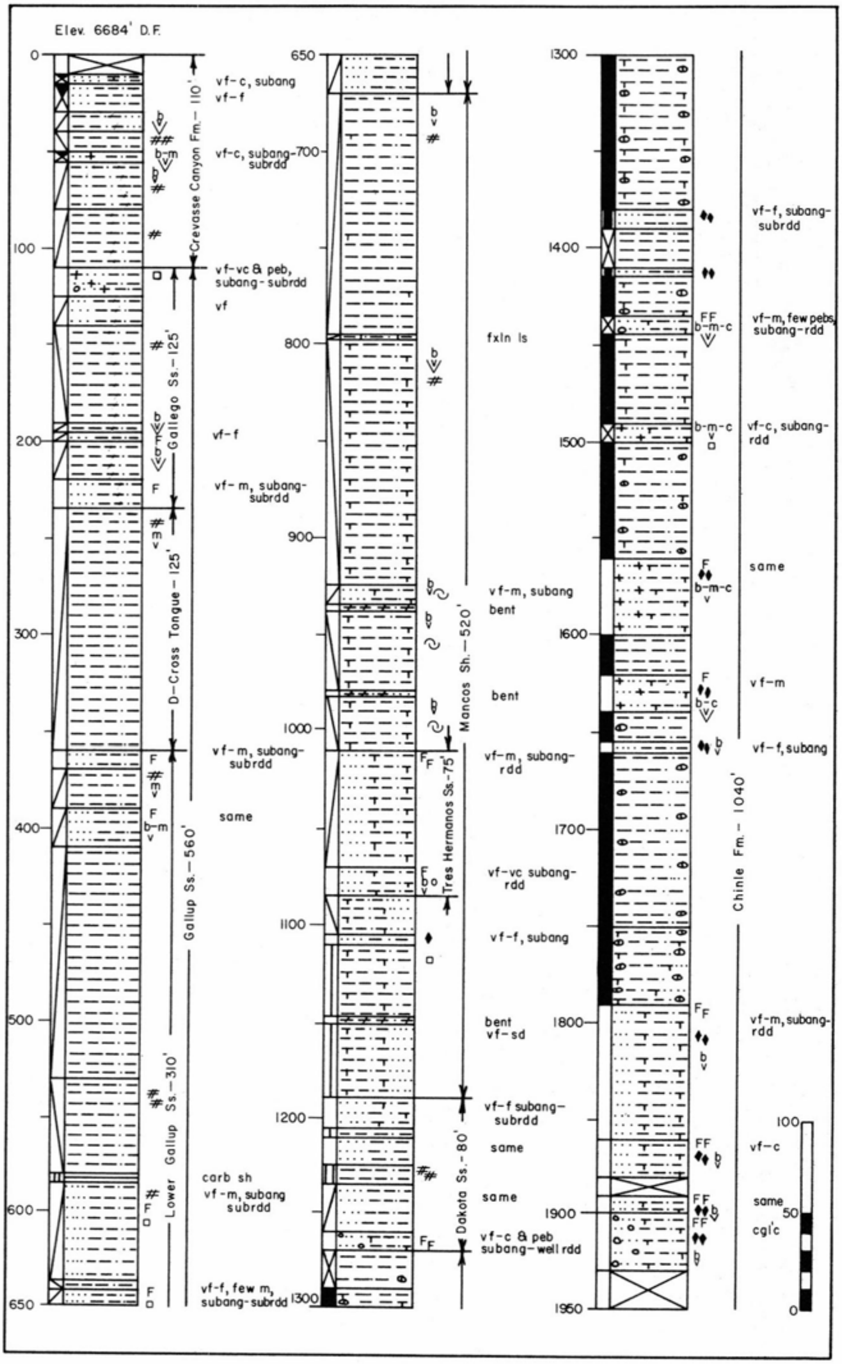


Figure 4

CLEARY NO. 1 WHEELER FEDERAL

1980N, 1980E, sec. 6, T. 3 N., R. 16 W.

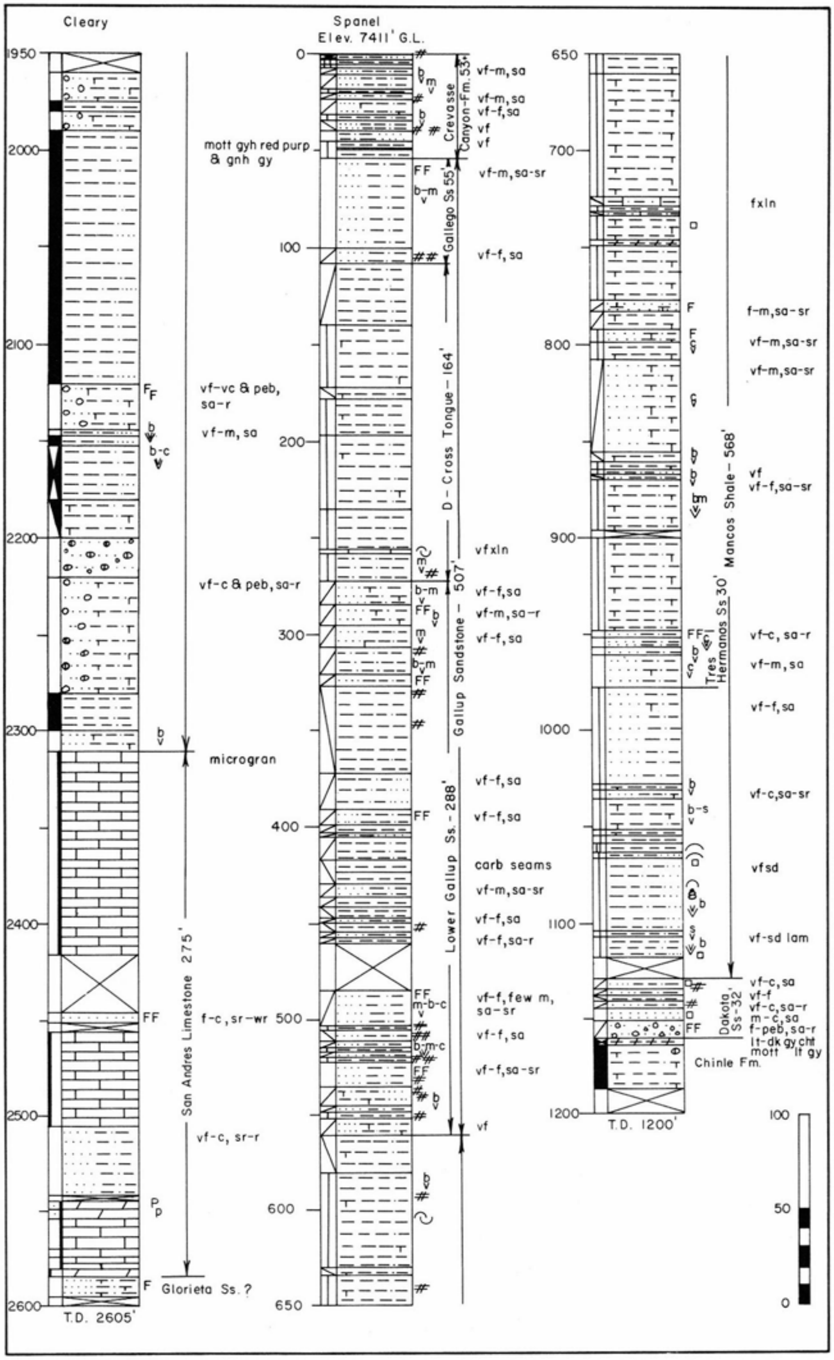


Figure 4 (cont.) and Figure 5

Cleary No. 1 Wheeler Federal (cont.)

Spanel & Heinze No. 1—9609 Santa Fe Pacific Railroad

550N, 740W, sec. 19, T. 4 N., R. 9 W.

clay, silt, and even very fine to fine quartz sand. To the west in the Huckleberry and Belcher wells, there is a marked decrease in impurities. Pyrite and fossil fragments are common throughout the section, chert occurs locally, and most carbonate beds are porous and permeable.

The thickest section of San Andres Limestone known in Catron County is the 417 feet on Horse Mountain (pls. 1 and 2). The interval thins to the north and east with the thinnest section (219 feet) in the deep Spanel well. The San Andres appears to thicken southward at the expense of the Glorieta Sandstone, for the combined thickness of the two units is fairly uniform.

The contact with the underlying Glorieta Sandstone was chosen at the base of the lowest thick carbonate interval. Therefore, some sandstones are included in the San Andres, and in most instances, thin limestones are present in the Glorieta interval. Intertonguing relationships between these two formations has long been recognized. Beds of the Glorieta Sandstone consist of white, very fine to coarse, subangular to well-rounded quartz sandstones. Sand grains are friable to well cemented with either silica or calcium carbonate. Although the range in grain size noted above suggests rather poor sorting, individual beds are composed of fairly well-sorted sands. Pyrite is a common secondary mineral, and in some beds white clastic grains of chert are abundant.

The Glorieta Sandstone thins to the west and south from 308 feet in the deep Spanel well to 213 feet in the Huckleberry well, 187 feet in the Belcher well, and 95 feet on Horse Mountain. This southward thinning is consistent with outcrop data to the east. The contact with the underlying Yeso Formation is based primarily on a color change from white or very pale orange in the Glorieta to various shades of red in the Yeso. Commonly, the color change coincides with an abrupt change in grain size, sorting, rounding, and accessory minerals.

Primarily for descriptive purposes, the Yeso Formation has been subdivided into lower, middle, and upper members. In many respects, these intervals are similar to the Meseta Blanca, Torres, and Joyita members of the Socorro region. However, much work remains to be done in western New Mexico before any reasonable correlations can be attempted.

The upper member consists of from 70 to 200 feet of pale red, moderate reddish orange, and very pale orange, very fine to fine, subangular to rounded, friable, quartz sandstone. Most grains are frosted and ferromagnesium minerals are fairly common. Minor medium to coarse grains are present in the deep Spanel well. Included in the interval are a few thin beds of grayish red shale.

The middle member contains a complex sequence of lithologies consisting of gypsum-anhydrite, dolomite, sandstone, shale, and minor limestone. Granular to crystalline gypsum and anhydrite beds are white and pale to moderate yellowish brown. Several beds contain laminae of dolomite, and quartz sand grains are present locally. Gypsum-anhydrite beds make up about seven per cent of the total Yeso section in the Belcher and Huckleberry wells. Similar thicknesses may be present in the area of the deep Spanel well but samples were incomplete.

Sandstones vary in color from moderate reddish orange through moderate reddish brown, moderate brown, and pale red. Almost all the sands contain a weak carbonate cement of dolomite or calcite and are friable. Individual sand grains are very fine to fine and considerable silt-size material is included. Commonly, however, the sandstones are bimodal, containing a few medium to coarse, sub- to well-rounded grains embedded in the finer matrix. Most grains are frosted and ferromagnesium minerals are fairly abundant. Dolomites are granular, pale to dark yellowish brown, silty, and gypsiferous. The only limestones observed were in the lower part of the interval in the Huckleberry well. Shales and siltstones are mostly moderate to dark reddish brown, moderate brown, and grayish red. The total thickness of these fine-grained clastics is much greater in the Huckleberry and Belcher wells than in the deep Spanel well.

Moderate reddish orange and moderate brown sandstone makes up the bulk of the lower member. In the deep Spanel well, these sands are rather typical of the Meseta Blanca Sandstone Member in outcrops and wells to the east and north. The sandstones consist of silty, very fine- to fine-grained quartz sand with minor to abundant medium to coarse grains "floating" in the finer matrix. Finer grains are subangular and coarser grains rounded. Ferromagnesium minerals are common and most grains are frosted. The interval is similar in the Huckleberry well, but there is a marked decrease in the number of medium to coarse grains. In the Belcher well, almost the entire interval consists of moderate reddish orange siltstones.

The Yeso Formation thickens to the south from 1195 and 115.6 feet in the Skelly and deep Spanel wells to 1412 and 1433 feet in the Belcher and Huckleberry wells. East of Catron County, the Yeso thickens to more than 1400 feet in the Spanel No. 1-9608 well in western Socorro County and is approximately this thickness in outcrops northwest of Socorro. The amount of fine clastics (siltstones and shales) increases to the west with a sand/shale ratio of 5.8 for the deep Spanel well, 0.9 in the Huckleberry well, and 0.4 in the Belcher well. There is also an over-all decrease in the average sand grain size from east to west.

Based on well samples, the contact between the Yeso and Abo formations is less certain in western Catron County than to the east. In the deep Spanel test, there is a rather sharp change in color from lighter shades of red to the typically deep reds of the Abo. This coincides with a decrease in sand grain size, an increase in the number and thickness of shale and siltstone beds, poorer sorting and rounding, and the introduction of weathered feldspar grains. In the Huckleberry and Belcher wells, a transition zone of from 70 to 90 feet is present between the Abo and Yeso formations. The contact was chosen at the base of this transition zone. In the Huckleberry well, this coincides with a fairly sharp break on the electric log.

The maximum thickness of the Abo Formation is 590 feet in the Huckleberry well. The unit thins to the west (453 feet in the Skelly test), southwest (244 feet in the Belcher well), and east (472 feet in the deep Spanel well). Farther east, however, in the Spanel well drilled in Socorro County, it thickens to slightly more than 700 feet. The thinner Abo sections in Catron County are interpreted to be a reflection of the buried ancestral Zuni uplift. The combined thickness of 2023 feet for the Yeso and Abo formations in the Huckleberry well, about 400 feet thicker than in the other complete tests in Catron County, suggests that this well was located on a structurally lower part of the uplift, although still higher than to the east and northeast.

The Abo consists almost entirely of shale and sandstone with some conglomerate at the base. Sandstones are mostly pale red, grayish red, and moderate brown. Individual grains, mostly quartz, range from silt to very fine and fine sand in the upper part, becoming coarse and conglomeratic toward the base. Feldspar is present in varying amounts and the basal interval consists of arkosic conglomerate. Most sand grains are angular to subangular and sorting is poor. The degree of cementation varies from well to well. In the deep Spanel and Skelly tests, the sandstones are fairly well cemented with dolomite, although in the Huckleberry and Belcher wells they are friable. Shales and siltstones make up about sixty-five per cent of the Abo interval. They are grayish red, moderate to dark reddish brown, and moderate brown. Dolomite is the most common cement, and shales or siltstones may be soft to very hard. Mica, particularly biotite, is more common than in the finer clastics of the Yeso Formation. Shales near the base of the section in the deep Spanel well contain small concretionary grains up to 5.0 mm of dark gray and grayish red silty limestone. Grains of this type are common in the basal part of the Abo throughout most of west-central New Mexico. They are not found, however, over the higher parts of the ancestral Zuni uplift and were not seen in the Huckleberry, Skelly, or Belcher wells. Often these grains are interpreted to be from bedded limestones, and Pennsylvanian tops have been picked on the basis of this material in well cuttings. Shales containing limestone grains also tend to have higher resistivities on electric logs.

TRIASSIC SYSTEM

Triassic rocks in Catron County are all referred to the Chinle Formation. The Moenkopi Formation does not appear to be present, nor was it recognized in the Belcher well in Arizona. However, the nearest exposures of the Moenkopi are only eight miles west of Catron County in T. 10 N., R. 30 E., Apache County, Arizona. It does not appear to be possible, based on present data, to subdivide the Chinle Formation into the various members applied in northeastern Arizona and adjacent parts of New Mexico.

OUTCROPS

The Chinle Formation crops out for about fifteen miles along Carrizo Creek and its tributaries in northwestern Catron County (pl. 1 and fig. 6). About 230 feet of the interval are exposed beneath the Dakota Sandstone in this area (Marr, 1956; O'Brien, 1956). The section consists of grayish red and light greenish gray shales and interbedded, poorly sorted sandstones and conglomerates. In the Skelly No. 1 M. N. Teel test drilled on the north side of Carrizo Creek, the Chinle is 650 feet thick.

Figure 6

CHINLE SHALES CAPPED BY THE DAKOTA SANDSTONE ON NORTH SIDE OF CARRIZO CREEK

Possible Triassic rocks crop out above the Permian exposures at Horse Mountain on the north side of the San Agustin Plains. Foster and Kottlowski *(in* Stearns) measured 114 feet of fine- to medium-grained, reddish sandstones containing minor pebbles of quartz, quartzite, and chert. Although these beds appear to be more representative of Triassic strata, conclusive evidence is lacking and they may be part of the lower Tertiary sedimentary interval.

SUBSURFACE DATA

Complete sections of the Chinle Formation were penetrated in the second and third stratigraphic tests drilled by the Skelly Oil Company and in the Huckleberry, deep Spanel, Cleary, and Belcher wells. The section consists of interbedded sandstones, shales, and conglomerates, with shale constituting about sixty per cent of the formation. Shales are mostly grayish red and grayish red-purple, mottled, very light gray to white and light greenish gray, silty, bentonitic, calcareous, and soft. Concretionary grains and nodules of calcium carbonate similar to those that occur in the lower part of the Abo Formation were found throughout the Triassic interval. These limestone pellets are mostly silty and commonly are the color of the enclosing shales, although very light to dark gray grains are also present. Locally, the concretionary material has been reworked to form thin beds of limestone-pebble conglomerate.

Sandstones are similar in color to the shales with an occasional light gray to white interval. Sorting is generally poor with most beds containing a high content of clay and silt, and sand-grain size ranges from very fine to coarse and pebbly. Sand grains are subangular to subrounded with minor well-rounded grains; most grains are frosted. In addition to quartz, there are numerous clasts of feldspar, chert, quartzite, magnetite-ilmenite, biotite, muscovite, and chlorite. Most sandstones are weakly cemented with calcium carbonate and are friable.

In the deep Spanel test is an interval about 100 feet in thickness and approximately 700 feet below the top of the Chinle Formation that consists of white, fine to medium, subangular to rounded, frosted, fairly well-sorted quartz sandstone, locally well cemented with silica. Included are some grains and what appear to be thin beds of very light gray chert. The interval strongly resembles the Glorieta Sandstone and, inasmuch as it was not seen in other wells, may represent a local source area from the Glorieta.

The Chinle Formation thins to the southwest in Catron County from 1473 feet in the deep Spanel test to 1040 feet in the Cleary well, 985 feet in the second Skelly test, 760 feet in the Huckleberry well, 650 feet in the third Skelly test, and 163 feet in the Belcher well. Thinning appears to be primarily the result of pre-Dakota erosion, although some depositional thinning is probably involved as well. As noted by

Foster, Triassic rocks maintain a fairly uniform thickness in west-central New Mexico beneath Jurassic rocks, but thin abruptly south of the Jurassic zero isopach line in southern Valencia County.

JURASSIC SYSTEM

Rocks of Jurassic age appear to be absent in Catron County. North of the Rio Salado, Jurassic sediments pinch out in T. 5 N. To the south, Triassic beds are directly overlain by upper Cretaceous sediments. The Cretaceous also overlies the Triassic in the Carrizo Creek exposures and to the northwest in adjacent parts of Arizona. Jurassic rocks crop out about ten miles north of western Catron County at Atarque. Relationships between Atarque and Carrizo Creek are obscured by Quaternary basalts, but Jurassic sediments are absent in the second Skelly test only three miles south of the Valencia county line.

On the geologic map of New Mexico by Darton (1928), a small outcrop of Jurassic rocks is shown in the southern half of T. 4 S., R. 15 W. This outcrop is labeled "Jnw," indicating sediments of either Navajo, Todilto, or Wingate equivalents. On the map by Stearns, the area is shown as being underlain by Quaternary alluvium and Datil rhyolite pyroclastics.

CRETACEOUS SYSTEM

In western Catron County, Dane and Bachman (1957), Willard and Weber (1958), and Willard (1957a) have subdivided the Cretaceous section in order of decreasing age into the Dakota Sandstone, Mancos Shale, and Mesaverde Group. In eastern Catron County, Dane and Bachman further subdivided the Mesaverde Group into the Gallup Sandstone at the base and the Crevasse Canyon Formation above, and also mapped two isolated exposures of Point Lookout Sandstone. The Cretaceous nomenclature of the San Juan Basin was extended into this area primarily by Pike (1947) and more recently by Tonking (1957) and Givens (1957). Subdivision of the Gallup Sandstone was amplified by Dane, Wanek, and Reeside (1957), and still more recently, Gadway (1959) discussed the Cretaceous sediments in parts of McKinley, Valencia, and Catron counties, and Dane (1959) described the type locality of the Tres Hermanos Sandstone Member of the Mancos Shale.

Because of the nature of outcrop distribution, it is impossible physically to trace individual units from type localities to the north into exposures in the Carrizo Creek and Rio Salado drainage areas. Considerable thickness variations of individual beds and the fairly uniform gross lithologic features of Cretaceous sandstones and shales result in any subdivision being somewhat arbitrary. In general, the method of subdivision in both surface and subsurface stratigraphic work is based primarily on counting the number of major sandstone bodies up from the base of the Cretaceous section. In surface studies this has been amplified by paleontological work, topographic expression, and color. In the subsurface, all Cretaceous sandstones and shales are white, black, or various shades of gray, and almost all sandstones are friable or weakly cemented, Therefore, the red, buff, or brown colors noted on the surface are the results of near-surface oxidation of iron-bearing minerals and are dependent on the amount of these minerals within an individual lithic unit. In the case of secondary pyrite particularly, this is a variable factor. Secondary cementation through oxidation of included minerals or introduction of carbonates or silica through permeable zones under surface and near-surface conditions results in selective hardening of parts of standstone units. The net result is a cliff-slope topography so characteristic of the Cretaceous in the Colorado Plateau, but complicated by variations within individual beds along the strike. Paleontological studies, largely incomplete, have imparted (unintentional in most instances) a time-rock significance to units that are basically rock-stratigraphic or biostratigraphic zones dependent on environmental conditions. Justification for the extension of San Juan Basin terminology into this area is simply that the units have a similar order of arrangement and can thus be said to be homotaxial equivalents. Lacking a new approach to the problems of Cretaceous stratigraphy, the standard terminology is applied in the subsurface work presented in this paper. If nothing else, it is hoped that this will point out some of the problems involved and that additional data as accumulated may result in more realistic conclusions.

DAKOTA SANDSTONE

Outcrops of the Dakota Sandstone are limited to low bluffs along Carrizo Creek and its tributaries in northwestern Catron County. In sections measured by Marr, by O'Brien, and by Crutcher (1956), the interval consists of interbedded very pale orange, grayish orange, and light gray, very fine- to medium-grained sandstone, and grayish yellow, light gray, and black shale. Some of the sandstone beds contain sparse pebbles, and a thin conglomeratic interval is usually present at the base. In the subsurface of western Catron County, the Dakota varies considerably from well to well. Samples from the Huckleberry test consist mostly of light gray conglomerate with minor white, very fine-to medium-grained sandstone at the top of the section and some medium to dark gray shale. Grains consist mostly of quartz and are sub-angular to well rounded and frosted. In the Cleary well, the basal unit is a very light gray conglomeratic sandstone, but the bulk of the section is light gray to white, argillaceous, silty, very fine- to fine-grained subangular to subrounded sandstone with thin beds of dark gray to black, silty, carbonaceous shale. The Cretaceous section in the Belcher well in eastern Arizona was not subdivided, but basal beds are light gray, argillaceous, very fine- to fine-grained, subrounded, frosted sandstone, and medium gray, sandy, calcareous shales containing abundant biotite.

On D-Cross Mountain in western Socorro County, Pike measured a thin conglomeratic sandstone at the base of his Cretaceous section and correlated this with the Dakota. In the shallow Spanel test (fig. 5), about eight miles northwest of D-Cross, there is a similar conglomeratic sandstone directly above the Chinle Formation, but this basal unit is overlain by white to light gray, very fine to coarse sandstones and minor shale that are here included with the Dakota Sandstone. Coarse material is lacking in the deep Spanel well, another eight miles to the west. Here the Dakota consists of a light gray to white, silty, very fine-to medium-grained, subangular to subrounded sandstone with minor glauconite and biotite, and medium gray, silty, carbonaceous shales.

Pike measured 15 feet of Dakota Sandstone on D-Cross Mountain, and Givens measured 20 feet in the same general area. Winchester (1920) noted from 0 to 40 feet in the Alamosa Creek (Rio Salado) Valley and Tonking 6 to 17 feet in the Puertecito area of western Socorro County. In the subsurface, the contact with the overlying Mancos Shale was picked at the top of a dominantly sandstone interval that underlies darker argillaceous sandstones considered more typical of the Mancos. In part, this explains the somewhat thicker Dakota intervals in the subsurface where topographic expression cannot be considered. However, it is likely that the 70 feet of conglomerate in the lower part of the Dakota in the Huckleberry well would be considered part of this interval even if it formed a slope. In addition, Crutcher measured 102 feet of Dakota in Little Blanco Canyon in southwestern Valencia County. Thicknesses for the Dakota Sandstone in the subsurface from east to west are Red Feather No. 2 Smith (fig. 7), 30 feet; shallow Spanel, 32 feet; deep Spanel, 76 feet; Huckleberry, 94 feet; Cleary, 80 feet; and Belcher about 20 feet. On Carrizo Creek, Marr, O'Brien, and Crutcher each measured from 20 to 60 feet of Dakota Sandstone.

MANGOS SHALE

Outcrops of the Mancos Shale in Catron County are limited to the Carrizo Creek area. Gadway reports a thickness of almost 500 feet of Mancos in a section measured south of Carrizo Creek in T. 1 and 2 N., R. 20 W. Much of his measured section, however, has been mapped by Dane and Bachman as part of the Mesaverde Group, although

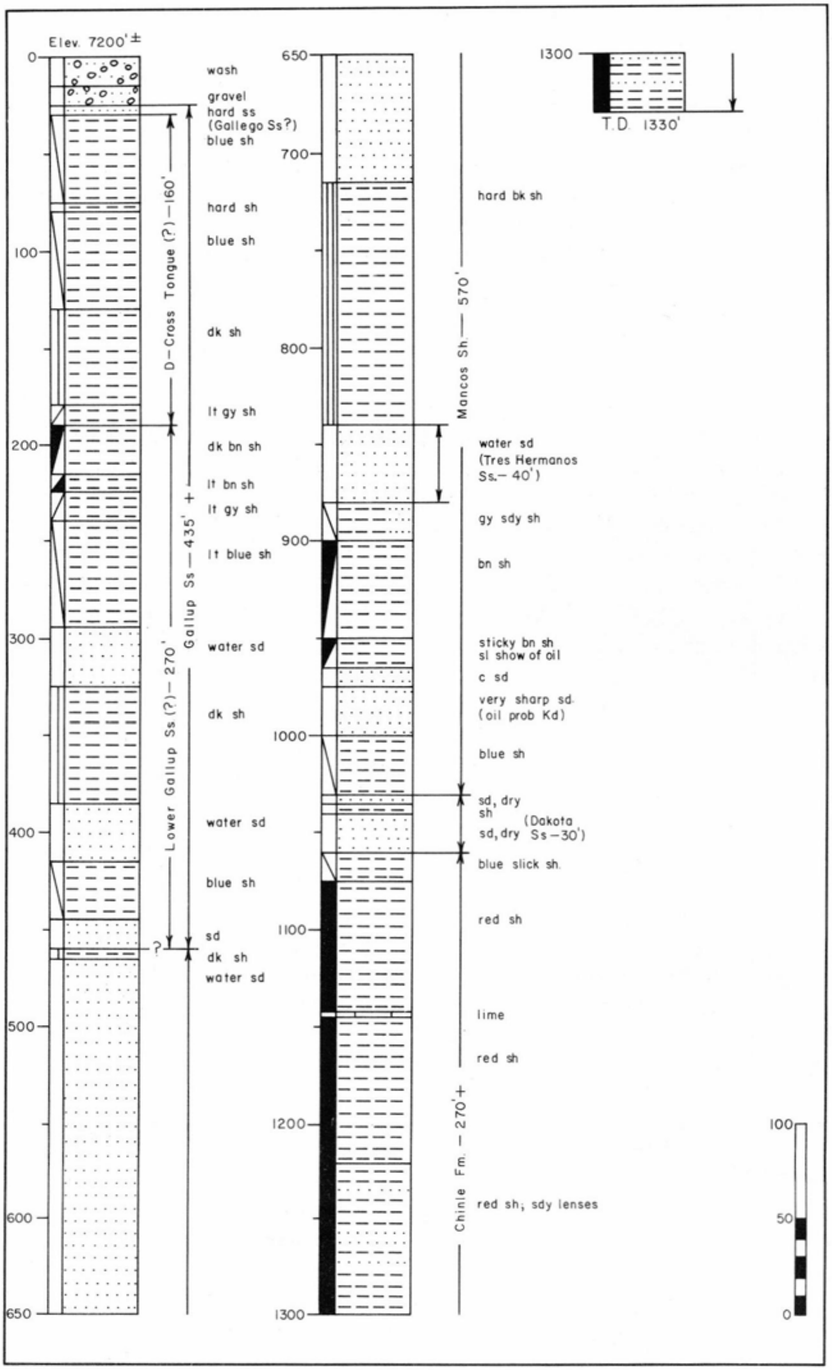


Figure 7

RED FEATHER NO. 2 M. P. SMITH (DRILLER'S LOG)

SESENE, sec. 30, T. 4 N., R. 9 W.

Willard and Weber show most of this area as being underlain by Mancos Shale. The third Skelly test, about six miles east of Gadway's section, was located on rocks also mapped as part of the Mesaverde Group (Dane and Bachman), and in this well Triassic rocks were encountered at a depth of only 244 feet. Gadway also shows a 100-foot sandstone interval, containing *Gryphea newberryi,* about 200 feet above the base of the Mancos. He correlates this sandstone with the Tres Hermanos Sandstone of the D-Cross area in western Socorro County (Dane). This sandstone, or another in approximately the same stratigraphic position, has apparently been mapped as the basal unit of the Mesaverde Group in western Catron County and adjacent parts of Valencia County, New Mexico, and Apache County, Arizona. The thickness of Mancos measured by Gadway is close to the interpreted thickness for this interval of 520 feet in the Cleary well and 527 feet in the Huckleberry well. In the Belcher well, Mancos shales and sandstones apparently directly underlie the Baca Formation. It should be pointed out that in western Catron County, the base of the Tres Hermanos (?) serves as a convenient contact for mapping purposes. Tonking in the Puertecito area also found that the Tres Hermanos was a useful break between the Mancos Shale and his La Cruz Peak Formation that includes the upper part of the Mancos as defined by others.

In eastern Catron County, beds assigned to the Mancos Shale in the deep Spanel well are 534 feet thick, and in the shallow Spanel test eight miles from outcrops on the east side of D-Cross Mountain, they are 568 feet thick. Pike measured only 386 feet of Mancos on D-Cross and Givens in two sections in the same area measured 291 and 319 feet. Winchester (1920), in a section measured in the gap south of D-Cross, reported a thickness of 1020 feet from the top of the Dakota Sandstone to the top of the Gallego Sandstone. The lower 463 feet of this section consists mostly of shale and appears to represent the Mancos interval. Southward thinning of the Mancos Shale from the 998 feet measured by Pike (reduced to 600 feet by reinterpretation by Dane, Wanek, and Reeside) at the north end of Cebolleta Mesa to the thicknesses recorded above has been attributed to intertonguing relationships between shales of the Mancos and sandstones of the Mesaverde.

For descriptive purposes, the Mancos Shale is divided into a lower shale member, the Tres Hermanos Sandstone Member, and an upper shale member. The lower shale member consists mostly of dark gray, silty, sandy (very fine- to fine-grained) shale, and light to dark gray, argillaceous, very fine- to fine-grained, subangular to subrounded, friable sandstone. One or two bentonite beds were recorded in the deep Spanel, Cleary, and Belcher wells; apparently bentonite beds are not present in the Huckleberry and shallow Spanel wells. Although only a few beds were calcareous in the two Spanel Catron tests, almost all intervals contained appreciable amounts of calcium carbonate in the three wells drilled to the west. Pelecypod fragments are fairly abundant in most samples, and biotite and chlorite are sparse to abundant. Based on the arbitrary top and base of the unit, thicknesses in an east-west direction are as follows: shallow Spanel, 149 feet; deep Spanel, 126 feet; Huckleberry, 96 feet; Cleary, 102 feet; and Belcher, 135 feet (?). As noted previously, Gadway measured about 200 feet of this interval south of Carrizo Creek. He also indicates a comparable thickness in the Huckleberry well. There are several sandstones in this well that might be correlated with the Tres Hermanos Member, and final choice in this paper was made by electric log correlations with the deep Spanel well that is closer to the type locality.

The unit shown on the well logs as the Tres Hermanos Sandstone consists of one or several sandstone beds, in part separated by thin shales. The interval is 30 feet thick in the shallow Spanel well; 28 feet in the deep Spanel, 28 feet in the Huckleberry, 75 feet (?) in the Cleary, and 77 feet in the Belcher. In general, the Tres Hermanos Sandstone is composed of medium gray to white, very fine- to medium-grained or very fine- to coarse-grained, silty, subangular to rounded, frosted, calcareous, friable, quartz sandstone. Accessory minerals include biotite, chlorite, minor glauconite, and pyrite. Sandstones in the Huckleberry and Cleary wells are argillaceous. In the shallow Spanel well, grains are well cemented with silica.

The upper shale member of the Mancos consists mostly of medium to dark gray, silty, calcareous shale containing minor biotite and carbonaceous material and abundant pelecypod fragments. Interbedded are thin, light to medium gray limestones, argillaceous, very fine- to medium-grained sandstones, and very light gray, thin bentonite beds. Thicknesses for this part of the Mancos are 388 feet in the shallow Spanel well, 380 feet in the deep Spanel well, 403 feet in the Huckleberry well, and 340 feet in the Cleary well.

In general, Mancos shales and sandstones are quite similar to the shales and sandstones of the Mesaverde Group, except that Mancos beds are for the most part darker gray and more calcareous than younger Cretaceous sediments.

GALLUP SANDSTONE

Winchester measured 2082 feet of strata south of D-Cross Mountain that he named the *Miguel Formation.* This formation was later subdivided by Pike, who extended the nomenclature of the San Juan Basin into the Rio Salado area. Pike considered that approximately the lower 1000 feet of Winchester's Miguel Formation represented the Gallup Sandstone and Mancos Shale of the southern San Juan Basin. Pike further subdivided the then Gallup Member of the Mesaverde Formation into an upper, a middle, and a lower part. The upper part was noted as being the same as the Gallego Sandstone of Winchester, and the middle shale was correlated with the Pescado Tongue of the Mancos from the type locality southwest of the Zuni Mountains. Dane, Wanek, and Reeside agreed with Pike's subdivision of the Gallup Sandstone except for the Pescado Tongue. They concluded that the middle shale unit occupied a position somewhat higher than the Pescado and accordingly renamed this unit the *D-Cross Tongue* of the Mancos Shale. Givens, also in the D-Cross area, used the term *La* Cruz *Peak Formation* for the interval considered Gallup by Pike and later once again defined as Gallup by Dane, Wanek, and Reeside.

Pike considered only 70 feet of his section measured at the north end of Cebolleta Mesa as being correlative with the Gallup Sandstone to the northwest, but he also noted a 60-foot sandstone in the upper part of his Mancos Shale as a tongue of the Gallup Sandstone. This section was reinterpreted (Dane, Wanek, and Reeside), and 398 feet of the upper part of Pike's Mancos interval were considered as part of the Gallup. In addition, 50 feet of Pike's Dilco Coal Member were assigned to the Gallup; the revised thickness for this section is now 518 feet. On D-Cross Mountain, Pike measured 530 feet of Gallup, and, by reinterpretation of the section of the Miguel Formation, Winchester measured 557 feet of this interval south of D-Cross.

In the subsurface, the striking similarity of Cretaceous sandstones, as well as shales, results in very arbitrary tops throughout the Mesaverde interval. Electric log correlations, shale-sandstone relationships, and thickness above the base of the Cretaceous were relied on heavily in the subdivision of the Mesaverde Group, and in particular the Gallup Sandstone, in this report. In the two Spanel Catron wells, the results appear fairly satisfactory; farther west, correlations are extremely tenuous. Thicknesses for the Gallup Sandstone in the subsurface are 507 feet in the shallow Spanel well; 521 feet in the deep Spanel; 529 feet in the Huckleberry well; and 560 feet in the Cleary well. Gadway's interpretation of the Gallup interval in the Huckleberry well is approximately 320 feet.

The Red Feather No. 2 well is the closest test drilled to the D-Cross section (about seven miles) that penetrates through the Cretaceous into Triassic rocks. The only information available for this well is a driller's log, but the top of the Triassic at a depth of 1060 feet appears reliable. According to the geologic map of northwestern New Mexico (Dane and Bachman), this well was located on outcrops of the Gallup Sandstone near the top of this formation. Thus the 1060 feet to the top of the Triassic represents the combined thickness of Dakota Sandstone, Mancos Shale, and most of the Gallup Sandstone, and further gives a minimum thickness for these units based on surface correlations. This minimum thickness compares with combined thicknesses of 1107 feet in the shallow Spanel well, 1131 feet in the deep Spanel well, and 1150 feet in the Huckleberry well and is fairly close to the 931 feet measured by Pike on D-Cross Mountain.

Gallego Sandstone. As measured by Pike on D-Cross, the Gallego Sandstone consists of 98 feet of gray, even-bedded sandstone in several benches. The Cretaceous section southwest of D-Cross as measured by Winchester and by Pike is duplicated by a fault first noticed by Givens in 1952 and later discussed in some detail by Dane, Wanek, and Ree-side. Winchester's Bell Mountain Sandstone at the top of his Miguel Formation is the upfaulted equivalent of the Gallego Sandstone. In the duplicated section this interval is 80 feet thick. In the deep Spanel test, the Gallego Sandstone is 89 feet thick and consists of very light gray, silty, very fine- to medium-grained, subangular to subrounded, friable, quartz sandstone and minor light to medium gray, silty shale. The interval is similar in the shallow Spanel well, except that most grains are frosted, biotite, muscovite, and carbonaceous fragments are abundant, and it is apparently only 55 feet thick. In the Huckleberry well, 106 feet of light gray to white, very fine- to coarse-grained, subangular to rounded, frosted sandstone and medium gray, silty, carbonaceous shale may correlate with the upper part of the Gallup. Somewhat similar sandstones, in part conglomeratic, along with medium gray, silty shales in the Cleary well occupy the approximate stratigraphic position of the Gallego Sandstone to the east. The sandstones are markedly thinner and more shale is included in the 125 feet of upper Gallup than in the other oil tests.

D-Cross Tongue. The middle member or D-Cross Tongue of the Gallup Sandstone consists entirely of medium to dark gray shale in the deep Spanel well. The upper part of the unit is calcareous, biotite is fairly abundant throughout, and some muscovite and sericite are present near the base. Pelecypod fragments were found in several samples in the lower half of the member and a thin bed of very light gray bentonitic shale occurs just above the base. Megascopically visible carbonaceous material is absent. The D-Cross Tongue is similar in most respects in the shallow Spanel well. Biotite does not appear to be so common here and a thin limestone interval is present near the base. A thick shale sequence such as is present in the two Spanel wells and on D-Cross Mountain is not developed above the Mancos in the Huckleberry well. The interval designated as D-Cross consists of relatively thin, interbedded sandstones and shales. In the Cleary well, the entire Gallup interval contains considerably more shale than in any of the other well sections examined in Catron County. The D-Cross as defined in this well is a light gray, silty, slightly carbonaceous shale.

The D-Cross Tongue is 170 feet thick as measured by Pike on D-Cross Mountain, 164 feet in the shallow Spanel well, 146 feet in the deep Spanel, 118 feet in the Huckleberry well, and 125 feet in the Cleary well.

Lower Gallup Sandstone. The lower part of the Gallup Sandstone consists of interbedded sandstones and shales. Sandstone makes up about 51 per cent of the interval in the section measured by Pike on D-Cross Mountain, and similar percentages were recorded in the shallow Spanel (47 per cent), deep Spanel (56 per cent), and Huckleberry (58 per cent) wells. However, sandstone apparently constitutes only 35 per cent of this interval in the Cleary test. Most of the sandstones are light gray, although some are very light gray to white and are quite similar in this as well as in other respects to the Gallego Sandstone. Grain size is very fine to fine and silty with a few beds containing grains that are very fine to coarse. As in most Cretaceous sands, sorting is poor. Sand-size grains are subangular to rounded and frosted grains are common in some beds. Biotite, muscovite, and chlorite were found in most sandstone units in both Spanel wells but do not appear to be common in the Huckleberry or Cleary wells. Carbonaceous material, although not so abundant as in the Crevasse Canyon Formation, was seen in most sandstones, particularly in the lower part of the interval.

Shales within the lower Gallup are mostly medium gray, but range from light gray to black. Silt is more abundant than in the overlying D-Cross Tongue, and some shale beds contain very fine to fine sand. Biotite is present in many of the shale intervals and carbonaceous material, commonly partly replaced by pyrite, is fairly abundant. Some pelecypod fragments were seen in the uppermost shale in the deep Spanel well and in the lower part of the interval in the Huckleberry well.

The lower Gallup Sandstone interval is 262 feet thick on D-Cross Mountain, 288 feet in the shallow Spanel well, 286 feet in the deep Spanel well, 305 feet in the Huckleberry well, and 310 feet in the Cleary well.

CREVASSE CANYON FORMATION

The Crevasse Canyon Formation was named by Allen and Balk (1954) from exposures on the west side of the San Juan Basin for that part of the Mesaverde Group between the Gallup and Point Lookout formations. The term was extended into the Rio Salado area by Tonking and was also used in this area by Givens, by Dane, Wanek, and Reeside, and by Gadway. By definition it includes the Dilco and Gibson Coal members of the former Mesaverde Formation, now classified as a group. Earlier, Winchester (1920) measured 1809 feet of non-marine yellow sandstone, sandy shale, and coal beds of Cretaceous age on the north side of Blue Mesa in western Socorro County. He named this series of rocks the *Chamiso Formation* and considered them correlative in part with Mesaverde strata of the San Juan Basin. The Chamiso is underlain by the Miguel Formation of Colorado age and is overlain on Blue Mesa by the Tertiary Datil Formation. The section on Blue Mesa now called the *Crevasse Canyon Formation* was remeasured by Foster and Kottlowski *(in* Foster) and appears to have a maximum thickness of about 1070 feet, although some additional section may be present to the west.

Parts of the Crevasse Canyon Formation were penetrated in both Spanel wells and in the Huckleberry and Cleary wells. The following description is based primarily on a detailed examination of the deep Spanel well that penetrates the thickest section of the Crevasse Canyon near outcrops in western Socorro County.

The Crevasse Canyon Formation consists of interbedded shales and siltstones (57 per cent), sandstone (43 per cent), and locally a small amount of coal (fig. 8). Shales are mostly medium gray, silty, carbonaceous, and soft. The carbonaceous material occurs as flakes, fragments, and thin seams. A few shale beds contain very fine quartz sand. Most of the sandstones are impure and poorly sorted. Considerable clay and silt

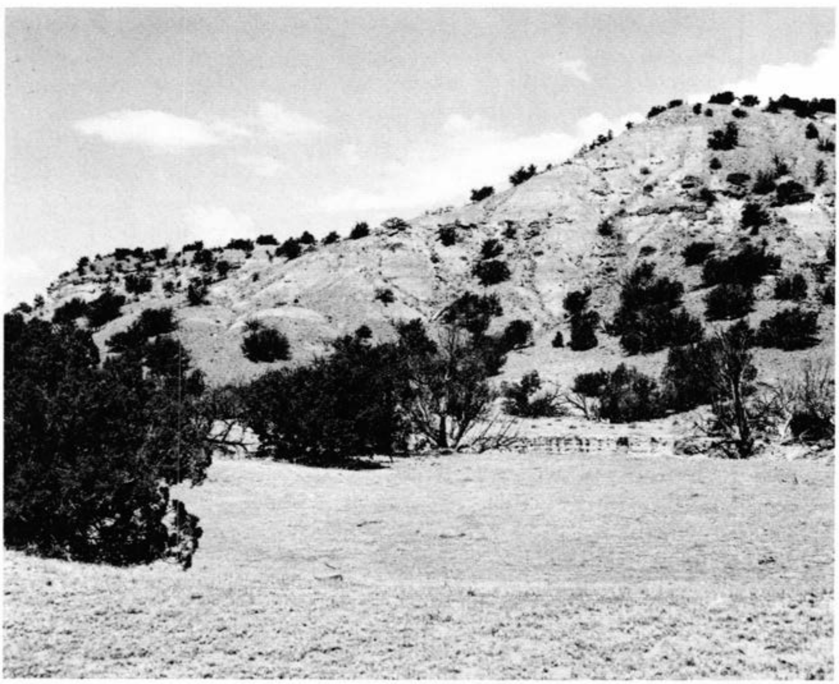


Figure 8

MESAVERDE GROUP SANDSTONES AND SHALES NEAR SALT LAKE (sec. 16, T. 2 N., R. 17 W.)

are present throughout the section, and sand-size grains range from very fine to very coarse but are mostly very fine to medium. There appears to be an over-all slight increase in grain size to the west. Almost all the sandstones are friable or weakly cemented with calcium carbonate, although locally a few grains are strongly bonded with pyrite or silica. Biotite is abundant in both sandstones and shales, and there are a few fragments of chlorite and muscovite. Weathered feldspar occurs in most sandstone intervals but not in large amounts. Sandstones vary in color from very light to light gray except near the surface where both sandstones and shales are mottled light gray, grayish orange, and pale to dark yellowish orange. The true thickness of coal beds could not be determined. Coal occurs as two thin beds, probably not more than a foot thick each, in the basal part of the section in both Spanel wells. Coal does not appear to be present in either the Huckleberry or Cleary wells.

Beds of the Crevasse Canyon are 575 feet thick in the deep Spanel well, 53 feet in the shallow Spanel, about 610 feet in the Huckleberry well, and 110 feet in the Cleary well. Of course in each case this represents an erosional remnant of the original thickness.

TERTIARY AND QUATERNARY SYSTEMS

Most of Catron County is underlain by a complex sequence of extrusive volcanic rocks and associated sediments of Tertiary and Quaternary age. Reconnaissance mapping of most of Catron County by Willard (1957a, 1957b), Willard and Givens (1958), Willard and Weber (1958), Weber and Willard (1959a, 1959b), and Willard, Weber, and Kuellmer (1961) has been published by the New Mexico Bureau of Mines and Mineral Resources. In addition, a detailed study by Stearns of a part of the north side of the San Agustin Plains is now available. Most of the following discussion of the Tertiary and Quaternary rocks is based on these publications and an article by Willard (1959).

LOWER VOLCANIC GROUP

Rocks of this sequence consist of black, green, and purple basaltic andesites and andesitic pyroclastics that are commonly highly altered. Locally, the andesites are interbedded with gray to grayish white latitic tuff beds and flows of banded reddish brown porphyritic latite. The lower andesitic sequence crops out in southeastern Catron County on the north and east sides of the Luera Range and on the east side of the Black Range (pl. 1). In Catron County, the lower andesite sequence is overlain by Datil volcanics; the base is not exposed. Relationships with the Baca Formation that directly overlies Cretaceous sediments to the north are not known, but Robert H. Weber (personal communication, 1964) has found pebbles of altered andesite in the Baca Formation in western Catron County, suggesting that at least in part the lower andesites predate Baca sedimentation.

BACA FORMATION

Sedimentary strata beneath the Datil volcanics in northern Catron County that contain sparse or no volcanic material and are commonly of a red color are generally considered to be correlative with the type Baca Formation of the northern Bear Mountains in western Socorro County. Willard (1959) pointed out some of the inconsistencies concerning the type locality and correlations of this formation, and the interested reader is referred to his publication for a discussion of the origin and usage of the term.

The Baca Formation consists of red, yellow, and gray sandstone, arkosic sandstone, and shale with numerous conglomeratic lenses containing pebbles, cobbles, and boulders of quartzite, limestone, and granite. As noted above, sparse pebbles of andesite have been found in the sequence, and Winchester (1920) reported obsidian pebbles in the lower part of his measured section at the north end of the Bear Mountains in Socorro County. The presence of obsidian pebbles has not been confirmed by later workers. Benzidine tests conducted by Willard (1959) in the upper part of the section in Baca Canyon were strongly positive, suggesting the former presence of volcanic ash.

Two wells penetrated partial sections of the Baca Formation. The Huckleberry well encountered 370 feet of interbedded light gray and grayish orange conglomerate, pale reddish brown silty shale, and minor argillaceous sandstone above the Cretaceous. The conglomerates contain pebbles, and probably coarser material, of quartz, feldspar, chert, and quartzite. In a section measured five miles west of the Huckleberry well in sec. 30, T. 3 N., R. 16 W., there are only 250 feet of Baca remaining between Cretaceous sediments and the Datil Formation. In the surface section, pebbles of rhyolite (apparently Precambrian), a schistose quartzite, and schist were found in the lower part of the interval, indicating a Precambrian terrain in at least part of the source area to the south.

In the Belcher well in Arizona, 235 feet of Baca-like beds were drilled from the surface to the top of the Cretaceous. The interval is similar to that found in the Huckleberry well. It consists of moderate reddish orange conglomerate with pebbles of quartzite, chert, quartz, limestone, and granite; grayish orange, silty, very fine- to medium-grained subangular sandstone; and minor pale red shale. In a partial section of these rocks measured by Sirrine (1956) in sec. 28, T. 10 N., R. 30 E., Apache County, Arizona, Baca equivalents are 473 feet thick.

In addition to the coarser material mentioned above, Sirrine found andesite pebbles in the upper part of his section.

The Baca Formation appears to be overlapped to the north by the lower sedimentary interval of the Datil Formation; in T. 3 N., R. 17 W., Datil sediments directly overlie the Mesaverde Group. The interval may not be present, therefore, in southern Valencia County. To the south, the formation thickens, but data are lacking and relationships are obscured by later volcanics. The southern extent of the interval is not known.

DATIL FORMATION

The Datil Formation underlies the southern two thirds of Catron County. It has been subdivided by Willard and Weber into a volcanic sedimentary facies, latite facies, rhyolite facies, and andesite facies. The contacts between units are gradational, both horizontally and vertically; thus lithic types as mapped are not wholly restricted to a particular facies. To the east, in the Puertecito area, Tonking named the latite facies the *Spears Member* and the rhyolite facies the *Hells Mesa Member*. His units have not been extended into Catron County except for the work of Givens in the northeastern corner of the county.

The volcanic sedimentary facies consists of light gray, greenish gray, and reddish gray sandstones, siltstones, mudstones, volcanic conglomerates, latite tuffs and flows, and thin beds of rhyolite tuff. Conglomeratic fragments are mostly of latite and andesite with limestone, granite, and quartzite pebbles and cobbles noted in some areas.

In northern Catron County, the volcanic sedimentary facies rests conformably on or is gradational into the underlying Baca Formation, and interfingers with or is overlain by the latite or rhyolite facies. In northwestern Catron County, the volcanic sediments are overlain unconformably by later Tertiary or Quaternary basalts.

Some of the wells in the Quemado area were located on Quaternary alluvium above the volcanic sedimentary facies and probably penetrated parts of this interval. There is, however, no subsurface information available for this or any other part of the Datil Formation in Catron County. In the measured section in sec. 30, T. 3 *N.,* R. 16 W., the volcanic sediments are overlain unconformably by Quarternary basalts, and only 248 feet of the interval are preserved. The section thins farther toward the north end of the same mesa where the section was measured. To the south, the unit is more conglomeratic and thickens to more than 1000 feet in the Spur Lake area (fig. 9). In a partial section measured by F. W. Rutledge and L. J. Rehkemper *(in* Sirrine) south of Springerville in sec. 28, T. 7 N., R. 30 E., Apache County, Arizona, the interval exceeds 780 feet in thickness.

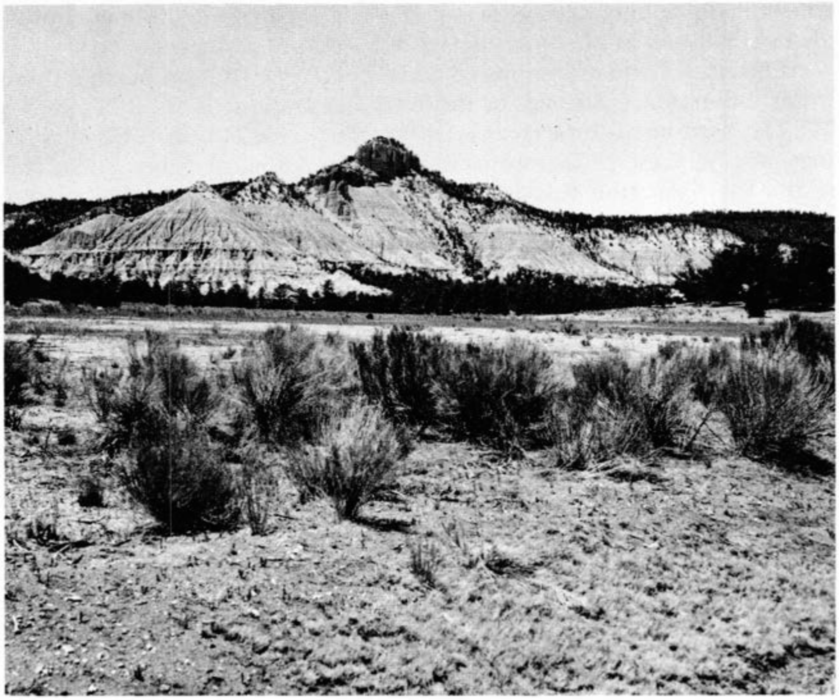


Figure 9
DATIL VOLCANIC SEDIMENTARY FACIES NEAR SPUR LAKE
(sec. 5, T. 4 S., R. 20 W.)

The following description of the latite facies is quoted from Willard (1959):

> This facies in the Gallinas and Datil Mountains consists of light gray to grayish purple latitic tuff, welded tuff, tuff breccia, agglomerate, conglomerate, and sandstone. Locally it contains thin rhyolite tuff beds. It disconformably overlies, or is gradational into, the Baca Formation, and is gradational upward into rocks of the rhyolite facies. To the west in the area of Pie Town, the latitic pyroclastics grade into a series of water deposited volcanic sediments. South in the Luera Range, and along the east front of the Black Range, the latitic facies changes to a series of gray to reddish, banded, porphyritic latite flows interlayered with rhyolite tuff, welded tuff, and flows.

The maximum thickness of the latite facies is not known. Naturally, it varies considerably from one area to the next. In a test drilled by Southland Royalties in sec. 35, T. 2 S., R. 8 W., Socorro County, to a depth of 1795 feet, 515 feet of latitic rocks below rhyolites were drilled. The well bottomed in a latite tuff, so the entire section was not penetrated. In the hills southwest of Horse Springs, latite flows vary in thickness from 0 to 500 feet, according to Stearns.

The rhyolite facies (fig. 10) consists of light gray, white, and buff

Figure 10
DATIL RHYOLITE TUFF NEAR HEAD OF RAILROAD CANYON
(sec. 18, T. 8 S., R. 12 W.)

rhyolite flows, tuffs, tuff breccias, and welded tuffs with local conglomerates of volcanic and nonvolcanic detrital material. Phenoclasts of biotite, sanidine, and quartz are common. This facies is widely exposed in Catron County and for the most part is overlain unconformably by post-Datil basalts and basaltic andesites, also of Tertiary age.

In the Southland Royalties test mentioned, the rhyolite facies is 570 feet thick. Here it is overlain by sediments probably correlative with the Gila—Santa Fe groups. Rhyolite flows and tuffs are considerably thicker than this in parts of Catron County, but absolute figures are not available. Ferguson (1921) noted a total of 8000 feet of Tertiary volcanics and sediments in the Mogollon mining district, of which 4400 feet consisted of rhyolite flows and tuffs. However, Ferguson goes on to state, "This total is of course not a measure of the original thickness of the formations, as these rocks are not all present throughout the area. The rhyolites in particular are very uneven in thickness, and a flow may be lacking in one section and show a thickness of several hundred feet a short distance away."

Two absolute ages for the rhyolite facies in Catron County have been published (Weber and Bassett, 1963). Material dated consisted of obsidian nodules from a flow-banded rhyolite in the upper part of the Datil Formation in sec. 32, T. 9 S., R. 16 W. and a glass from a vitrophyre, also from the upper part of the Datil in sec. 33, T. 7 S., R. 19 W. The range in age was from 26.7 to 28.7 m.y., which would place the age for this part of the Datil in the Oligocene.

According to Willard (1959),

> andesitic rocks are gray to black and weather to a reddish brown. Most flows are coarsely porphyritic; lath-shaped feldspar phenocrysts 1 inch long are common. Fine-grained massive andesites are present, however, and become the principal type south of the map area [southern Catron County] . . . . Typically the andesites form cliffs, but some of the coarsely porphyritic and jointed flows break down into piles of highly rounded 'boulders of disintegration,' many 10 feet across. Flows in the Gallo Mountains interfinger with rhyolite pyroclastics. Southwest of these exposures the andesite is medium-grained, equigranular, is less commonly interlayered with rhyolite, and at places rests on volcanic sediments. At the eastern limit of White House Canyon, near Datil, a flow of coarsely porphyritic andesite rests on latite and is overlain by rhyolite pyroclastics. In the Luera Range, southeast of the San Agustin Plains, porphyritic andesite rests on the lower volcanic group and is overlain by rhyolite. The general relations suggest that the flows of the andesite facies are present in several zones in the rhyolite facies, but regionally they are concentrated in its older parts.

Andesites vary from 25 to 650 feet in thickness in the area around the San Agustin Plains, and the thickness apparently increases to the south (Stearns).

TERTIARY BASALTS AND BASALTIC ANDESITES

Tertiary flows and pyroclastics of this type form most of the higher parts of the Datil—Mogollon Plateau. They cap the Mangas, Pelona, Luera, 0 Bar 0, Black, and Mogollon mountains (p1. 2). The flows range from dark to medium gray, are aphanitic and locally scoriaceous, and characteristically contain scattered small reddish brown crystals of iddingsite. Olivine, although present, is megascopically rare. In places this sequence includes thin beds of rhyolite tuff and tuff breccia and, in the Mogollon Mountains, some rhyolitic flows, tuffs, and plugs that postdate the basalts. Sources for the flows are poorly preserved, but apparently Mangas, 0 Bar 0, and Shaw Peak, at least, represent remnants of volcanic centers. This interval unconformably overlies various parts of the Datil Formation in Catron County. The basaltic intrusives in northeastern Catron County are thought to be associated with this series of eruptions. In the San Agustin Plains area, thicknesses of 1000 to 2500 feet have been reported by Stearns.

SANTA FE GROUP—GILA CONGLOMERATE

Santa Fe—Gila sediments (fig. 11) consist of locally derived volcanic conglomerate and sandstone with some lacustrine clays, silts, and diatomite. Interbedded locally are thin rhyolite tuffs and basalt flows.

Figure 11

TERTIARY BASALT OVERLAIN BY GILA CONGLOMERATE SOUTH OF BLACK SPRINGS

(sec. 26, T. 9 S., R. 13 W.)

Very little data on the thickness of this interval are available and of course it varies from one depositional area to the next. A core test drilled to study the Plio—Pleistocene sediments and climates in the San Agustin Plains (Foreman, Clisby, and Sears, 1959) bottomed at 2000 feet in weakly consolidated clays and silts of possible Tertiary age. The lower 1050 feet encountered in the core test are mostly reddish brown and conglomeratic. These sediments may be part of the Santa Fe—Gila interval. Most of the upper 950 feet of the core consist of black to gray and green fine clastics, suggesting stable conditions of deposition in an alkaline lake. In the Southland Royalties well in western Socorro County, less than 50 feet of fine clastics (possibly San Agustin Lake sediments) overlie 660 feet of coarse conglomerate similar to Santa Fe—Gila deposits.

QUATERNARY BASALTS

Typical black basalt flows with phenocrysts of olivine cover a considerable part of northwestern Catron County, and abundant well-preserved cinder cones dot the low basalt-capped mesas between Spur Lake and Salt Lake. These flows overlie rocks ranging in age from the Cretaceous Mesaverde Group to Quaternary alluvium. Away from the eruptive centers, the flows vary from about 10 to 50 feet in thickness.

Summary of Oil Tests

Approximately twenty tests for petroleum have been drilled in Catron County, all but seven of which were prior to 1951. Locations, elevations, total depths, and remarks concerning these wells are given in Table 1, and the more important tests are plotted on Plate 1. The data presented in the table are a compilation from the files of the New Mexico Bureau of Mines and Mineral Resources and the Conservation Branch of the U.S. Geological Survey in Roswell.

The earliest report of drilling for oil in Catron County (formerly part of Socorro County) is found in a bulletin of the University of New Mexico by Ellis (1920). The test, the Kelley and Estelle No. 1, was located in sec. 17, T. 3 N., R. 14 W. In July 1920, the well was at a depth of 200 feet, plus or minus, where artesian water was encountered. Surface rocks in the area consist of Recent alluvium and the volcanic sedimentary interval of the Datil Formation. At a depth of 200 feet, the well may have reached the Baca Formation or still may have been in the lower part of the Datil Formation.

Between 1923 and May 1926, four wells were drilled in the extreme northeastern part of the county. These wells include the King test in T. 4 N., R. 12 W., the first of the two Gorman wells in sec. 34, T. 3 N., R. 9 W., and the two Red Feather wells in sec. 30, T. 4 N., R. 9 W.

No location within the township is available for the King well. At the depth given of 1000 feet, the test should have penetrated to the Gallup Sandstone or possibly as deep as the Mancos Shale. The No. 1 Gm-man well was drilled on the south end of the Cibola anticline (pl. 1) in 1924. Surface rocks in the area are part of the Cretaceous Crevasse Canyon Formation. At the total depth of only 168 feet, the well probably bottomed in this formation.

The Red Feather No. 1 Smith well, completed in 1925, was drilled to a depth of 510 feet on the Cow Springs anticline. Logs or samples were not available, but the well was spudded in what has been mapped as the Crevasse Canyon Formation. Based on data from the shallow Spanel well drilled about one mile to the north, the No. 1 Red Feather test bottomed in the lower part of the Gallup Formation.

The No. 2 Red Feather well, also drilled on the Cow Springs anticline, was completed in 1926. A driller's log was released for this well, and a graphic presentation of the data is shown in Figure 7. The well was drilled to a total depth of 1330 feet and bottomed in the upper part of the Chinle Formation. Based on the total thickness of Cretaceous rocks drilled, the surface formation at the locality of the well should be the D-Cross Tongue of the Mancos Shale. Bates noted that Mancos Shale was exposed along the crest of the Cow Springs anticline. The geologic map of northwestern New Mexico by Dane and Bachman

TABLE 1. LIST OF OIL TESTS DRILLED IN CATRON COUNTY

WELL	SECTION LOCATION	S.	T.	R.	YEAR COMP.	ELEV. (feet)	TOTAL DEPTH (feet)	REMARKS
R. C. Bailey-Monsen No. 1 A. Baca	1120S, 1750W	3	1N	16W	1928	<7000	500	Cretaceous at T. D.(?).
R. C. Bailey No. 1 H. Baca	W SE NW	3	1N	16W	1933	<7000	505(?)	Cretaceous at T. D.(?); show oil 450-480 ft.
R. C. Bailey No. 2 H. Baca	C NW SW	3	1N	16W	1936	<7000	505	Cretaceous at T. D.(?); may have deepened Engle well.
E. E. Engle No. 1	1980S, 660W	3	1N	16W	1926	<7000	450	Cretaceous at T. D.(?).
Skelly No. 1 M. N. Teel	SE SE SW	7	2N	19W	1952	6691 Gr.	2369	Yeso Fm. at T. D. No. 3 stratigraphic test.
Bowser & Fenner No. 1 R. C. Bailey	480N, 1275W	35	2N	16W	1928	<7000	300	Baca Fm. at T. D.
A. E. Fenner No. 1 R. C. Bailey	660N, 924W	35	2N	16W	1929	<7000	408	Water.
A. E. Fenner No. 2 R. C. Bailey	NW SW	35	2N	16W	1930	<7000	670	Cretaceous at T. D. Show oil and gas 483 ft.
C. Huckleberry No. 1 Federal	330N, 330E	11	2N	16W	1956	7109	5642	Tested to Precambrian; Pennsylvanian absent.
Skelly No. 1 Goesling	CSW	27	3N	21W	1952	6372 Gr.	2602	Tested to Precambrian; Pennsylvanian absent. No. 1 stratigraphic test.
Cleary No. 1 Wheeler Federal	1980N, 1980E	6	3N	16W	1963	6684 D.F.	2605	San Andres Ls. test.
Kelley & Estelle No. 1	?	17	3N	14W	1920	?	200±	First test in Catron County; artesian water.
E. J. Gorman No. 1 Gorman	365N, 1185W	34	3N	9W	1924	7177	168	Shallow test of Cibola anticline.
E. J. Gorman No. 2 Gorman	NE NW NW	34	3N	9W	1933	7177	501	Test of Gallup Fm. on Cibola anticline.
Skelly No. 1 C. A. Teel	SE SW	27	4N	19W	1952	6553 Gr.	1140	Test of San Andres Ls. No. 2 stratigraphic test.
King et al. No. 1	?	?	4N	12W	1923		1000±	No additional information.
A. N. Spanel & W. O. Heinze No. 1-9617 Santa Fe Pacific R.R.	2080N, 560E	27	4N	11W	1959	7401 Gr.	5394	Test to Precambrian on Hickman anticline. Show of oil and gas in San Andres(?).
Red Feather No. 1 M. P. Smith	N NW NE	30	4N	9W	1925	7400±	510	Shallow Cretaceous test on Cow Springs anticline.
Red Feather No. 2 M. P. Smith	SE SE NE	30	4N	9W	1926	7400±	1330	Complete Cretaceous test on Cow Springs anticline.
A. N. Spanel & W. O. Heinze No. 1-9609 Santa Re Pacific R.R.	550N, 740W	19	4N	9W	1959	7411 Gr.	1200	Cretaceous test on Cow Springs anticline.

is not on a large enough scale to accurately determine the surface formation at this locality, but it appears to be the Gallup Sandstone. The driller's log indicates mostly shale to a depth of 295 feet with the upper 30 feet possibly valley fill and part of the Gallego Sandstone. The base of the D-Cross Tongue was picked at a depth of 190 feet for a thickness of this interval of 160 feet. The contact between the lower Gallup Sandstone and the Mancos Shale was arbitrarily chosen slightly above a thick interval designated simply as water sand in the driller's log. Sandstones this thick (250 feet) do not occur in the Cretaceous sequence in this area. A forty-foot sandstone from 840 to 880 feet occupies the position of the Tres Hermanos Sandstone, and occurs at about the same position above the Dakota Sandstone as in the shallow Spanel well. The Dakota Sandstone is restricted to thirty feet of sandstone with minor shale directly above fifteen feet of "blue slick shale" considered part of the Chinle Formation. The top of the Dakota Sandstone appears to be at a depth of 1030 feet, and the Chinle Formation at 1060 feet.

Beginning in 1926 and continuing to May 1933, the only drilling activity was in the vicinity of Quemado where six shallow wells were drilled. These include the E. E. Engle, or possibly the Quemado Oil No. 1 Engle, in sec. 3, **T.** 1 N., R. 16 W.; Bowser and Fenner No. 1 R. C. Bailey in sec. 35, T. 2 N., R. 16 W.; R. C. Bailey and Monsen No. 1 Anastacio Baca in sec. 3, T. 1 N., R. 16 W.; A. E. Fenner No. 1 R. C. Bailey in sec. 35, T. 2 N., R. 16 W.; A. E. Fenner No. 2 R. C. Bailey in sec. 35, T. 2 N., R. 16 W.; and the R. C. Bailey No. 1 H. Baca in sec. 3, T. 1 N., R. 16 W. All these wells were shallow tests, the deepest (Fenner No. 2 Bailey) having a total depth of 670 feet. Surface rocks in the area consist of valley fill, Baca Formation, and the lower sedimentary interval of the Datil Formation. All except the Fenner No. 2 Bailey test were spudded in valley fill overlying either the upper part of the Baca Formation or the lower part of the volcanic sediments. Several of the deeper wells probably bottomed in Cretaceous rocks.

In November 1933, E. J. Gorman drilled the second test on the Cibola anticline. This well was drilled to a total depth of 501 feet and probably tested part of the Gallup section.

The next test drilled in Catron County was the R. C. Bailey No. 2 H. Baca, located in sec. 3, T. 1 N., R. 16 W. The well was abandoned in 1936 at a depth of 505 feet, probably in the Crevasse Canyon Formation.

Through 1936, a total of only thirteen wells had been drilled in Catron County. The deepest test both in feet and in a stratigraphic sense was the Red Feather No. 2 Smith well that bottomed in the Triassic at 1330 feet. Oil shows had been reported from this well and two of the tests in the Quemado area. No further exploratory drilling was done in the county until December 1951, when the Skelly Oil Company began the first of three stratigraphic tests in the Carrizo Creek area of northwestern Catron County. The first test, the No. 1 Goesling, was spudded in the Chinle Formation in sec. 27, T. 3 N., R. 21 W. Stratigraphic tops are as follows: San Andres Limestone, 425 feet; Glorieta Sandstone, 674 feet; Yeso Formation, 923 feet; Abo Formation, 2118 feet; and Precambrian, 2571 feet. The second test, the No. 1 C. A. Teel, was drilled about ten miles to the northeast in sec. 27, T. 4 N., R. 19 W. on outcrops of Mancos Shale. The test was drilled to 1140 feet where it was abandoned in the San Andres Limestone. Tops are Chinle Formation, 100 feet and San Andres Limestone, 1085 feet. The No. 1 M. N. Teel, the last of the three tests, was also spudded in outcrops of Mancos Shale. The location for this test is sec. 7, T. 2 N., R. 19 W., about six miles southwest of Salt Lake. Stratigraphic tops are Chinle Formation, 244 feet; San Andres Limestone, 894 feet; Glorieta Sandstone, 1154 feet; and Yeso Formation, 1388 feet.

In November 1956, the Claude Huckleberry No. 1 Federal was drilled to a total depth of 5642 feet in sec. 11, T. 2 N., R. 16 W. This test penetrated about the maximum thickness of pre-Tertiary sedimentary rocks present in the northern part of Catron County. Surface rocks are considered part of the Tertiary Baca Formation. Other tops are as follows: Crevasse Canyon Formation, 370 feet; Gallup Sandstone, 980 feet; Mancos Shale 1509 feet; Dakota Sandstone, 2036 feet; Chinle Formation, 2130 feet; San Andres Limestone, 2890 feet; Glorieta Sandstone, 3240 feet; Yeso Formation, 3453 feet; Abo Formation, 4886 feet; and Precambrian, 5476 feet. Samples of this well were examined from 110 feet to total depth. Sample interpretations are shown graphically in Figure 1.

The next test to be drilled in the county was spudded in August 1959, when A. N. Spanel and W. 0. Heine drilled their No. 1-9617 Santa Fe Pacific Railroad test in sec. 27, T. 4 N., R. 11 W. The test was located on the Hickman anticline and drilled to a depth of 5394 feet in an attempt to test Pennsylvanian rocks along the western margin of Wengerd's (1959) Lucero Basin. A graphic log of the well is given in Figure 2. Tops as determined from the samples and mechanical logs are Crevasse Canyon Formation, surface; Gallup Sandstone, 575 feet; Mancos Shale, 1096 feet; Dakota Sandstone, 1630 feet; Chinle Formation, 1706 feet; San Andres Limestone, 3191 feet; Glorieta Sandsone, 3410 feet; Yeso Formation, 3740 feet; Abo Formation, 4898 feet; and Precambrian, 5370 feet. Pennsylvanian rocks were not present.

In November 1959, the same company drilled the No. 1-9609 Santa Fe Pacific Railroad in sec. 19, T. 4 N., R. 9 W. to test reported oil shows in the Dakota interval on the Cow Springs anticline (fig. 6). Tops for this well are Crevasse Canyon Formation, surface; Gallup Sandstone, 53 feet; Mancos Shale, 560 feet; Dakota Sandstone, 1127 feet; and

Petroleum Possibilities

Large areas covered by extrusive volcanic rocks have discouraged exploration for oil and gas in Catron County. The volcanics in themselves are not detrimental to the formation or preservation of liquid or gaseous hydrocarbons, but they do effectively conceal the location of prevolcanic structures. In addition, the thickness of Cenozoic rocks varies so greatly that it is difficult to determine at a given locality the depth to strata more favorable for exploration. Prospects have also dimmed in recent years in northern Catron County, where pre-Tertiary rocks are exposed, because of the absence of Pennsylvanian beds beneath much of the area.

NORTHERN CATRON COUNTY

In northern Catron County, additional testing of the San Andres, Glorieta, and Yeso intervals is warranted. Complete tests of the thick Permian sequence have been made in only three wells, Skelly No. 1 Goesling, Huckleberry, and the deep Spanel well. The last of these is the only Permian test on the known structures of northeastern Catron County. The San Andres Limestone also was tested in the other two Skelly tests and the Cleary well. Most of the Yeso Formation also was tested in the Skelly No. 1 M. N. Teel. Numerous dolomites, limestones, and sandstones of Permian age are porous and permeable and were deposited and exist under a reducing environment, three favorable exploratory factors.

Most favorable intervals in the Cretaceous section are widely exposed in the northern four townships, and only parts of the possible section are present in much of this area. Possibilities for the discovery of oil from the Cretaceous are therefore somewhat limited, even though in general this is considered the most favorable part of the stratigraphic section. The maximum Cretaceous section present is on the order of 2000 feet, and only a small number of wells, Huckleberry, Cleary, both Spanel wells, and the second Red Feather well, have examined thick sections of Cretaceous strata.

Any additional testing of Pennsylvanian rocks should be restricted to the extreme northeastern corner where rocks of this age may be present, as shown on Plate 1. The Cow Springs and Cibola anticlines may be later reflections of Upper Paleozoic movements, and therefore there may be some possibility for updip stratigraphic traps in Pennsylvanian rocks on the east flank of these structures.

SOUTHERN CATRON COUNTY

In the southern two thirds of Catron County, lack of information concerning buried structural features makes any estimate concerning a possible pre-Tertiary sequence very tenuous. In a given area, Tertiary volcanics and sediments may directly overlie anything from Cretaceous to Precambrian. However, at least in some sections of the county, a largely marine sequence consisting of Cretaceous, Permian, Pennsylvanian, and possibly older Paleozoic rocks should be preserved. Triassic rocks pinch out to the south, as shown- on Plate 1, and pre-Pennsylvanian sediments pinch out to the north in southern Catron County.

Structurally, the San Agustin Plains appears to be a complex graben. If this is true, the Plains should be underlain by volcanic and sedimentary rocks of Tertiary age similar to those in the bounding uplifts. Meager subsurface information from adjacent areas supports this conclusion. The Tertiary rocks should be underlain by a fairly thick sequence of Cretaceous, Triassic, Permian, and Pennsylvanian sediments. Cenozoic deposits appear to be only about 2000 feet thick or less in the northern part of the plains but are much thicker to the south. Based on present knowledge of post-Mesozoic rocks, it should be possible to correlate the sequence from drill cuttings and thus have some concept of progress and perhaps even make some estimates of thicknesses of the various units. The Cretaceous section, depending on completeness, would be the prime exploratory target, although Permian and Pennsylvanian strata also warrant some testing.

Based on mapping by Willard (1957b), there are a few areas around the margins of the Luera Range in southeastern Catron County where pre-Datil volcanics crop out (pl. 1). This sequence of andesites and basaltic andesites probably does not exceed 500 feet in thickness, and areas of outcrops would make excellent locations for stratigraphic tests to determine the pre-Tertiary geology of the area.

Most of southeastern Catron County, south of the San Agustin Plains, does not appear to be very complex structurally, at least as far as Cenozoic time is concerned. This area is rather favorable for exploration because of the possible completeness of the stratigraphic section. Depending on the extent of pre-Tertiary faulting, there could be between 2000 and 3000 feet of Cretaceous rocks, 3000 feet of Permian strata (mostly carbonates), about 1000 feet of Pennsylvanian, and from zero to 600 feet of sediments from Ordovician to Mississippian age. The Tertiary volcanics, however, are probably several thousand feet thick in most of this part of the county.

Southwestern Catron County is quite complex structurally and also is an area of considerable mineralization associated with faulting. Most of this area is not considered favorable for oil and gas exploration.

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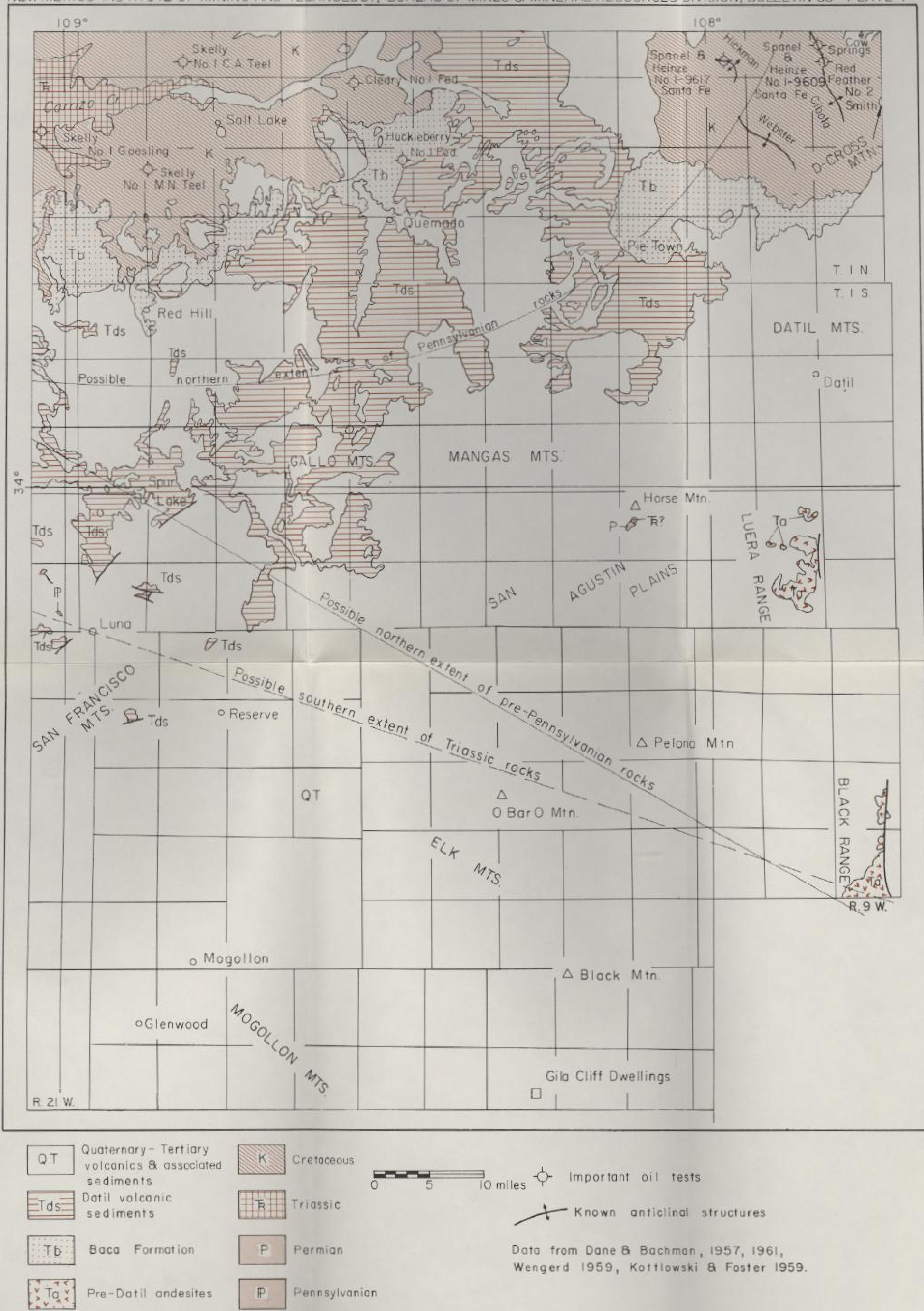
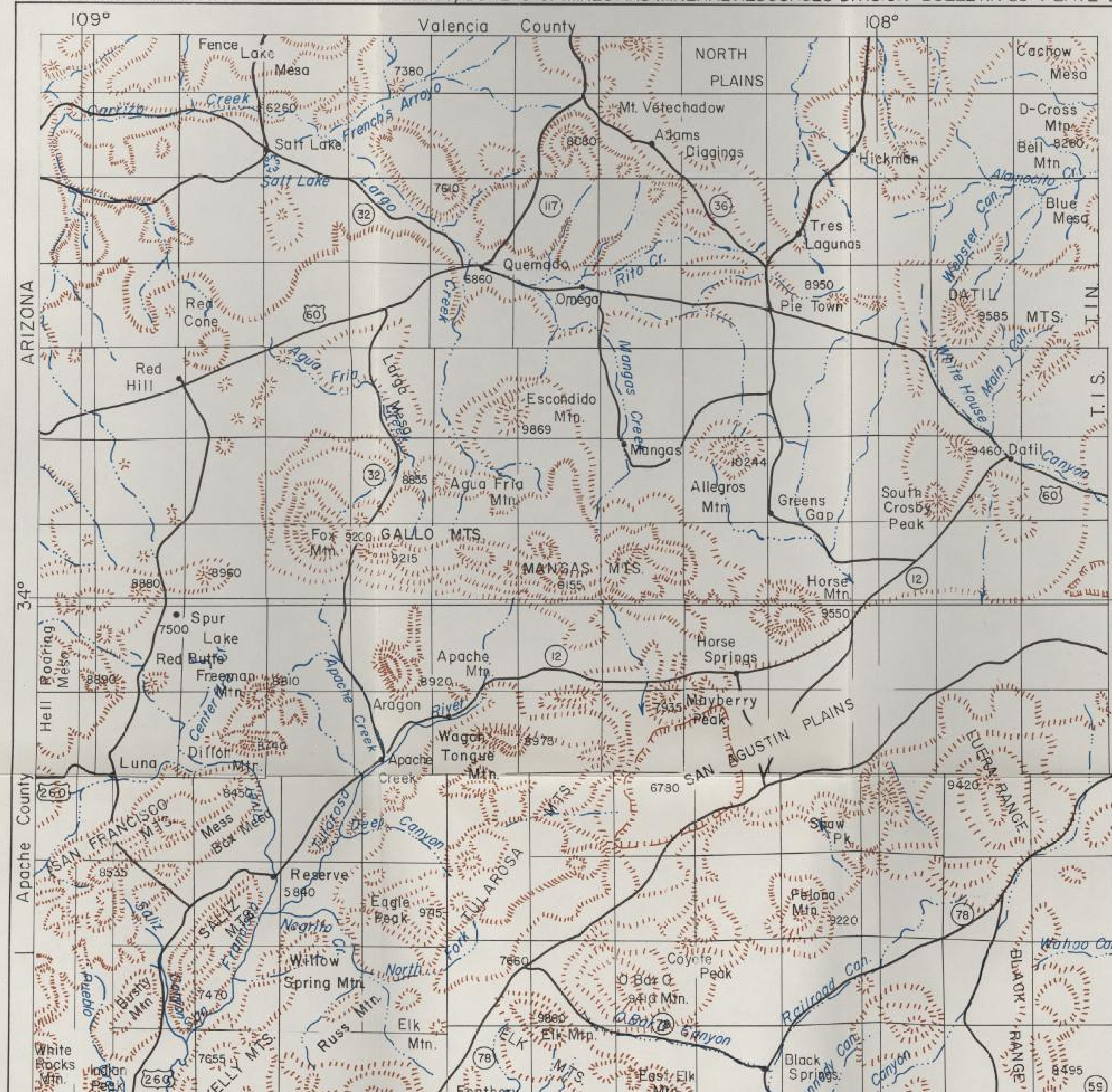


Outcrop Distribution of lower and Pre-Datil Sedimentary and Volcanic Rocks



Base & Topography modified from U. S. Geol. Survey: Topographic map of New Mexico, 1/500,000; Army Map Service: Saint Johns, Socorro, Clifton & Tularosa Topographic Maps, 1/250,000; N. Mex. State Highway Dept. 30' Quadrangle Maps: Atarque Lava, Acoma, Salt Lake, Quemado, Datil, Reserve, Horse Springs, Luera Mts., Glenwood, Beaverhead, & Chloride.

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PHYSIOGRAPHIC MAP OF CATRON COUNTY