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# MESOZOIC STRATIGRAPHY OF THE LAGUNA-GRANTS REGION

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## INTRODUCTION

Good exposures and vistas of most of the Mesozoic stratigraphic units, which are present in the southeastern part of the Colorado Plateau, crop out along the San Jose valley and along 1-40 from Laguna to Grants, New Mexico. Along this route, the section starts with the Triassic Chinle Formation near Mesita (fig. 1), progresses through the Jurassic formations to Cubero, then through the Upper Cretaceous Dakota Sandstone and Mancos Shale, and back through the section to the Chinle at Grants. Cretaceous units above the Mancos Shale crop out in the regions north of Laguna and Grants, and Permian units are exposed in the region south of Grants. Typical outcrop characteristics are visible along 1-40 and on the mesas which flank the San Jose valley. This valley is roughly parallel to some major facies changes in the Jurassic and Cretaceous rocks and to three areas of truncation of underlying units by angular unconformities, all of which are discussed in the following pages.

This region has been studied for more than 100 years (Dutton, 1885; Herrick, 1900; Hunt, 1936; Pike, 1947; Silver, 1948; and many more). Detailed geologic map coverage for the Laguna-Grants area is shown on Figure I.

## STRATIGRAPHY

Stratigraphic relationships of rocks in the Laguna-Grants region are shown on a diagrammatic north-south cross section (fig. 2) and listed in Table 1 and Figure 2.

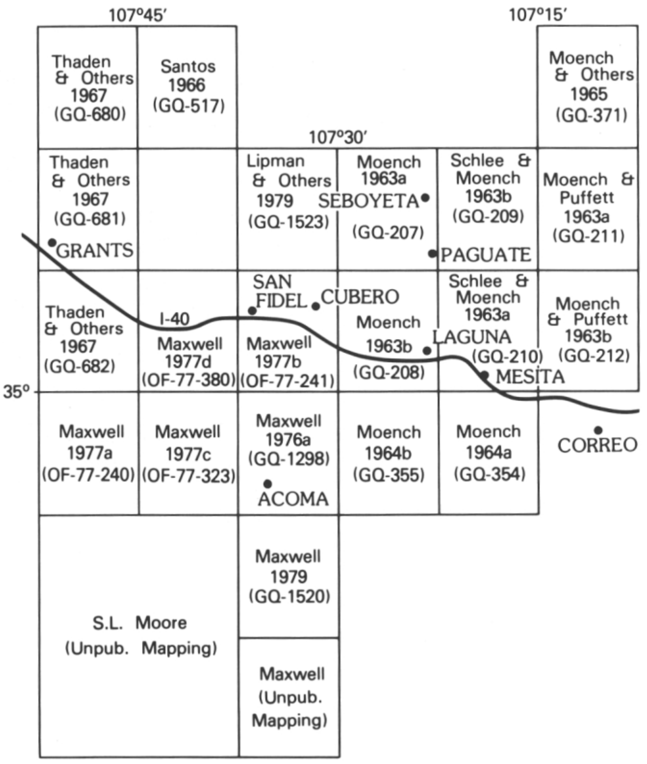


*Figure 1. Geologic map coverage (1:24,000) for the Laguna-Grants area; major towns (e.g., Laguna) and I-40 are given for reference.*

### Triassic Strata

The Triassic Chinle Formation is predominantly dark reddish shale that erodes to form broad flat valleys such as the lower San Jose and Arroyo Colorado. Rocks exposed in the Mesita area (fig. 1) are the Correo Sandstone of the Petrified Forest Member. The Correo is exposed on small mesas or hogbacks along 1-40 between the N.M. 6 interchange

*Table 1. Mesozoic strata of the Laguna-Grants area.*

| Stratigraphic unit | Thickness, in meters | Symbol |
|---|---|---|
| CRETACEOUS | | |
| Menefee Formation | | Kmf |
| Point Lookout Sandstone | | Kp |
| Upper part | 40 | Kpu |
| Hosta Tongue | 30 | Kph |
| Crevasse Canyon Formation | | Kcc |
| Gibson Coal Member | 100 | Kcg |
| Dalton Sandstone Member | 40 | Kcd |
| Stray sandstone | 0-13 | Kcs |
| Dilco Coal Member | 60 | Kcdi |
| Gallup Sandstone | 17-27 | Kg |
| Shale Member | 0-40 | Kgs |
| Gallego Member | 7-20 | Kgg |
| Mancos Shale | | Km |
| Satan Tongue | 0-20 | Kms |
| Mulatto Tongue | 0-100 | Kmm |
| D-Cross Tongue | 8-20 | Kmd |
| Juana Lopez Member | 0-10 | Kms |
| Semilla Sandstone Member | 0-10 | Kms |
| Tres Hermanos Sandstone Member | 0-80 | Kmt |
| Middle Tongue | 100-120 | Kmr |
| Whitewater Arroyo Tongue | 23-47 | Kmw |
| Lower Tongue | 35-70 | Kml |
| Clay Mesa Tongue | 13-20 | Kmc |
| Dakota Sandstone | | Kd |
| Twowells Tongue | 0-30 | Kdt |
| Paguate Tongue | 0-20 | Kdp |
| Cubero Tongue | 0-20 | Kdc |
| Oak Canyon Member | 20-30 | Kdo |
| Basal Sandstone and Conglomerate facies | 0-30 | Kds |
| JURASSIC | | |
| Morrison Formation | 0-100 | Jm |
| Jackpile Sandstone | 0-30 | Jmj |
| Zuni Sandstone | 0-100 | Jz |
| Bluff Sandstone | 40-70 | Jb |
| Summerville Formation | 20-50 | Js |
| Todilto Limestone | 0-3 | Jt |
| Gypsum member | 0-30 | Jtg |
| Entrada Sandstone | | Je |
| Upper Sandstone member | 25-65 | Jeu |
| Medial Siltstone member | 0-10 | Jem |
| Iyanbito Member | 0-12 | Jei |
| TRIASSIC | | |
| Wingate Sandstone, Rock Point Member | 0-80 | Trwt |
| Chinle Formation | | Trc |
| Petrified Forest Member | 230 | Trcp |
| Correo Sandstone Bed | 0-30 | Trcc |

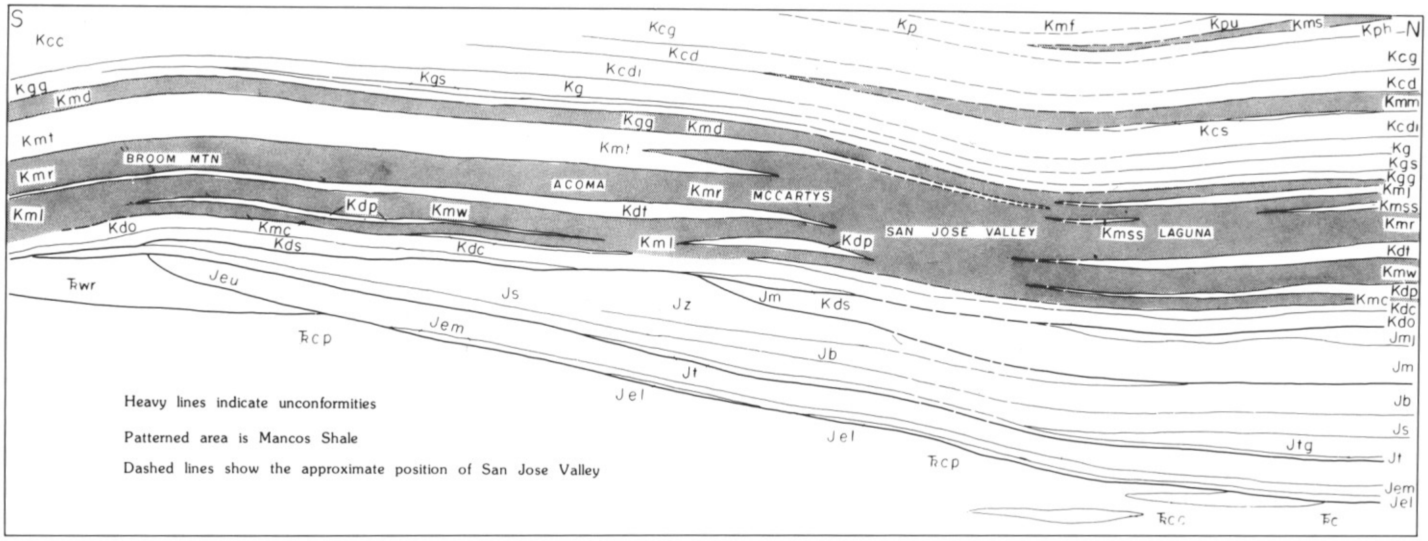


*Figure 2. Diagrammatic north-south cross section showing stratigraphic relationships of units in the Laguna-Grants area. Representative localities are shown in block letters. See Table 1 for explanation of symbols.*

and Mesita. It consists of interbedded lenticular sandstone, mudstone, and conglomerate. The overlying part of the Petrified Forest Member is exposed in the bottom few meters of the outcrop area adjacent to the railroad overpass east of Mesita, and more extensively to the south where as much as 230 m is exposed on the western side of Arroyo Colorado. The upper Petrified Forest Member is composed largely of variegated red, purple, and gray, inconspicuously stratified shale, with occasional lenses of sandy mudstone, sandstone, and conglomerate. The shale generally weathers to a characteristic badlands topography. Thin lenses of small ironstone concretions are common in the middle part, and limestone, or nodular-limestone lenses, and chert pans are locally present in the lower parts. The uppermost part of the Petrified Forest is marked locally by a bleached zone produced by pre-Entrada weathering.

The Petrified Forest Member is unconformably overlain by the Entrada Sandstone in the areas around Mesita and Grants. Toward the south, on the western side of Arroyo Colorado, the Petrified Forest is overlain by the Rock Point Member of the Wingate Sandstone. The Rock Point is composed of about 80 m of light-reddish-brown shaly siltstone and silty sandstone overlain by about 20 m of thick- to massive-bedded, white, fine-grained sandstone with thin interbeds of dark-red-brown silty shale. The base of the Rock Point Member is marked locally by a bleached zone in the underlying rocks and by nodular limestone, scattered chert grains, and local cracks or channels filled with sandy calcareous mudstone; in other areas it appears to be conformable with the underlying Petrified Forest Member. The unconformity at the base of the Entrada Sandstone cuts steeply, south to north, across the Rock Point Member and into the Petrified Forest Member (Maxwell, 1976b).

## Jurassic Strata

Jurassic units are well exposed along the highway between Mesita and Cubero. Although similar in appearance and lithology for many tens of kilometers to the north and west, to the south these Jurassic units change rapidly in character and pinch out.

The Entrada Sandstone, oldest of the Jurassic units in the region, ranges from 25 to 70 m thick in the northern part of the area and is truncated to the south. It is divided into three members: a lower cliff-forming sandstone member, a medial slope-forming silty member, and an upper cliff-forming sandstone member, which overlaps southward across the lower two members (fig. 1). The lower member, the Iyanbito Member (Green, 1974) which ranges from 3 to 12 m in thickness in most places, is light brown to light orangish brown, fine to coarse grained, and thin to massive bedded, with medium-scale festoon cross-bedding. Deep scours at the base of the unit contain coarse sandstone and quartz-pebble conglomerate lenses; scattered pebbles and large cobbles are common on the unconformable contact with the underlying Chinle Formation. Small lenses of limestone or calcareous mudstone occur at the base of the Entrada and locally fill scours and narrow cracks in the underlying Chinle. The Iyanbito Member pinches out 31 km south of Cubero (figs. 1, 2). The medial silty member is moderate-brown to moderate-reddish brown, very thin- to thick-bedded shaly mudstone and siltstone with thin to very thin interbedded fine-grained sandstone. The Iyanbito has a thickness of 28 m northeast of the area and pinchouts 33 km south of Cubero. The upper sandstone member is massive, fine to coarse grained, crossbedded with the characteristic coarse grains or granules scattered along the crossbeds. The upper sandstone member becomes progressively coarser grained toward the south, and a fluviatile conglomerate at the base grades upward into the crossbedded eolian sandstone. This sandstone is pale red, pale reddish brown, and moderate reddish orange north of 1-40 on the southern flank of Mesa Gigante but gradually changes toward the south to grayish red and pale greenish white. A bleached altered zone about 3 m thick immediately under the Todilto Limestone is grayish orange pink to very pale orange and white. A thicker, north-trending zone of alteration 20 km south of Cubero, near Petoch Butte, occurs under the bleached zone; it is chalk white and contains corroded sand grains coated with kaolinite and isolated small clots of kaolinite. The basal conglomerate and eolian sandstone of the upper sandstone member are truncated by an angular unconformity at the base of the Summerville Formation 40 km south of Cubero, where a conglomerate occupies the stratigraphic position of the Todilto Limestone (fig. 2).

The Todilto Limestone comprises two members in the Mesita area (fig. 1), the lower limestone member about 3 m thick and an upper gypsum member 30 m thick. The lower limestone member is light bluish gray, gray, and brownish gray, sandy and argillaceous, with alternating light and dark laminae; broken pieces have a fetid odor. The laminated limestone is interbedded with or grades into thin- to medium-bedded light-bluish-gray limestone. The limestone member ranges in thickness from about 30 cm near the southern pinchout, 27 km south of Cubero, to about 3 m in the Mesita area and as much as 10 m near

Grants. The limestone member directly overlies the Entrada Sandstone in most exposures but locally overlies and grades into a lenticular unit of thin-bedded to laminar calcareous siltstone and sandstone lenses and layers, and interbedded, thin, very sandy limestone. This lower unit ranges from 0 to as much as 10 m in thickness, is irregularly scattered in occurrence, and apparently represents an early stage filling of topographic lows as the Todilto seas encroached on the underlying eolian sandstone. Where the gypsum member is absent, the contact with the overlying Summerville Formation is generally gradational over several tens of centimeters; the irregular contact zone locally contains thin limestone lenses or beds and rounded limestone concretions that have algal structures mixed with or interlayered with grayish-green siltstone. The gypsum member is predominantly anhydrite in the subsurface, which weathers to gypsum near the surface. The hummocky gray-white outcrops above the Entrada on the southern flank of Mesa Gigante, especially prominent across the river from Mesita, are the gypsum member. It constitutes an abundant and potentially valuable resource adjoining the AT&SF railroad. The gypsum member pinches out about 10 km south of Laguna and is essentially absent in the outcrops to the west, in Acoma valley and at Grants. The Todilto is composed only of limestone in the exposures west of these areas.

The Summerville Formation and the Bluff Sandstone in the Laguna-Grants region are probably not correlative with those units at their type localities, as recent studies have indicated, but discussion in this paper follows past usage.

The Summerville Formation in the Mesita area is present but poorly exposed on the slopes of the mesas north of 1-40, overlying the upper gypsum member of the Todilto, below the prominent cliffs of Bluff Sandstone. Excellent exposures are present along 1-40 just west of Mesita where many characteristic features are well illustrated, such as the intraformational folds and faults and the sandstone pipes which are probably related to spring vent areas (Moench and Schlee, 1967). In this area, and for many tens of kilometers to the north, the Summerville is composed of interbedded dark reddish-brown to very light-gray, friable mudstone and moderate-brown to very pale-orange, fine-grained to very fine-grained, friable to well-cemented sandstone. The Summerville becomes progressively lighter in color to the west and south and is composed of white to pale-brown, medium to massive, evenly bedded sandstone, interbedded with grayish-green and light maroon structureless siltstone and thin brick-red to dark-brown mudstone. The sandstone, generally clean and well sorted, is made up of rounded fine- to silt-size grains. The upper contact, with the Bluff Sandstone, is placed at the uppermost continuous red mudstone, which generally coincides with the first sandstone containing fluviatile bedding structures (Maxwell, 1976a).

The Summerville Formation becomes progressively coarser to the south; the characteristic dark-red mudstone layers pinch out, and the red siltstone and very fine-grained sandstone grade into light-greenish-white and tan medium-grained sandstone containing lenticular pebble conglomerates (Maxwell, 1979). The formation thins from about 50 m toward the north to about 20 m in the area 40 km south of Cubero. The unconformable contact between the Summerville Formation and Entrada Sandstone south of the Todilto pinchout is marked by scattered, large, well-rounded, and polished pebbles; thin organic-rich lenses; and thin lenses of conglomerate that become thicker and more continuous to the south. Southward the Summerville unconformably overlaps across the Entrada Sandstone, and even farther south, the Summerville rests directly on the upper part of the Triassic section (fig. 2). The Summerville Formation is truncated by the basal Dakota unconformity 49 km south of Cubero (fig. 2). The contact with the overlying Bluff Sandstone, prominent to the north and east, becomes gradational and indistinct to the south, marked only by a change from thin-bedded sandstone to massive crossbedded sandstone (Maxwell, 1976b).

The Bluff Sandstone is variable in color throughout the region; pale reddish brown around Mesita and in the region toward the north and east, grayish yellow green to the west, and yellowish gray to white toward the south. The Bluff is very fine-grained to medium-grained fluviatile sandstone with thin to very thick flat beds that are crossbedded on a small scale. The Bluff Sandstone is 50 to 70 m thick in the vicinity of Mesita, but southward it merges with the overlying eolian Zuni Sandstone (fig. 2). The Zuni Sandstone thickens southward, from a few meters of lenticular eolian sandstone (on top of the Bluff Sandstone) in the north to as much as 100 m of eolian sandstone (that grades downward to about 40 m of fluviatile sandstone) in the south.

The Zuni Sandstone, in its exposures in the Acoma valley and locally in the region around Laguna and Mesita, has spectacular large-scale crossbedding and forms smooth and rounded exposures. It is variable in color, generally yellowish gray or grayish yellow-green, but locally it is grayish green or even chalk white. The sandstone is composed of very well-sorted, well-rounded, fine- to medium-grained quartz. Toward the south the Zuni and Bluff combine to form impressive vertical cliffs on the borders of mesas and associated buttes. For example, cliffs of the Zuni and Bluff include Petoch Butte, 300 m high; Enchanted Mesa, 145 m high; and Acoma Pueblo (Sky City), perched 70 m above the valley floor (Maxwell, 1976a, b).

The Bluff and Zuni sandstones are erosionally thinned toward the south and truncated by the basal Dakota unconformity 40 km south of Cubero. Figure 3 shows the truncation of both the Entrada by the Summerville, and the Zuni by the Dakota (see also Silver, 1948, fig. 4).

The Zuni Sandstone, or the Bluff Sandstone to the north and east where the Zuni is absent, is unconformably overlain by the Morrison Formation. The lower slopes of the mesas on both sides of the San Jose valley between Laguna and Cubero are Morrison Formation. These slopes are mostly covered by talus and landslides, some of which extend out onto the valley floor. The Morrison Formation is cut out in Acoma valley, on an irregular east-west line, by an angular erosional unconformity at the base of the overlying Dakota Sandstone (Maxwell, 1976a).

The Morrison Formation comprises four units, from oldest to youngest, the Recapture, Westwater Canyon, and Brushy Basin members and

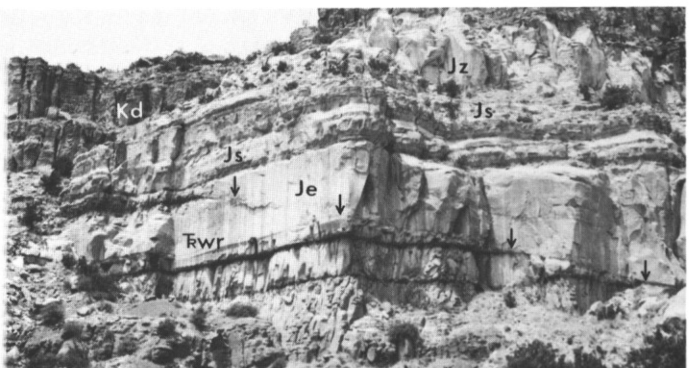


*Figure 3. Photograph of the Jurassic unconformities south of Acoma Pueblo. Trwr, Rock Point Member of Wingate Sandstone; Je, Entrada Sandstone; Js, Summerville Formation; Jz, Zuni Sandstone (and Bluff Sandstone in the basal part); Kd, Dakota Sandstone (the darker weathering rock in the upper left corner is a channel in basal Dakota Sandstone truncating the Zuni Sandstone and part of the Summerville). Arrows point to unconformity between Triassic and Jurassic rocks and truncation by the unconformity at the base of the Summerville (see also Silver, 1948, fig. 4).*

the Jackpile sandstone, an informal unit of economic importance. The Recapture is grayish-red and greenish-gray mudstone, siltstone, and sandstone. The Westwater Canyon is grayish-yellow to very pale orange, fine- to coarse-grained, friable to well-cemented sandstone. The Brushy Basin Member is composed largely of green claystone, mudstone, and silty shale, with a lenticular sandstone and conglomerate facies occupying some of the middle and lower parts. Chen pans composed of nodular, tannish-gray, dense limestone with reticulate and septarian-like thin veinlets of bright red and orange chert are locally common south of Seama (south of Cubero).

The sandstone and conglomerate facies of the Brushy Basin Member is grayish yellow, very pale orange, and very light gray and is very fine to coarse grained. It is composed of poorly sorted, angular to rounded grains of quartz; red, orange, and gray chert; feldspar; and rock fragments.

A lenticular crossbedded conglomerate, variable in thickness, is present throughout the region at the base of the Brushy Basin Member. It is composed of angular-to-rounded rock fragments in a matrix that varies from silt-to-coarse sand-size, angular to well-rounded quartz grains. Rock fragments include chert, limestone, quartzite, gneiss, schist, sandstone, shale, and clay balls, with local concentrations of silicified dinosaur bones. The conglomerate rests unconformably on a paleosol developed on the Zuni Sandstone; the paleosol is generally 3-6 m thick, but locally it is absent or is as much as 10 m thick. The upper 20-100 cm of the paleosol is reworked Zuni Sandstone with considerable addition of angular quartz, feldspar, and red and green clay and mudstone chips; the bedding is very irregular. This reworked zone is light reddish brown to brick red in color, with irregular white, purplish white, and greenish layers. This reworked zone grades downward into a zone containing rounded residual masses of Zuni Sandstone surrounded by concentrically banded red mudstone, which in turn grades into unweathered Zuni Sandstone. Where the soil is thickest, the upper reworked zone grades downward into thin-bedded irregular lenses of light-brownish-red argillaceous sandstone layers. These layers alternate with similar layers of white, very light-pinkish-yellow, and light-yellowish-gray sandstone, which grades into Zuni Sandstone.

A roadcut west of the Acoma interchange of 1-40 exposes this unit in a slide block. The paleosol and the overlying conglomerate are well exposed adjacent to N.M. 23, 4.8 km (3 mi) north of Acoma Pueblo, below Deadmans Rock (Maxwell, 1976a). Locally, the conglomerate rests directly on or is inset into unweathered Zuni Sandstone. The roadcut farther up the hill exposes the unconformable contact with the overlying Dakota Sandstone. Here, Cretaceoous shales rest directly on the Brushy Basin Member, with only a few thin lenses of the basal sandstone present.

## Cretaceous Strata

The Cretaceous units in the region are a series of transgressive and regressive continental, paralic, and marine sandstones (the Dakota and Gallup sandstones and sandstones of the Mesaverde Group) which intertongue with the marine Mancos Shale (fig. 2).

The oldest Cretaceous unit, the Oak Canyon Member of the Dakota Sandstone, can be separated into two units: a basal unit and an upper marine unit. The basal unit of the Oak Canyon Member is composed of two distinct and easily separated facies, a lower fluviatile conglomerate and sandstone and an upper paralic sandstone. The sandstone facies of the basal unit consists of medium- to coarse-grained, poorly sorted, rounded-to-angular quartz grains and has festoon crossbedding. Lenses and layers of conglomerate, especially at the base of the lower unit, have prominent scour and fill structures, with grit and pebbles composed largely of black chert. Smaller amounts of red, orange, gray, satiny-gray, and brown chert and agate are also present, along with sparse rock fragments of schist, gneiss, and granite. Quartzite is locally common. Most pebbles have low sphericity but a high degree of rounding, and a few pebbles are very angular. The basal unit occurs locally north and east of Laguna and continuously along and south of Acoma valley in northeast-trending channels, which are below the paralic facies. The conglomerate lenses merge and thicken southward, up to as much as 24 m thick; are cut into the underlying formations (fig. 3), and successively truncate all of the underlying Jurassic units and the upper units of the Triassic.

The paralic facies of the basal unit is a light gray-to-white, thin-bedded, fine- to medium-grained sandstone composed of angular to well-rounded grains predominantly of quartz, with sparse feldspar, chert, and quartzite grains. The cement is siliceous, and the bedding is disturbed locally by trails and burrows. This facies is present only in the northern part of the area; it pinches out near Acoma Pueblo (where black shales rest directly on the Zuni Sandstone) and west of Mesa Negra (in Los Pilares quadrangle; see Maxwell, 1977a).

The upper unit of the Oak Canyon Member includes paralic and marine shales, siltstones, and sandstones. The lower part of this unit is very carbonaceous black shale and silty claystone, with locally very thin layers (2-10 mm) of coal. These beds grade upward into dark-gray silty claystone and silty shale and into light-gray and grayish-tan sandy siltstone and very fine grained sandstone with abundant carbonaceous material and several thin, but extensive, layers of white and light-grayish-white bentonite. The contact between the lower and upper parts is a transgressive disconformity generally marked by a layer of sideritic oolites or by thin limey sandstones with marine fossils. Megascopic fossils are conspicuously absent in the lower part of the Oak Canyon Member but are abundant in the upper part which contains numerous thin-bedded, light-gray, weathered-brown, fossiliferous-limestone lenses and concretions. The lower part also contains limestone or aragonite cone-in-cone concretions in sandstone and siltstone that is light gray and grayish tan and is locally calcareous or carbonaceous. The sandstone is very fine grained and thin bedded, and the siltstone is generally shaly with abundant finely comminuted carbonaceous material. The unit con- tains many lenses and layers of fine- to medium-grained sandstone similar to the overlying Cubero Tongue.

The Cubero Tongue of the Dakota Sandstone is composed of very fine-grained sandstone and siltstone. Carbonaceous plant fragments, tracks, trails, and borings are abundant, especially near the top. The Cubero forms vertical cliffs and extensive mesas throughout the Laguna-Paguate area, along 1-40, and in Acoma valley but pinches out a few kilometers toward the south. The Cubero is overlain by the Clay Mesa Tongue of the Mancos Shale.

The Mancos Shale, throughout this region, forms broad flat valleys, or it forms steep rubble-covered slopes and extensive areas of landslides. The shale is mostly a light- to dark-gray claystone with local calcareous lenses and silty or sandy zones which grade upward into the overlying units. The Mancos generally weathers to a light gray and grayish tan.

The Clay Mesa Shale tongue crops out locally in the Laguna-Paguate area but is mostly covered to the west. It merges with the main body of the Mancos Shale in the area between Cubero and McCartys. The Clay Mesa is overlain by the Paguate Tongue of the Dakota Sandstone.

The Paguate Tongue, present under the town of Paguate, around Laguna and to the west along the San Jose valley, pinches out under a landslide between Paraje and Cubero but reappears again west of San Fidel to form the small mesas south of the 1-40. In the area around McCartys, it comprises a deltaic facies of fine- to medium-grained, extensively crossbedded sandstone that is thicker than the normal section. Occurrences in the remainder of the region are similar to the Cubero and Twowells tongues. The Paguate pinches out again on Canipa Mesa, between McCartys and Acoma, but reappears to the south as a series of lenses. The Paguate is overlain by the Whitewater Arroyo Tongue of Mancos Shale; the type section is south of Gallup, near

Twowells. The Whitewater is overlain, in turn, by the most extensive tongue of the Dakota Sandstone, the Twowells Tongue.

The Twowells is exposed north and west of Laguna, but like the Paguate it pinches out east of Cubero and reappears near McCartys. With the exception of the area between Cubero and McCartys, the Twowells Tongue is recognized over a large area, merging with the main body of the Dakota in a 160-km stretch along the New Mexico—Arizona boundary from Cottonwood Canyon to Window Rock, Arizona and extending for 225 km southeastward (Dane and others, 1971).

The Twowells Tongue in the Laguna-Grants region is composed of fine-grained to very fine-grained, silty sandstone, with local thin medium- to coarse-grained lenses. The Twowells is commonly thin to medium bedded, but locally thicker lenses have foreset-type crossbeds that dip northeastward. Resistant slabby beds at the top grade downward to silty sandstone with thin interbeds of siltstone. The lower part of the tongue contains many imprints, burrows, and trails as well as disturbed bed- ding. The uppermost part contains *Pycnodonte* aff. *P. kellumi* (Jones) (Hook and Cobban, 1977) which was called a broad form of *"Gry- phaea" newberryi* Stanton by Landis and others (1973). The Twowells Tongue forms bold massive cliffs with square vertical faces in most exposures. It is overlain by the middle tongue of the Mancos Shale.

The lower tongue of the Mancos Shale, as shown on Figure 2, includes the Whitewater Arroyo and Clay Mesa tongues where the Paguate Tongue of the Dakota is absent.

The middle tongue (often called the main body) of the Mancos Shale overlies the Twowells Tongue and is dark-gray shale with a thin but extensive marker bed of fossiliferous limestone about 10 m above the Twowells which contains the guide fossils, *Pycnodonte newberryi* (Stanton) and *Sciponoceras gracile* (Shumard) (Hook and Cobban, 1977). This marker bed continues across the area where the Twowells and Paguate are missing and is the only mappable distinction between the Cubero Tongue and the Gallego Member of the Gallup Sandstone. The lower and middle tongues and the D-Cross Tongue become, in effect, a single Mancos Shale unit. On the northern slopes of San Jose valley in the Cubero—San Fidel area, a calcareous, siliceous, or sandy fossiliferous zone near the top of the middle tongue is probably an equivalent alent of the Juana Lopez Member of the Mancos, which is well developed in exposures around and north of Laguna, and is overlain by the D-Cross Tongue of Mancos Shale. Thin lenses of sandstone or siltstone are also locally common in the upper part and are probable equivalents of the Semilla Sandstone Member of the Mancos farther north.

South of the San Jose valley the middle tongue is overlain by the Tres Hermanos Member of Mancos Shale, which is overlain by the D-Cross Tongue. The northernmost recognizable exposures of the Tres Hermanos are along the northern base of Mesa Negra where the upper sandstone and middle shale members are present but poorly developed, and the lower sandstone member thins over short distances. Across the valley, near San Fidel and Cubero, characteristic lithologies of the Tres Hermanos, SemiIla, or Juana Lopez are not evident, and diagnostic fossils have not been found. The SemiIla is equivalent to about the middle of the Tres Hermanos, and the Juana Lopez is equivalent to the very top section of, and section just above, the Tres Hermanos.

The Tres Hermanos Sandstone Member of the Mancos Shale was first named and described by Herrick (1900) and was widely miscorrelated for decades until its stratigraphic position was recognized by Dane and others (1971). The Tres Hermanos has three mappable units south of Mesa Negra; these continue southeastward for 150 km or more. In the Blue Mesa area, 25 km south of McCartys, the Tres Hermanos is composed of a basal sandstone member; a middle shale member of shale, siltstone, thin sandstone lenses, and coal beds; and an upper sandstone member (S. L. Moore, written commun., 1980).

The D-Cross Tongue of Mancos Shale overlies the Tres Hermanos, merges with the middle tongue in the San Fidel area, and becomes a mappable unit again above the Juana Lopez east of the Cubero area. Few outcrops occur in landslide chaos covering the slopes on both sides of the San Jose valley. The bold cliffs protruding through the landslide-covered slopes are the Gallego Member of the Gallup Sandstone and the main Gallup Sandstone. The shale tongue interbedded with the Gallup sandstones *(fig.* 2) is similar to the Mancos Shale but, toward the south, is more silty, is less fossiliferous, and contains increasing numbers of thin interbedded-sandstone lenses. The shale tongue finally pinches out about 60 km to the south. The color changes from the Mancos gray to lighter gray, gray-brown, and light yellowish gray.

The Gallup Sandstone, the Dalton Sandstone Member of the Crevasse Canyon Formation, and the Point Lookout Sandstone are all similar in appearance and lithology. These units consist generally of fine-grained, grayish-orange to yellowish-gray, thin to massive, even-bedded sandstone, with local areas of channels and cross-stratification.

The Dilco Coal Member of the Crevasse Canyon Formation overlies the Gallup Sandstone and is composed mostly of thin-bedded to lamellar sandstone, siltstone, and shale with numerous interbeds of highly carbonaceous shale and coal (most of which are only a few centimeters thick). The thickest coal bed observed in the sparse outcrops was about 50 cm. Several 1- to 11/2-m-thick beds of very carbonaceoous shale with small lenses of coal may be mineable locally if coal lenses thicken sufficiently.

Lenticular sandstones above the Dilco north of San Jose valley, and locally to the south, are correlated with the Stray sandstone, an informal unit which is similar to the other Crevasse Canyon sandstones. It is overlain by the Mulatto Tongue of the Mancos Shale.

The Mulatto Tongue is composed largely of fissile olive-gray shale, with interbedded yellowish-gray siltstone and sandstone. The siltstone becomes predominant toward the south, and the interbedded sandstone lenses become thicker and more numerous until the unit merges with the enclosing Crevasse Canyon Formation. The Mulatto Tongue is overlain by the Dalton Sandstone and Gibson Coal Members of the Crevasse Canyon Formation.

The Gibson Coal Member of the Crevasse Canyon Formation, though not exposed in the area, is assumed to be present in the northern part of the Cebollita Mesa and on Mesa Negra, under a sandstone bed correlated with the Point Lookout Sandstone and beneath slopes covered by landslides and talus. Colluvial material containing fragments of very carbonaceous shale and black powdery coalified materials is common in some areas.

The Hosta Tongue of Point Lookout Sandstone, the Satan Tongue of Mancos Shale, the upper part of the Point Lookout, and the overlying Menefee Formation are exposed locally under the basalt-capped mesas around Mount Taylor and in the region northeast of Grants but are not recognized to the south.

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