GEOLOGY AND COAL RESOURCES OF MESITA DE YESO QUADRANGLE, CIBOLA COUNTY, NEW MEXICO

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by

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Contents: (1) Discussion of Geology and Coal Resources

(2) Geologic Map with cross sections (accompanying)

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GEOLOGY

General

The Mesita de Yeso quadrangle lies in the southwest part of the Zuni Basin, a broad, shallow structure that extends southwestward from the Zuni Mountains of New Mexico into east-central Arizona. As such, the quadrangle lies near the southeast margin of the Colorado Plateau. The regional dip in the study area is very gently, but perceptibly, northeastward toward the Gallup sag which comprises the northeast and deepest part of the Zuni Basin. The northeastward dips are interrupted locally by broad, low amplitude, NW-SE-trending folds, by NW-SE-trending monoclinal flexures up on the northeast side, and also by minor faulting. At least two monoclines have been identified in the area. The longest and most pronounced of the two is the Atarque monocline (Anderson, 1982b) which extends 15 mi northwestward from the Atarque Lake quadrangle across the northern part of the Venadito Camp quadrangle. The other monocline extends northwestward from the Mesita de Yeso quadrangle across the southwest edge of the Upper Gallestina Canyon quadrangle where it flattens out for 2 1/2 mi and then continues northwestward in the Plumasano Basinn quadrangle (Fig. 1); this latter monocline can be traced for approximately 12-14 mi and is referred to as the Gallestina monocline, also on Fig. 1.

These major structural elements parallel the axis of the Zuni uplift, but perhaps just as significantly, they appear to represent the southeastward extension of the structural axes that wrap around the southern end of the Defiance uplift, as shown by

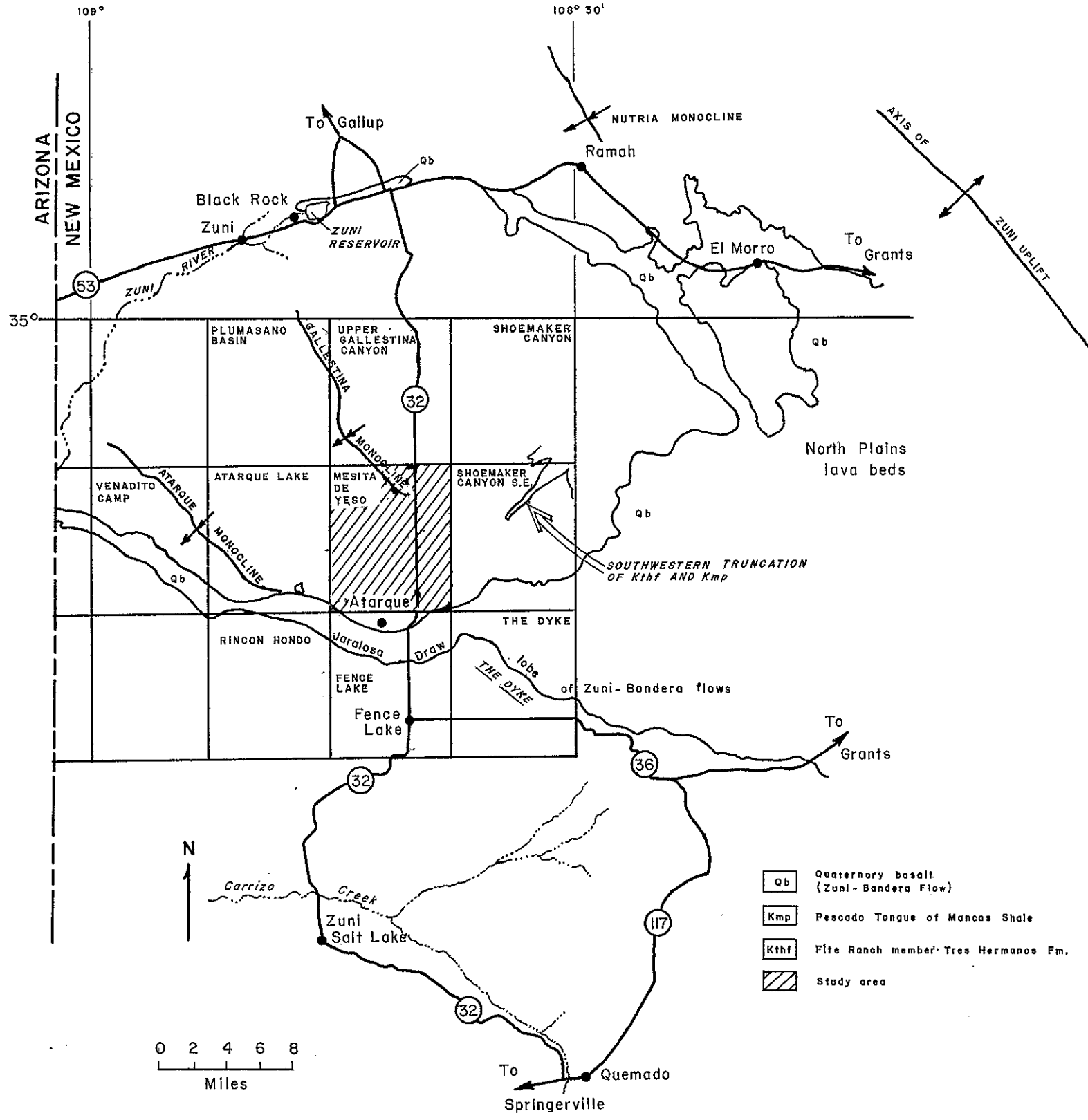


Fig. 1 Index map of study area showing monoclines and truncation of Tres Hermanos Formation.

Davis and Kiven (1975). These structures also align very closely with the northwest-trending dike system in the The Dyke, Techado, Adams Diggings, and Pie Town areas.

The monoclinal flexures are the most significant structural features present not only locally but in a much broader context. Kelly (1955) stated that "In many respects the monoclines are the principal structural features of the Colorado Plateau. Most of the deformation has occurred along them." Their significance is related to the concept of northeast-southwest horizontal compression of the Colorado Plateau area during the Laramide orogeny. As a response to the regional compression, discrete, individual basement blocks were uplifted by reverse movemennts along segments of high-angle fracture zones (Davis, 1978). These reverse faults produced monoclinal folding in the overlying strata. Groupings of these monoclines -- some of which may be traced for more than 100 mi in length -- have been attempted on the basis of similarity of trends, which, when related to the deep faults, serve to subdivide the Precambrian basement into a mosaic of crustal blocks.

The rock units that crop out in the area under consideration are 1) Upper Cretaceous sandstones and shales that exceed 500 ft in thickness where the Tres Hermanos Formation (Hook, Molenaar, and Cobban [1983] in press) is present, 2) highly crossbedded eolian sandstones of Jurassic age that range up to 100 ft in thickness, and 3) Triassic shales, mudstones, siltstones, and sandstones that make up the Chinle Formation, which is estimated to be 800-1,000 ft thick locally (see Anderson

1982b; O'Sullivan, 1977). Additionally a 32-ft-thick section of flat-bedded, reddish-brown silty sandstone and sandy siltstone that is well exposed in the Los Pilares area, 500 ft south of the quadrangle boundary is sec. 14, may be the equivalent of the Rock Point Member of the Wingate Sandstone (Triassic) described by Harshbarger, Repenning, and Irwin (1957, p. 8). However, this sandstone-siltstone is not a mappable unit throughout most of the Mesita de Yeso quadrangle.

The Paleozoic section in the subsurface may be inferred from an oil test drilled 10 mi to the north of the Mesita de Yeso quadrangle in the NE 1/4 sec. 5, T. 9 N., R. 18 W., in 1963 by Cities Service Oil Co. (Maxwell and Nonini, oral communication). This test penetrated a 1,400 ft section of Paleozoic rocks capped by the San Andres Limestone. Upon the presumption that thicknesses locally are uniform, a sedimentary section of approximately 2,900 ft overlying the Precambrian basement may be present in the study area.

Scattered remnants of the Upper Tertiary Bidahochi Formation are present in the area from the north side of Carrizo Creek on the south to Pinehaven on the north. This unit represents an apron of alluvial material deposited along a northwest-trending fluvial system in the upper reaches of the ancestral Little Colorado River drainage basin. Within the Mesita de Yeso quadrangle, the formation is restricted to the south-central portion where it caps Mesita de Yeso, the topographic feature from which the quadrangle takes its name. Here the Bidahochi consists of white or pinkish gray sandstone and conglomerate with clast lithologies suggesting a source area

in the Datil, Mangas, and Gallo Mountains south and east of Quemado. Reworking of the coarse-grained fluvial deposits on the Zuni Plateau and Santa Rita Mesa to the south may have provided additional sources. Basal elevations of this deposit on Santa Rita Mesa range between 7,200 and 7,300 ft, whereas the base of the Bidahochi Formation on Mesita de Yeso is between 7,000 and 7,100 ft; alternatively the two may be equivalent age. Northward in the vicinity of Pinehaven the presence of granitic debris in the formation indicates a source area in the granite-cored Zuni Mountains (repenning and others, 1958).

Major unconformities in the local section occur at system boundaries-the Jurassic/Triassic, the Cretaceous/Jurassic, and the Tertiary/Cretaceous. The Upper Jurassic Zuni Sandstone is an eolian and partly fluvial unit deposited unconformably on the Rock Point Member of the Wingate Sandstone. The local relief on the Rock Point surface may approach 100 ft, as in the southeast corner of the Plumasano Basin quadrangle. In the Fence Lake quadrangle just east of the townsite of Atarque, the Zuni thins considerably and contains some atypical facies, namely reddish-brown, very fine grained, silty sandstones. Sixteen miles to the south, along Carrizo Creek, the Jurassic has disappeared completely. Thus, the southward pinchout of Jurassic rocks occurs 60 mi due west of the area in which Silver (1948) first nonted the pinchout in his paper discussing Jurassic overlap. This southward pinchout indicates strong east-west control on Jurassic sedimentation.

The Dakota Sandstone forms the basal Cretaceous rocks in this area and consists of approximately 100 ft of nonmarine, marginal marine, and marine sandstones and shales that were deposited in front of and immediately behind the shoreline of the advancinng interior seaway during Cenomanian time. The lower two-thirds to three-fourths of the formation is nonmarine, with fluvial-channel sandstones at the base overlain by paludal shales. The shales are locally carbonaceous with very minor coaly beds. The very thin, lenticular, coaly beds are of poor quality and represent accumulation in a transgressive sequence. Following the Dakota-Mancos transgression, the regressive Moreno Hill Formation and the partly equivalent Tres Hermanos Formation (Hook, Molenaar, and Cobban 1983, in press) were deposited throughout much of west-central New Mexico. These partly equivalent units contain coal in beds up to 2 and 3 ft in thickness, locally thicker (Campbell, 1981) and of higher quality than that found in the Dakota. The coal occurrences on the Mesita de Yeso quadrangle are somewhat thinner than this and are essentially restricted to the Tres Hermanos Formation outcrops which here define the southwest edge of the Gallup-Zuni coal field. Coal resources are discussed in greater detail in the last section of this report.

Study Area

Structure

The gentle northeasterly dips prevalent in the Mesita de Yeso quadrangle area have produced a topography consisting of

sandstone-capped low mesas and northwest-southeast-trending cuestas. Superimposed on this structural framework are 1) a minor structural high in the form of a dome called Mesita de Yeso in the south-central portion of the quadrangle and 2) a monoclinal flex, or assymmetric anticline, considered to be the southeast end of the Gallestina monocline (see Fig. 1), which extends into the north-central part of the quadrangle.

The Mesita de Yeso high is more accurately a northeast-trending anticlinal fold plunging northeast and truncated by a fault(s) at its southwest end. A northwest-trending fault on the west extends into sec. 14 of the quadrangle from the Los Pilares area immediately south and parallels the southwest terminus of Mesita de Yeso; however, the fault cannot be traced across the drainage to the north. The displacement at Los Pilares is approximately 25 ft. Additional faulting is shown in secs. 13 and 14 immediately south of the quadrangle boundary on the Fence Lake quadrangle by McLellan and others (1981), but these faults cannot be traced northward. However, a northwest-trending fault shown by these authors as following Canon Ancho in sec. 13 may possibly extend northwestward to intersect a north-trending fault in the SE 1/4 sec. 11, T. 6 N., R. 18 W. (shown on the accompanying map).

Mesita de Yeso is apparently a cross fold very similar to those described on the Venadito Camp and Atarque Lake quadrangles to the west (Anderson, 1982a, b), where they are thought to be related to the sinuosity of the northwest-trending Atarque monocline (see Fig. 1). The Mesita de Yeso is especially similar to the structure forming the sec. 5 mesa (T. 6 N., R. 19 W.) on

the Atarque Lake quadrangle. Mesa Colorado, a prominent local feature just off the western edge of the study area, is thought to owe its prominence to a thickening of the Jurassic sandstone section rather than to any significant cross folding (Anderson, 1982b).

The monoclinal flexure that enters the quadrangle at the northwest corner and terminates just short of NM-32 is shown in structure section A-A' on the accompanying map. Maximum dips recorded on the monoclinal face were only 11° southwest (in sec. 34 of T. 8 N., R. 18 W.); nevertheless, the flexure is a distinct, abrupt, linear feature, here considered to be the southeastward extension of the Gallestina monocline of Stricker and Anderson (1983, in preparation). Like the Atarque monocline 10 mi to the southwest, this monocline has a sinuous trace with an especially sharp bend at the quadrangle boundary in sec. 34. Both these monoclines are likely to be associated with high-angle or high-angle-reverse faults in the Precambrian basement as shown on the map cross section. The origin of high-angle basement faults has been discussed by Davis (1978), who considered them to be a response to northeast-southwest-directed horizontal compression at the Colorado Plateau during the Laramide orogeny. The faults produced the monoclinal folding typical of the Colorado Plateau.

Other structures on the quadrangle consists of a curved, northwest-trending, asymmetric anticlinal fold in the S 1/2 sec. 36, T. 8 N., R. 18 W. and an east-west-trending fault in the extreme southeast corner of the quadrangle in secs. 16 and 17;

the trace of this fault follows Terrero Draw. The upthrown block is on the north, but apparently eastward tilting of the upthrown block occurred as greater displacement exists on the west end. This tilting "against drainage" has resulted in the formation of swamp conditions from time to time in Terrero Draw as is evidenced by the black, peaty soils found in scattered patches.

Stratigraphy

The oldest rocks exposed on the quadrangle are those of the Chinle Formation. Although the formation was mapped, it was not studied in detail because outcrops are poor and most of the area underlain by the Chinle (the southwest corner of the map) has an alluvial cover. Considerable areas of alluvium were mapped here because of the uncertainty surrounding the extent of the Rock Point Member of the Wingate and the sudden appearance and disappearance of the Jurassic sandstones locally.

The upper part of the Chinle locally consists of red, maroon, and gray mudstone, siltstones, shale and thin sandstones that are assigned to the Petrified Forest Member. Stewart, Poole, and Wilson (1972) described and measured sections of the Chinle at two nearby localities. At one locality north of St. Johns, Arizona, between 34°42'N and 34°46'N, the upper part of the Petrified Forest Member is 591 ft thick within a total Chinle sequence that is 827 ft thick. At the other locality near Zuni, New Mexico, 178 ft of Petrified Forest Member was measured. The thickness of the Chinle was not determined in the study area as the base is not exposed. The Chinle was estimated to be 800 to 1,000 ft thick on the adjacent Atarque Lake quadrangle by

Anderson (1982b). O'Sullivan (1977) placed his 400-m (1,320-ft) isopach a few miles to the north of the Mesita de Yeso quadrangle area, with the Chinle Formation thinning to the south.

A 32-ft-thick section of reddish-brown, flat-bedded silty sandstone is exposed at Los Pilares just 500 ft south of the quadrangle in sec. 14 (T. 6 N., R. 18 W.) where it rests on Chinle Formation mudstones and shales. This uniform sequence is here considered to be the equivalent of the Rock Point Member of the Wingate described by Harshbarger, Repenning, and Irwin (1957, p. 8) as a pale-reddish-brown silty sandstone at the type locality near Rock Point, Arizona. They further interpreted it as a quiet water deposit that accumulated in a southward-plunging basin (Rock Point Lagoon) fed by streams entering from the northeast, east, and southeast. An embayment at the eastern margin of the lagoon was shown extending across the New Mexico State line in the Zuni-Atarque area. The Rock Point Member, however, becomes unmappable a very short distance north of Los Pilares inside sec. 11, T. 6 N., R. 18 W. (see accompanying map). Its presence northward from this point on the quadrangle is uncertain; it appears as a 6-ft-thick unit at the base of Mesa Colorado, just off the west boundary of the quadrangle (Anderson, 1982b).

The white, fine-grained, crossbedded sandstone comprising the uppermost Jurassic rocks and capped by the Dakota Sandstone is the Zuni Sandstone. Anderson (1983, in preparation) defines the Zuni as consisting of the undivided equivalents of the Cow Springs and Entrada Sandstones. The name Cow Springs was proposed by Harshbarger, Repenning, and Jackson (1951) for the greenish-gray to light-yellowish-gray, fine-grained, crossbedded

sandstone that weathers to grayish-white rounded cliffs. At the type section 4 mi east of Cow Springs, Arizona, the Cow Springs Sandstone is 342-ft-thick and is unconformably overlain by the Dakota Sandstone. Additional work by Harshbarger, Repenninng, and Irwin (1957) extended the Cow Springs terminology into the Zuni Reservation of New Mexicô, where they stated it is not easily distinguished from the underlying Entrada. A 440-ft-thick section near Black Rock was designated as Cow Springs Sandstone resting on the flat-bedded Rock Point Member of the Wingate Sandstone and unconformably overlain by the Dakota Sandstone. From there the unit may be traced in outcrop southeastward through the Plumasano Basin quadrangle and into the Mesita de Yeso quadrangle, although it thins considerably at two localities -- sec. 35, T. 9 N., R. 19W., and sec. 31, T. 8 N., R. 18 W.

Northwest of the study area toward Fort Defiance and Black Mesa, this sandstone grades laterally into the Summerville and Bluff Formations and overlies the Entrada. Northward and northeastward near Todilto Park the sandstone appears to intertongue with the Westwater Canyon Member of the Morrison Formation and is considered to be an eolian deposit contemporaneous with the fluvial Morrison (Harshbarger, Repenning, and Irwin, 1957, p. 50). From the Lupton, Arizona, area southward, the contact between the Cow Springs and the underlying Entrada becomes unidentifiable (Harshbarger, Repenning, and Jackson, 1951). Hackman and Olson (1977) used the term Cow Springs-Entrada (Jcse) for this interval in the Zuni area.

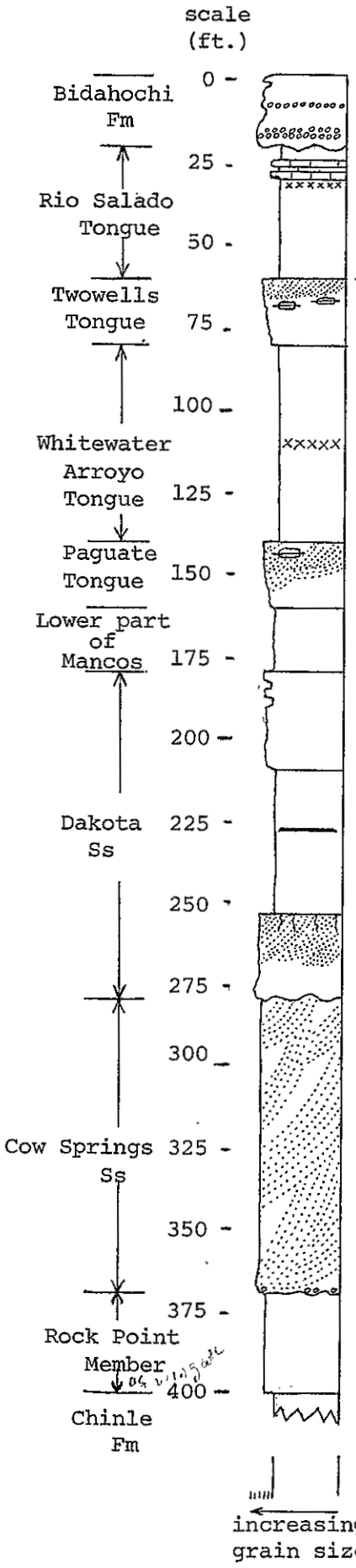
In the Los Pilares area immediately south of the Mesita de Yeso quadrangle the basal Zuni Sandstone commonly has a thin conglomeratic zone, 1-3 ft thick, resting on an irregular surface. The irregular surface is locally developed on a 4-ft-thick, greenish-gray siltstone and very fine grained silty sandstone that -- in contrast to the underlying reddish-brown siltstone -- is indistinctly bedded and noncalcareous. As no break in deposition is apparent at the reddish-brown/greenish-gray boundary, the unit is considered to be all Rock Point. The base of the Zuni and, hence, the Upper Triassic-Upper Jurassic unconformity is represented by the irregular surface and the conglomerate.

The remainder of the Zuni, which measures 90 ft in all, is composed of white to pinkish-gray fine-grained sandstone. Its most distinguishing characteristic is the large-scale sets of high-angle festoon and planar crossbedding which indicate an eolian origin. Crossbed dip directions are to the southwest generally with 22°-24° dips. A zone of dark-brown, ferruginous concretions with crossbed laminations passing through them forms a prominent break 60 ft above the base. As previously mentioned local variations in thickness are considerable, and the unit contains some red beds near the townsite of Atarque and in the southeast corner of the Plumasano Basin quadrangle. Because much of the Triassic sequence and the Cretaceous sequence is shale, wherever a thick, resistant Jurassic sandstone is present local

prominences like Los Pilares and Mesa Colorado (Atarque Lake quadrangle) have developed. Fig. 2 is a composite stratigraphic column for the Mesita de Yeso-Los Pilares area.

The Cretaceous rocks consist, in ascending order, of the main body of the Dakota Sandstone, an intertongued Dakota Sandstone-Mancos Shale sequence, the Rio Salado tongue of the Mancos, and the coal-bearing Tres Hermanos Formation. The rocks called the main body of the Dakota Sandstone are the marine, marginal marine, and nonmarine rocks that make up the lowest part of the Cretaceous sequence in west-central New Mexico (Hook, Cobban, and Landis, 1980). In the study area the Dakota is composed of a basal, crossbedded, fluvial sandstone or conglomerate of varying thickness, a paludal shale sequence containing carbonaceous shale and very thin coal beds, and marginal-marine sandstones that form the upper 25 ft of the unit (Fig. 2). Root tubes were noted at the top of the fluvial sandstone in the SE 1/4, NE 1/4 sec. 17, T. 7 N., R. 17 W. Fossils collected locally in the upper marine sands include the bivalves Pycnodonte cf. P. kellumi and Exogyra levis and Turritella sp. and various other gastropods. The Dakota is overlain by the lower part of the Mancos Shale, a 20-ft-thick arenaceous shale that is exposed in the NE 1/4 sec. 1, T. 6 N., R. 18 W.; elsewhere it is covered or unrecognizable. This shale tongue is probably equivalent in part to the Clay Mesa Tongue, which has a type section designated in the Laguna, New Mexico, area (as do most of the intertongued Dakota-Mancos units [Landis, Dane, and Cobban, 1973]). However, because of the pinchout of an underlying sandstone tongue (the Cubero) a few miles southwest

Fig. 2. Composite stratigraphic column for the Mesita de Yeso-Los Pilares area



Ss and cgl.; ss rich in lithic fragments; cgl composed of vesicular basalt, basaltic andesites, rhyodacite, other volcanics, and qtzite

Sh, gray; calc. sh and calcarenite beds 30-35 ft. above base are rich in P. newberryi (Stanton) fragments; numerous thin bentonitic beds below and in calc. beds are white to orange weathering

Ss, very fn to fn grained, pale yellowish gray to pale olive, burrowed, com. bioturb., cross-bedded in upper parts; thin shale interbeds com.; fossiliferous in mid & up parts

Shale, gray to med. dark gray; E. trigeri (Coquand) present especially in middle part, selenite xtals; 15" thick white to orange bentonite bed near the middle, but is poorly exposed here.

Ss, very fn to fn grained, pale yellow gray to grayish orange; com fossiliferous at top, P. cf P. kellumi and large specimens of E. levis

Arenaceous sh; poor exposures

Ss, very fn to fn grained, grayish orange to pale yellow brown; com. flaggy bedded esp. near top; small burrows present in upper parts

Sh, gray to brownish gray; paludal; thin ss and arenaceous sh beds locally; carbonaceous zones with very thin coaly beds present near middle

Ss, fn to low med grained, grayish orange to pale yellowish brn; fluvial; locally conglomeratic at base

Ss, white to pinkish gray, very fn grained; thick sets of southwest dipping high angle planar and festoon cross beds; locally a pebble conglomerate zone at base; variation in thickness is considerable; where thin it may be greenish gray and more poorly cemented

Ss and siltst, lower very fn grained ss with siltst, reddish brown, flat bedded; locally 3' to 4' greenish gray zone at top

(section not measured)

Explanation
- burrows
- cross-bedded
- root tubes
- carbonaceous
- xxxxx bentonite bed

of Laguna, the term Clay Mesa cannot be extended into the study area and hence the informal term "lower part of the Mancos Shale" is used here (see Hook, Cobban, and Landis, 1980).

Overlying the shale is the Paguate Tongue of the Dakota Sandstone; the Paguate consists of a 20-ft-thick, massive, crossbedded, coarsening-upward sandstone unit that commonly has a fossil-hash zone at the top composed almost exclusively of shells of Exogyra levis and Pycnodonte cf. P. kellumi. Large brown ferruginous/calcareous concretions may also be present in the upper part. The unit characteristically weathers to a light-tan or pale-grayish-orange color. Topographically it is generally a small cliff former, but outcrops are very restricted on this quadrangle. Good outcrops may be found in the Se 1/4 sec. 36, T. 7 N., R. 18 W., where large specimens of E. levis have been collected. Northward the unit merges with the main body of the Dakota, as the lower part of the Mancos Shale pinches out. Near the village of Two Wells, 14 mi due north of Zuni, at the type localities of the Twowells Tongue of the Dakota and the Whitewater Arroyo Tongue of the Mancos, the Paguate is not present as a lithologic unit distinct from the main body of the Dakota Sandstone (Hook, Cobban, and Landis, 1980).

The Whitewater Arroyo Tongue of the Mancos Shale overlies the Paguate Tongue throughout the Zuni Basin. The name was proposed by Owen (1966) who applied it to a "well defined, persistent tongue of marine shale separating the Twowells [Tongue] from the rest of the Dakota Sandstone in the southwestern part of the San Juan Basin" (and in the Gallup Sag area). A type section was

designated in Whitewater Arroyo in sec. 17 of T. 12 N., R. 19 W., near the village of Two Wells, where it is 80 ft thick and described as a gray to olive-gray, silty, oyster-bearing shale. It crops out only sparingly in the present study area where it consists of an estimated 60 ft of medium- to dark-gray fissile shale and contains the relatively large oyster Exogyra trigeri (Coquand) in its middle portion. Also very near the middle is a distinctive white- to orange-weathering 15-inch-thick bentonite bed that is, however, not well exposed here. Good exposures of the Whitewater Arroyo Tongue and the bentonite bed occur to the west on the Venadito Camp quadrangle in the NE 1/4 sec. 30, T. 7 N., R. 19 W., where it is protected by a cover of Twowells Sandstone. The bentonite bed has also been recognized 18 mi to the southwest on the Twentytwo Spring quadrangle and 75 mi to the east on D-Cross Mountain where it may be only 8 inches thick (Hook, Cobban, and Landis, 1980).

The Twowells Tongue of the Dakota Sandstone crops out in the eastern and northern parts of the quadrangle where it may reach 20 ft in thickness but is generally less. Good outcrops may be found along the monocline in the northern part of the quadrangle. The Twowells consists of 1) a basal, 4-ft-thick, very fine grained, flat- to wavy-bedded sandstone that is locally burrowed and very fossiliferous at the top; this basal portion with a thin, bentonitic clay overlying is well exposed along NM-32 in secs. 6 and 7, T. 6 N., R. 17 W.; 2) an overlying gray shaly sandstone of variable thickness, generally poorly exposed, that is also locally fossiliferous; and 3) an upper, fine- to lower-medium-grained, pale-yellowish-gray, crossbedded sandstone,

characteristically with thinly interbedded shale and clay clasts; wavy bedding is also characteristic of this upper sandstone. The Twowells is well displayed on the quadrangle boundary in the SW 1/4 sec. 35, T. 8 N., R. 18 W. An uncharacteristically massive, structureless, 12-ft-thick section of sandstone is exposed in the SW 1/4 NE 1/4 sec. 29, T. 7 N., R. 17 W., forming the upper part of the Twowells.

Fossils in the Twowells consist almost exclusively of Pycnodonte kellumi, fragments of Exogyra trigeri (Coquand), and small specimens of Exogyra levis. Evidence of burrowing and bioturbation is common throughout; the burrows include Ophiomorpha. Both the Twowells and the Paguate Tongues may represent minor regressive pulses in the Dakota-Mancos transgressive sequence. The Twowells in particular contains features, such as opposed crossbedding, that suggest deposition in a tidal channel environment.

The Rio Salado Tongue of the Mancos Shale represents a rapid return to open-marine, deeper water conditions or an interruption in sediment supply following deposition of Twowells. The Rio Salado consists of up to 240 ft of medium-gray and grayish-brown shale, calcareous shale, and thin calcarenites with an interbedded shale and very fine grained sandstone sequence at the top where it grades into the overlying Tres Hermanos Formation.

The name Rio Salado Tongue is proposed in Hook, Molenaar, and Cobban (1982, in preparation). It is defined as the shale tongue lying between the Twowells Tongue of the Dakota Sandstone and the Atarque Sandstone Member of the Tres Hermanos Formation

(or Atarque Sandstone Formation to the southwest) and is coextensive with these two units.

The thin calcarenite and calcareous shale beds that occur 30-40 ft above the base of the Rio Salado represent the equivalent of the Bridge Creek Limestone Member of the Greenhorn Formation (Hook, Cobban, and Landis, 1980). The beds may often be recognized at a distance in outcrop because the yellow-weathering calcarenites stand out in contrast to the typically gray Mancos Shale. The beds are well exposed just west of NM-32 in the SW 1/4 sec. 6, T. 6 N., R. 17 W., where the thin calcarenites contain abundant fragments of Pycnodonte newberryi (Stanton). Deposition of these beds is related to the very late Cenomanian (Greenhorn) transgressive maximum, an event that was marked by the deposition of limestone beds throughout most of the Western Interior seaway. The beds form important marker horizons, and also the guide fossil Pycnodonte newberryi (Stanton) appears in abundance at or just below this interval (Hook, and Cobban, 1977). Pycnodonte newberryi was collected in the NE 1/4 sec. 1, T. 6 N., R. 18 W. In the subsurface the Bridge Creek beds may be recognized by the distinctive resistivity kick they produce on the e-log, which is helpful in correlations.

About 100 ft above the Bridge Creek equivalent, limestone concretions commonly appear in the section, but this zone is not well exposed here. Locally associated with the concretions are the ammonites Mammites depressus, M. nodosoides, Proplacenticeras cumminsi, and Neoptychites cephalotus, (see Anderson, 1982a). Also, found locally in association with the concretions are

Ostrea sp., Veniella mortoni, Baculites sps., Turritella sp. and other gastropods. This part of the Rio Salado is present only in the extreme eastern portion of the quadrangle in secs. 21, 28, and 33 of T. 7 N., and sec. 4 of T. 6 N.

The Atarque Sandstone Member of the Tres Hermanos Formation is the term proposed in Hook, Molenaar, and Cobban (1983 in press) for the regressive coastal-barrier sandstone unit that overlies the Rio Salado Tongue of the Mancos Shale and as such marks the first major regression of the seaway following the Dakota-Mancos (Greenhorn) transgression. The Atarque Sandstone Member and the overlying nonmarine Carthage Member are in part equivalent to the Atarque Sandstone (Hook, Molenaar, and Cobban, 1983, in press) and the Moreno Hill Formation (McLellan and others, 1983, in press) which are the stratigraphic names used to the south and west of the Mesita de Yeso quadrangle (Anderson, 1982b).

At the time the Atarque Sandstone was deposited, the shoreline had assumed a general NW-SE trend in this area and the Atarque Member prograded northeastward into the Mancos seaway. The Atarque is a diachronous unit that becomes younger to the northeast. Throughout much of the Zuni Basin, it is a cliff-forming unit and consists of a lower flat-bedded sandstone which appears in most outcrops as the first massive unit overlying the transitional zone at the base; it coarsens upward from very fine to fine grained; 2) a medial, fine-grained, shaly unit of varying thickness, but generally 10-20 ft: and 3) an overlying, lower- to upper-fine-grained, crossbedded sandstone, fossilferous at the

top, that is 14-20 ft thick. Units 1) and 3) are similar to the lower and upper shoreface sandstones of Molenaar (1973). The lower shoreface unit is thought to have been deposited offshore beyond the zone where wave action or longshore currents influenced sedimentation. Deposition of the upper shoreface unit probably took place in the zone where longshore currents were active. Burrows, including Ophiomorpha, are common in the lower flat-bedded unit and less common above.

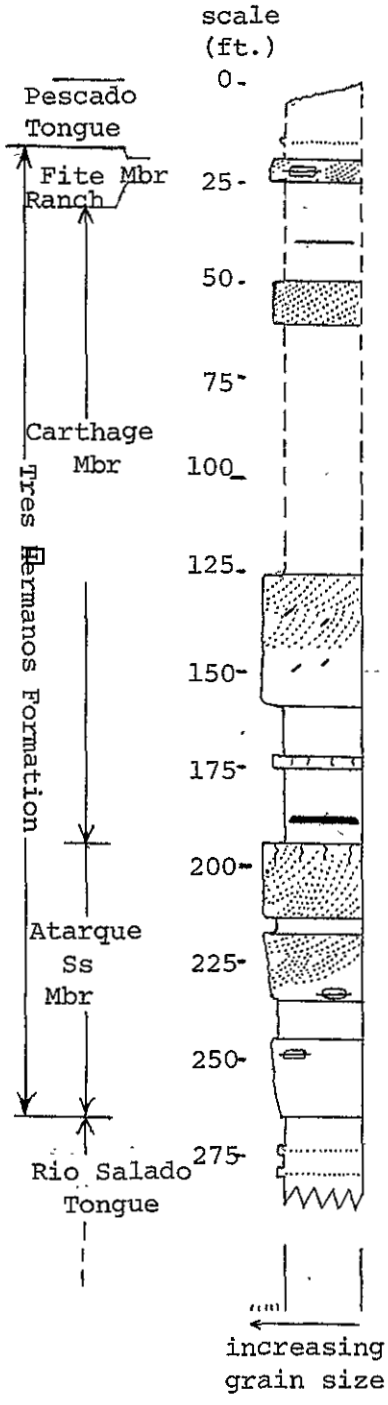
In addition to these three units on this quadrangle and eastward, an upper unit composed of white to very pale orange, upper-fine-grained, crossbedded sandstone forms a small but conspicuous cliff that rises above a small bench developed on the upper shoreface unit (Fig. 3). Twelve miles to the west this uppermost sandstone is present as a nonmarine unit, a fluvial or distributary channel sandstone (Anderson, 1982b), and was included with the overlying Moreno Hill Formation. On the Mesita de Yeso quadrangle, this white upper sandstone is more marine in nature (no clay clasts, no ripple marks, etc.) and is a relatively widespread, uniform deposit. The top is commonly burrowed and root penetrated and is overlain by a paludal shale. The thicker Atarque sequence here probably represents a shoreline stand between here and the Atarque Sandstone outcrops 12 mi to the west, with a resultant build-up of the upper shoreface unit.

The Atarque Sandstone Member (presesnt usage) corresponds to the Lower Gallup, or the Atarque Member of the Gallup, of Molenaar (1973); he also, however, included the overlying nonmarine carbonaceous shales, fluvial channel sandstones, and thin coal beds in this member. The faunal evidence presented

in Hook, Molenaar, and Cobban (1983, in press) points to a significant age difference between the Atarque and the Gallup. They recognize the Atarque as having been deposited during an earlier regressive cycle than the Gallup Sandstone and as being separated from the Gallup by the Pescado Tongue of the Mancos Shale and the associated underlying marine sandstone unit for which they propose the name Fite Ranch Sandstone Member of the Tres Hermanos Formation (see Fig. 3).

The Pescado Tongue is not present on the Mesita de Yeso quadrangle. Its southwesternmost occurrence is an erosional remnant approximately 4 mi to the east on the Shoemaker Canyon Southeast quadrangle. The underlying, very thin, Fite Ranch Sandstone Member extends a little farther southwest and comes within 3 mi of the Mesita de Yeso boundary (see Fig. 1). The authors of the redefined-Tres Hermanos paper (Hook, Molenaar, and Cobban, 1983, in press) stated that the presence of the Pescado Tongue of the Mancos Shale determines the area in which the Tres Hermanos nomenclature shall be used. Landward equivalents were, as previously mentioned, designated as the Atarque Sandstone and the Moreno Hill Formation. The point of nomenclature change would be the limit of mappable Pescado. However, in the present study extending the Tres Hermanos nomenclature southwestward around the end of the topographic feature upon which this limit occurs was deemed less confusing and perhaps more appropriate. This carries the name into the east-central part of the Mesita de Yeso quadrangle and thus it becomes the quadrangle in which the change in stratigrahic nomenclature takes place. To be more

Fig. 3. Composite stratigraphic column for the Mesita de Yeso--Shoemaker Canyon SE quadrangle boundary area. Upper, dashed part of section is present only on Shoemaker Canyon SE quadrangle



Sh, med gray to lt brownish gray; numerous thin ss beds near base

Transgr. marine ss; v fn to lower med grained; burrows, including Ophiomorpha, common

Paludal sh and fluvial channel ss; carb zone between fluvial channel ss and marine Fite Ranch member well exposed 2.5 mi east of quad boundary in NE¼ sec 24, T. 7 N., R. 17 W.

Fluvial channel ss, fn to lower med grained, cross bedded, clay clasts

Paludal sh, arenaceous sh, and thin, fn grained ss; 4 ft above base is coal zone up to 20 in thick with medial white ash bed; ss 20 ft above base is commonly burrowed and root penetrated with ripple marks locally indicating an eastward paleo flow direction

Ss, very pale orange, upper fin grained, cross bedded; top is root penetrated

fine grained interval (covered)

Ss, lower to upper fin grained, cross bedded; locally fossiliferous near top; (upper shoreface unit)

Shale and arenaceous shale interval

Ss, very fn to fn grained, flat bedded; burrows including Ophiomorpha present; (lower shoreface unit)

(Section not measured)

Explanation

- burrows
- cross-bedded
- root tubes
- coal or carb. zone
- clay clasts

specific east of NM-32 and north of the Quaternary basalt flow emanating from the North Plains the Tres Hermanos nomenclature is used; west of NM-32 and south of the basalt flow the names Atarque Sandstone and Moreno Hill Formation will be used for this interval. The nomenclature change corresponds with a change in coal-field terminology. The Tres Hermanos outcrops that extend into the east-central part of the Mesita de Yeso quadrangle define the southwest edge of the Gallup-Zuni coal field. Coal occurrences to the south and west are part of the Salt Lake Coal field.

Overlying the Atarque Sandstone Member of the Tres Hermanos Formation is the coal-bearing Carthage Member. This member was deposited on the emergent coastal-plain environment formed as the sea regressed. It consists of paludal and lacustrine shales with thin coals and sandstones and fluvial channel sandstones. The basal portion is paludal shale; the contact with the underlying, root-penetrated Atarque Member is sharp. Where present, the coal zone lies 3-7 ft above the base and characteristically has a 2-inch-thick white ash bed near the middle. In this general area the basal shale also contains one or more, thin, flat-bedded, burrowed and root-penetrated sandstones (Fig. 3). These flat-bedded sandstones have been used as an aid in identifying the top of the Atarque, but this top is more appropriately placed at the base of the paludal shale.

Most of the member has been eroded off the southwest-trending highland that extends onto the quadrangle. The thickest remaining section is at B.M. 7405 in the SE 1/4 sec. 28, T. 7 N.,

R. 17 W.; at this exposure which approaches 100 ft in thickness, a fluvial channel sandstone with clay galls, rip-up clasts, and channel-scour features rests on the paludal shale.

Tertiary Rocks

The light-gray and pinkish-gray fluvial sandstone and conglomerate unit that occurs only on Mesita de Yeso is here considered as part of the Bidahochi Formation. The conglomerate is composed largely of volcanics-vesicular basalts, basaltic andesites, and rhyodacites that suggest a source area in the Datil, Mangas, or Gallo Mountains south and east of Quemado. As previously mentioned the unit may be in part derived from or may be the equivalent of the coarse-grained deposit of similar lithology that is present over much of the Zuni Plateau and Santa Rita Mesa; the Santa Rita Mesa deposits 7 mi to the south and 150-200 ft higher in elevation are being designated as the Fence Lake Formation by McLellan and others (1982, in preparation).

The name Bidahochi was first proposed by Reagan (1924) for the conglomerate that overlies Cretaceous Rocks in the Ganado, Arizona, area just east of the Hopi Buttes volcanic field. Later work by McCaan (1938), Reiche (1941), and Hack (1942), established a correlation between the Bidahochi and the Tertiary sediments of the upper Little Colorado drainage in the Zuni Basin. Those sediments in the Pinehaven area contain some granitic debris suggesting a source in the granite-cored Zuni Mountains. In the present study area and westward, the coarse Tertiary sediments are largely of volcanic origin, with a minor

quartzite component probably derived from the Baca Formation (Eocene) which is locally conglomeratic. Repenning and Irwin (1954) established a reference section for the formation 15 mi east of the settlement of Bidahochi, Arizona, and recognized three members: a lower, largely lacustrine member; a middle volcanic member; and an upper, largely fluvial, member. Most of the Zuni Basin deposits would seem to correlate with their upper member; however, they also mentioned the possibility that southeastward, toward the source area, time equivalents of the lower member might be represented by fluvial deposits at the base of the upper member.

COAL RESOURCES

The Mesita de Yeso quadrangle, as previously mentioned, encompasses a small portion of the Gallup-Zuni coal field. The outcrop of Tres Hermanos Formation that extends into the east-central portion of the quadrangle defines the southwest edge of the coal field. Thin coals are present near the base of the Carthage Member of the Tres Hermanos in secs. 21, 28, and 33 of T. 7 N., R. 17 W.

In the SE 1/4 sec. 21 at the east quadrangle boundary, the coal zone lies 3 to 4 ft above the base of the paludal shale and consists of two 10-inch-thick coal beds separated by a 2-inch-thick white ash bed. No analyses were made on the weathered samples; however, coal in a similar stratigraphic position 10 mi to the south was reported by Campbell (1981) to be high volatile bituminous B rank. The coal extends eastward from this point and only 4% of the sec. (26 acres) is likely to be underlain by the two 10-inch beds; the sec. 21 coal resources are thus considered insignificant.

In the extreme SE 1/4 sec. 28, a coal zone was recognized approximately 6 ft above the base of the paludal shale; the coal is 12 inches thick, badly weathered, but of good quality. A problem exists in correlation with the sec. 21 outcrop as the 2-inch white ash bed is not readily apparent. Here as in sec. 21, the coal extends eastward and only about 4% (26 acres) of the section is underlain by the coal. The coal resources of sec. 28 are thus considered insignificant.

In sec. 33 slightly more than 20% of the area (130 acres) is underlain by the coal-bearing member, but at few places did the coal approach the 14-inch cut off used in calculating bituminous coal resources (U.S.G.S. Bull 1450-B, 1976). On "the point" in the SW 1/4 sec. 33, the coal zone is represented by a 2-ft-thick upper-fine-grained flat-bedded sandstone containing much woody trash and carbonaceous fragments. The coal resources for this section, and hence the quadrangle, are thus considered insignificant.

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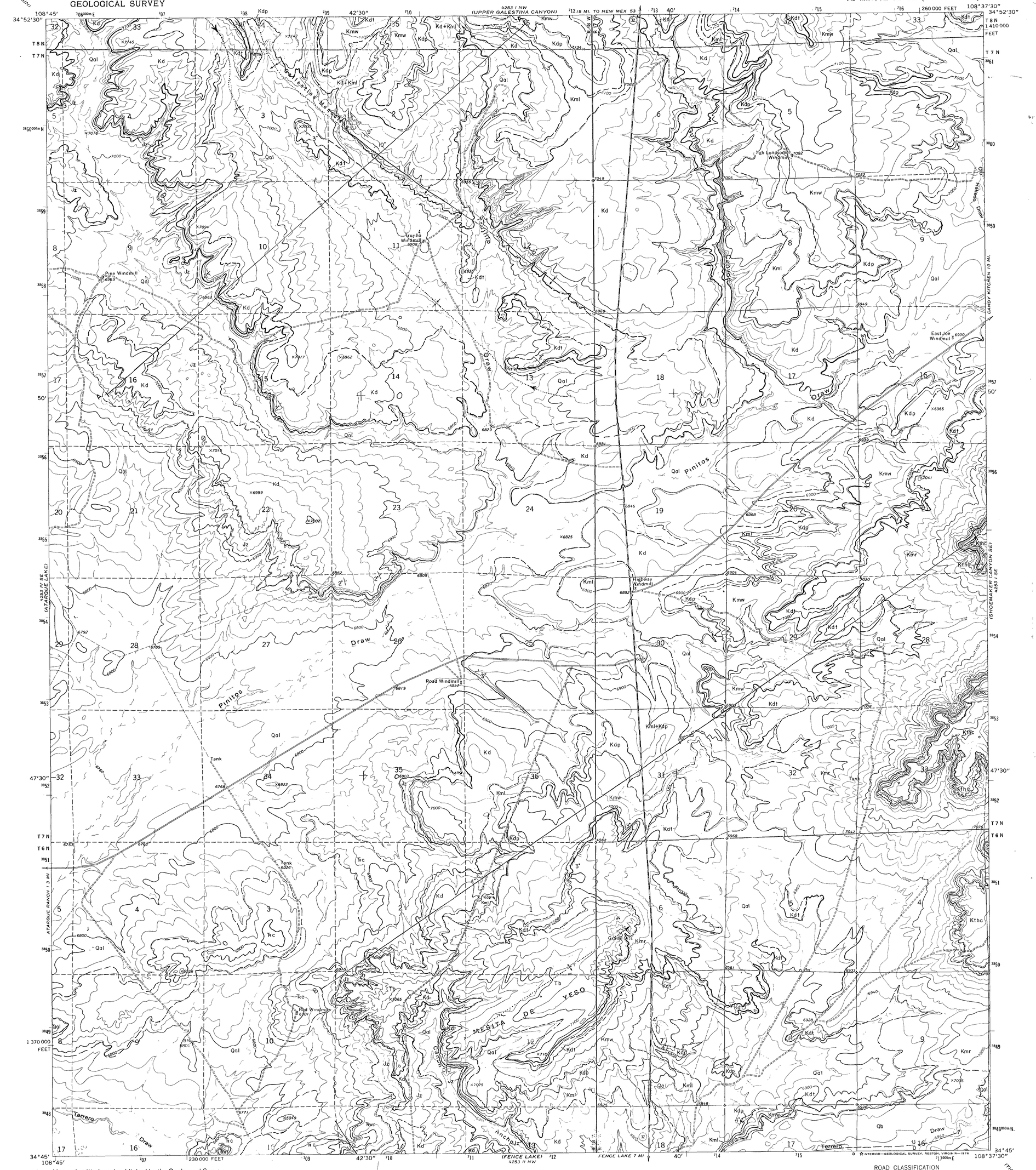
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MESITA DE YESO QUADRANGLE
NEW MEXICO– **CIBOLA CO.**
7.5 MINUTE SERIES (TOPOGRAPHIC)



DESCRIPTION OF MAP UNITS

Qal Alluvial deposits undifferentiated; clay, silt, sand, and gravel in arroyos, floodplains and on gentle slopes.

Qb Basalt flows; originating from centers to east in North Plains lava beds; olivine tholeite in composition with K-Ar age of 1.41 m.y. (Laughlin, Brookins, Damon, and Shafiqullah, 1979).

Tb Bidahochi Formation (Pliocene); light gray to pinkish gray lithic sandstone and coarse conglomerate. Conglomerate composed of vesicular basalt, basaltic andesite, rhyodacite, other volcanic rocks,and minor quartzite.

Kthc Carthage Member of Tres Hermanos Formation (Upper Cretaceous); paludal shale and mudstone, carbonaceous shale with minor coal, and fluvial channel sandstone. Shales are gray to light olive gray; carbonaceous zone 4-6 ft above base locally has up to 20 in of coal in 2 beds seperated by 2 in thick white ash bed. Maximum thickness on quadrangle-100 ft.

Ktha Atarque Sandstone Member of Tres Hermanos Formation(Upper Cretaceous); grayish orange to very pale orange very fine to upper fine grained marine sandstone; coarsens upward; well indurated, generally massive, cliff former; burrows present in lower and middle parts; fossiliferous-small bivalves, in middle part; upper part strongly cross-bedded predominantly of festoon type and is contrasted by its lighter color. Maximum thickness on quadrangle about 65 ft.

Kmr Rio Salado Tongue of Mancos Shale (Upper Cretaceous); medium to dark gray and brownish gray marine shale, silty shale, calcareous shale and calcarenite, with thin interbedded sandstone at the very top; weathers to gentle or moderately steep slopes which are generally covered by colluvium, talus, or landslide debris; base not exposed; calcarenite beds and calcareous shale with an underlying zone containing abundant Pycnodonte newberryi (Stanton) occur about 35 ft above the base; calcareous zone is Greenhorn Limestone (Bridge Creek Member) equivalent; upper 100 ft of the tongue contains numerous limestone concretion zones; associated with the concretions locally are the ammonites Mammites depressus, Mammites nodosoides, Proplacenticeras cuminsi, and Neoptychites cephalotus; also found in this association are Ostrea sp., various bivalves, Turritella and other gastropods. Thickness of tongue estimated at 240 ft.

Kdt Twowells Tongue of Dakota Sandstone (Upper Cretaceous); yellowish gray to pale olive, very fine to upper fine grained, shallow water marine sandstone; lower part very fine grained, commonly burrowed and bioturbated, with these features continuing into the middle, shaly part; upper part is cross bedded in thin sets and/or wavy bedded with thin shale interbeds; locally fossiliferous in all parts, but mainly middle and upper; fossils consist of Pynodonte kellumi, and small (relative to those in the Paguate Tongue) Exogyra levis; also found in association with these in sec. 34, T 8N., R 18W., is Exogyra trigeri (Coquand). Maximum thickness on quadrangle estimated at 20-22 ft.

Kmw Whitewater Arroyo Tongue of Mancos Shale (Upper Cretaceous); gray to medium dark gray marine shale; slope former, base not exposed; near the middle is a 15 inch thick white to orange weathering bentonite bed not well exposed in this area; selenite crystals common; the relatively large oyster Exogyra trigeri is locally abundant; estimated thickness of unit is 60 ft.

Kdp Paguate Tongue of Dakota Sanstone (Upper Cretaceous); pale yellowish gray to grayish orange, very fine to upper fine grained, massive well indurated, marine sandstone; coarsens upward; low angle cross bedding in upper part; small cliff former. Pycnodonte cf. P. kellumi and large specimens of Exogyra levis locally abundant at top especially in SE¼ sec. 36, T 7N., R 18 W.; large, brown, oblate concretions common in upper part; ripple marks noted in NW¼ sec. 5, T 7N., R 17W., maximum thickness of unit, 20 ft.

Kml Lower part of Mancos Shale (Upper Cretaceous); medium gray arenaceous shale; marine; nowhere well exposed; may be gradational into underlying Dakota Sandstone; thickness, 20 ft.

Kd Dakota Sandstone, main body (Upper Cretaceous); the marine, marginal marine, and nonmarine rocks that make up the lowest part of the Cretaceous sequence in west-central New Mexico (Hook, Cobban, and Landis, 1980). Base is fluvial channel sandstone sequence of varying thickness, locally conglomeratic; at places a paludal shale forms the base; middle portion mainly paludal shale with carbonaceous zones and minor coaly lenses; upper third is marine sandstone, thinly bedded and flaggy near top, locally fossiliferous- Pycnodonte cf. P. kellumi, Exogyra levis, and Turritella sp.; estimated thickness 100 ft.

Jz Zuni Sandstone (Upper Jurassic); white to pinkish gray, very fine grained sandstone; thick sets of high angle planar and festoon cross bedding indicate eolian origin; cross bed dip direction is southwest; pebble conglomerate zone at base in the south-central boundary area rests on an irregular surface formed on underlying Rock Point Member; silty, very fine facies may be greenish gray and poorly cemented; 90 ft thick at southern boundary.

Twr Rock Point Member of Wingate Formation (Upper Triassic); reddish brown, flat bedded, silty sandstone and sandy siltstone; at south central boundary area of quadrangle a pale greenish gray zone, lacking distinct bedding, is present at top of unit; irregular surface at top of greenish gray zone represents unconformity between Upper Triassic-Upper Jurassic sediments; thickness 32 ft. Unit is not mappable over most of the quadrangle.

Trc Chinle Formation (Upper Triassic); purple, maroon, reddish brown, and gray mudstone, shale, siltstone, and sandstone; in this area the upper part of Chinle is assigned to Petrified Forest Member; exposures poor and unit was not examined in detail; estimated thickness locally, 800-1000 ft.

MAP SYMBOLS

- Contact, dashed where approximate or inferred
- Fault, dashed where approximately located, U upthrown side, D downthrown side
- Syncline, trace of axial plane showing direction of plunge, dotted where projected beneath mapped units
- Anticline, trace of axial plane showing direction of plunge; dotted where projected beneath mapped units
- Monocline, trace of axial plane showing direction of plunge, dotted where projected beneath mapped units
- Strike and dip of beds

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1970 Field checked 1972

Projection and 10,000-foot grid ticks: New Mexico coordinate system, west zone (transverse Mercator)
1000-metre Universal Transverse Mercator grid ticks, zone 12, shown in blue 1927 North American datum

Fine red dashed lines indicate selected fence lines

UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1 24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

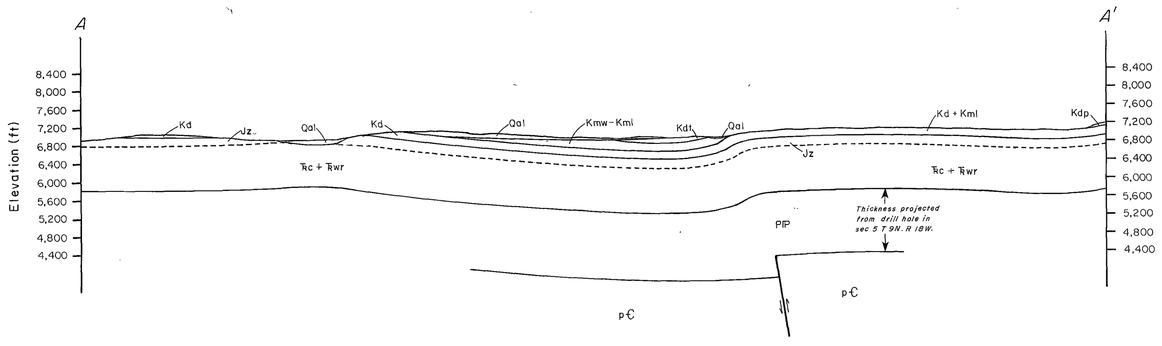
ROAD CLASSIFICATION

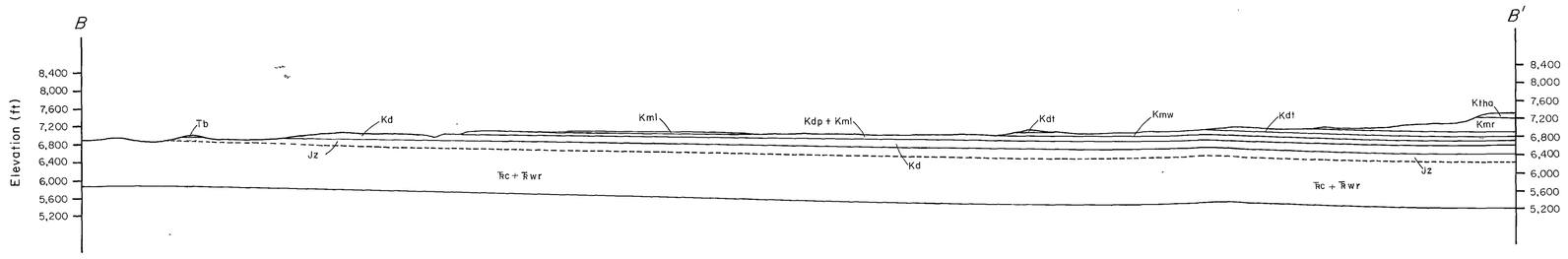
Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Unimproved road
Interstate Route U S Route State Route

QUADRANGLE LOCATION

MESITA DE YESO, N. MEX.

Plate 1





GEOLOGY AND COAL RESOURCES OF MESITA DE YESO QUADRANGLE, CIBOLA COUNTY, NEW MEXICO

NEW MEXICO BUREAU OF MINES
AND MINERAL RESOURCES

OPEN-FILE REPORT 171 BY ORIN J. ANDERSON

1982