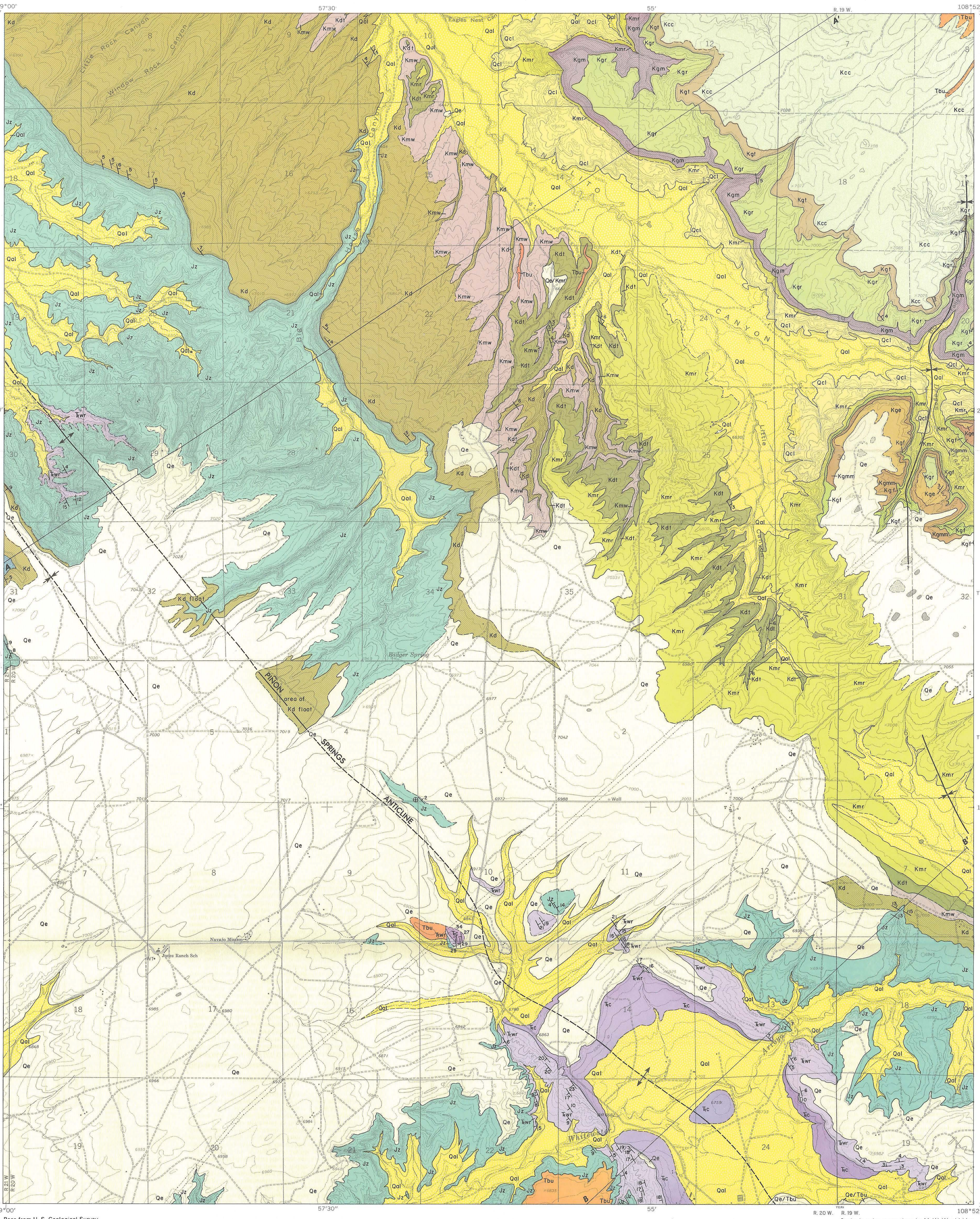
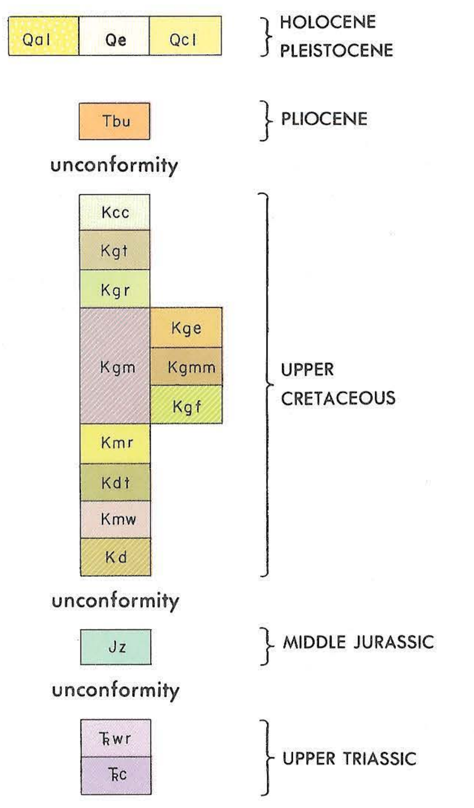


Base from U. S. Geological Survey
Geology by O. J. Anderson , 1985

Scale 1:24,000

Geologic color separations by M. W. Wooldridge
Layout by M. W. Wooldridge and J. B. Moody
Edited by J. C. Love

CORRELATION OF UNITS



DESCRIPTION OF UNITS

Qal **Alluvial deposits (Quaternary)**—sand, silt, and clay in the major drainages, their tributaries, and floodplains

Qe **Mostly eolian deposits (Quaternary)**—very fine grained windblown sand as sheet deposits on upland surfaces; no recognizable dune forms

Qcl **Colluvium and landslide debris (Quaternary)**—commonly covers slopes developed on Mancos Shale; includes toreva blocks

Tbu **Upper member of Bidahochi Formation (Pliocene)**—consists of moderately reddish brown to light-brown, largely unconsolidated to very friable, argillaceous sandstone; some mudstone, silty mudstone, and numerous pedogenic carbonate beds

Kcc **Crevasse Canyon Formation (Upper Cretaceous, Coniacian)**—an interbedded sequence of mudstone, shale, very fine to medium-grained crossbedded sandstone, carbonaceous shale, and minor lenticular coal beds; nonmarine; 0–300 ft thick but not all exposed

Kgt **Torrivio Member of Gallup Sandstone (Upper Cretaceous, Coniacian?)**—distinctive, medium- to coarse-grained feldspathic sandstone, commonly reddish brown with pronounced crossbedding; paleoflow directions to north, northeast, and east; considered to be a braided-stream deposit; base is sharp; 30–45 ft thick

Kgr **Ramah unit of Gallup Sandstone (Turonian)**—variable sequence of mudstone, fluvial-channel sandstone, carbonaceous mudstone, and minor coal; one coaly zone reaches 4.0 ft in thickness but is not persistent; unit overlies uppermost marine Gallup; 95–130 ft thick

Kgm **Gallup Sandstone, main part, undivided (Upper Cretaceous, Turonian)**—very pale orange and grayish-orange, very fine to fine-grained quartzose sandstone; generally in coarsening-upward sequences, each up to 40 ft thick; marine shoreface and tidal channel; divided into upper and lower parts by a variable sequence up to 90 ft thick that contains mudstone and thin coal beds and represents lower coastal-plain deposition; upper and lower sandstones mapped as E sandstone and F sandstone (see below) in east-central part; total thickness up to 220 ft

Kge **E sandstone member of Gallup Sandstone (Turonian)**—very pale orange and grayish-orange, very fine to fine-grained quartzose sandstone; generally in coarsening-upward sequences, one of which is 40 ft thick; flat bedding at base and crossbedding in middle and upper portions; burrows, including *Ophiomorpha*, are common; bioturbated zones; fining-upward sequences with opposed crossbed sets and clay drapes indicate tidal influence; a 20–25-ft-thick paludal shale separates two sandstone units; *Inoceramus dimidius*, found locally in upper part, indicates a Juana Lopez age; up to 85 ft thick

Kgmm **Middle part of main Gallup Sandstone (Turonian)**—gray mudstone and shale with minor carbonaceous mudstone and coal representing deposition on the lower coastal plain in a backswamp environment; contains a 3-ft-thick coal bed in south-central part of quadrangle; up to 90 ft thick

Kgf **F sandstone member of Gallup Sandstone (Turonian)**—very pale orange, grayish-orange, and yellowish-gray, very fine to fine-grained quartzose sandstone; consists of two coarsening-upward units, each ranging from 12 to 20 ft thick and separated by 10–18 ft of mudstone, carbonaceous mudstone, and high-ash coals; basal sand unit generally has gradational base through an 8-ft-thick zone of intercalated fine-grained sandstone and mudstone (transition-zone sediments); both sandstone units contain numerous burrows, including *Ophiomorpha*, and are locally bioturbated in lower part; basal part of upper sand unit is transgressive on coal-bearing paludal mudstones; 50–55 ft thick

Kmr **Rio Salado Tongue of Mancos Shale (Cenomanian and Turonian)**—gray to brownish-gray shale and arenaceous shale; base generally sharp on top of Twowells Tongue; 40 ft above base, platy limestone beds of Bridge Creek Limestone Member of Greenhorn Formation may be recognized locally (S1/2 sec. 25, T13N, R20W); 100 ft below top, thin, yellowish-gray, fossiliferous (shark teeth, small bivalves, and *Crassostrea*) sandstone beds equivalent to basal Tres Hermanos Formation were recognized in NE1/4SE1/4 sec. 19, T13N, R19W; the portion of *Kmr* above the sandstone beds is 37–40 ft thick and contains dark-brown to reddish-brown limestone concretions; total thickness 350–400 ft

Kdt **Twowells Tongue of Dakota Sandstone (Cenomanian)**—tan and very pale orange, lower very fine grained to lower medium-grained quartzose sandstone; bioturbated and burrowed, including *Ophiomorpha* and *Thalassinoides*; ripple laminations preserved locally in middle and lower parts; flat-bedded base; planar and trough-type crossbedding present in upper part; represents single progradational event; 35 ft thick maximum

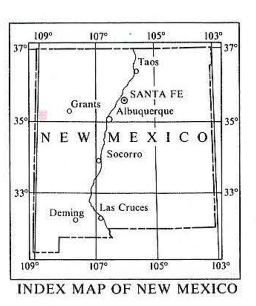
Kmw **Whitewater Arroyo Tongue of Mancos Shale (Cenomanian)**—gray to olive-gray silty shale; the oyster *Exogyra trigeri* is present, though not in abundance; base of unit is sharp; 40–50 ft thick

Kd **Main body of Dakota Sandstone (Upper Cretaceous, Cenomanian)**—grayish-orange and very pale orange, fine- to coarse-grained sandstone, conglomeratic sandstone, mudstone, carbonaceous mudstone, and coaly carbonaceous mudstone; basal sandstone rests unconformably on Jurassic rocks and contains a quartzite- and chert-pebble conglomerate in lower 4 ft; basal sandstone is of fluvial origin and reaches 35 ft thick maximum; the overlying mudstone and carbonaceous unit is of paludal origin and ranges up to 55 ft thick with the greater thicknesses coming at the expense of underlying sandstone; the upper part consists of an interbedded sequence of arenaceous shale and fine- to very fine grained quartzose sandstone containing smooth-walled, small-diameter burrows with affinities to *Skolithos* and *Thalassinoides*; at the top, a 12-ft-thick, coarsening-upward sandstone, containing the oyster *Exogyra levis* and the gastropod *Turritella* sp., may be the equivalent of the Paguate Tongue; total thickness of upper part is 30 ft; overall thickness for main body Dakota is 110–120 ft

Jz **Zuni Sandstone (Middle Jurassic)**—very fine to medium-grained, white to pinkish-gray, quartzose eolian sandstone characterized by thick sets of planar and planar–tangential, high-angle crossbeds; crossbed-dip direction variable, but southeast is most common; upper part equivalent to Cow Springs Sandstone; total thickness locally up to 500 ft; both upper and lower contacts unconformable

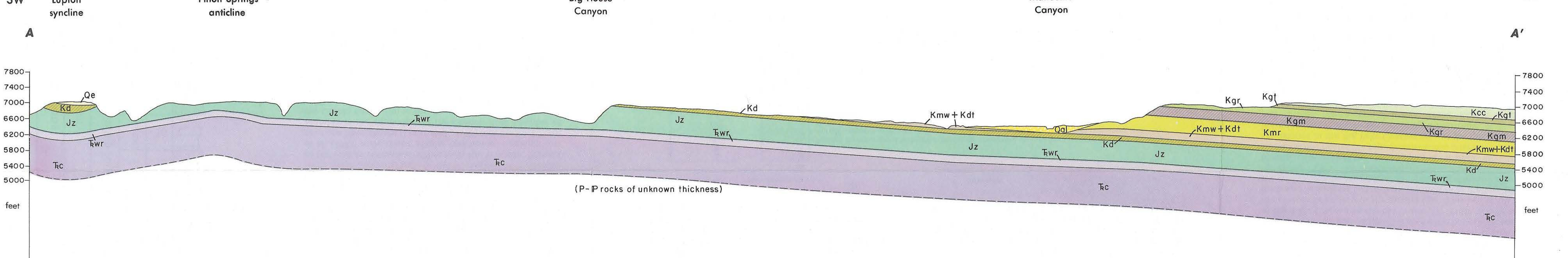
Ꞧwr **Rock Point Member of Wingate Sandstone (Upper Triassic)**—moderately reddish brown, interlayered, fine-grained sandstone, sandy siltstone, and silty mudstone; flaggy to slabby bedded; ripple marks trend north to N10°E; mud cracks common in fine-grained beds; conformable on Chinle Formation; total thickness 122 ft

Ꞧc **Chinle Formation, undivided (Upper Triassic)**—dusky- to grayish-red and purple mudstone and shale with minor, thin siltstone and sandstone beds; base not exposed; thickness (from subsurface data) 800 ft

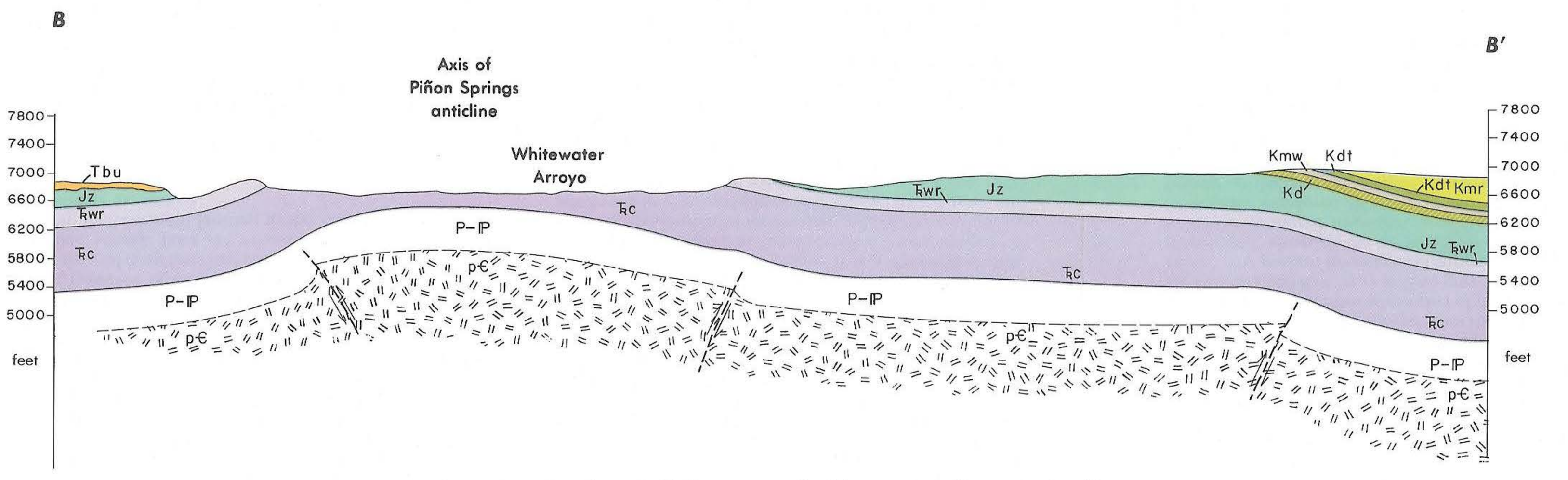


INDEX MAP OF NEW MEXICO

APPROXIMATE MEAN DECLINATION, 1980



Structure Section *A-A'*, showing northernmost extent of Piñon Springs anticline



Structure Section *B-B'* (basement faulting not well constrained)

Geology and mineral resources of Jones Ranch School quadrangle, McKinley County, New Mexico

by Orin J. Anderson, 1989

Abstract

Jones Ranch School 71/2-min quadrangle lies in the northwestern part of the Zuni Basin in west-central New Mexico. The northwest-trending Piñon Springs anticline crosses the quadrangle diagonally, creating as much as 1200 ft of structural relief and interrupting the rather uniform and gentle northeastward dips of the Paleozoic and Mesozoic rock sequence. Triassic and Jurassic rocks are exposed along the anticline and in several of the deeper canyons, but Upper Cretaceous rocks are present exclusively in the northeast and northern part of the quadrangle. Recent eolian sand covers the upland surface at 7000 ft in the southwest part.

The Upper Cretaceous rocks range from the Dakota Sandstone (Cenomanian) through the lower part of the Crevasse Canyon Formation (Coniacian). Because of their coal potential, the Cretaceous rocks are of the greatest interest. Coaly horizons were found in the Dakota Sandstone, the Gallup Sandstone, and the basal part of the Crevasse Canyon Formation. At only one locality was a coal bed thickness in the resource category (14 inches or more) recorded, and thus no coal resource estimates were made for the quadrangle.

A late Tertiary basin-fill unit, the Bidahochi Formation (Pliocene), occurs in this part of the Zuni Basin but is very restricted in this quadrangle. It is thin, commonly veneered with eolian sand, and restricted to several small patches in the southeast part where the breached Piñon Springs anticline makes a bend.

Mineral resources in the quadrangle are somewhat meager. Aside from the small coal resource—based on one observation—in the northeast part, some small potential for building stone exists in the Rock Point Member of the Wingate Sandstone.

INTRODUCTION

The Jones Ranch School 71/2-min quadrangle lies southwest of Gallup in the western part of the Zuni Basin. This area is included in the Navajo Section of the Colorado Plateau physiographic province by Fenneman (1931). The Navajo Section is characterized as being "mainly a country of sandstone with lesser amounts of shale. As the beds are generally not quite horizontal and have been subject to great erosion in an arid climate, the mesa, cuesta, rock terrace, canyon and dry wash are the distinctive features of the landscape." This description applies quite well to the Jones Ranch School quadrangle with the only addition being that sand-covered, undissected surfaces can stretch for miles locally, creating the impression of a broad flat area.

Access to the quadrangle is provided by NM–32 southward from Gallup for 15 mi, then west via the all-weather Jones Ranch School Road (no. 7046) for 7 mi (Fig. 1). No cities exist within the quadrangle, but the Jones Ranch Day School is operated by the Bureau of Indian Affairs. Numerous small ranches and single-family dwellings are scattered throughout the area, but the highest concentration is along Manuelito Canyon and in the Chichiltah Valley in the southeast part of the quadrangle. Dry-land farming has been attempted on the sand flats in the southwest part but has met with very limited success because annual precipitation is generally less than 13 inches.

Relief is moderate, the maximum being 500 ft in the west-central part of the quadrangle. Elevations range from a low of 6360 ft in the northwest, where a tributary of the Puerco River crosses the quadrangle boundary, to a high of 7068 ft in the west-central part of the quadrangle.

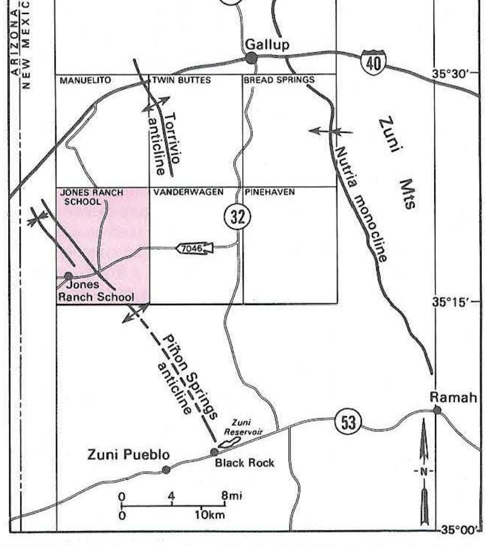


FIGURE 1—Index map of north half of Zuni Basin showing location of Jones Ranch School quadrangle, surrounding quadrangles, and major geologic and geographic features.

The drainage divide between Whitewater Arroyo and Manuelito Canyon, both tributaries of the Puerco, provides a smooth upland surface, which is followed by the Jones Ranch School Road. Whitewater Arroyo is a "Wyoming-type" drainage in that it flows across a structure (the Piñon Springs anticline), while Manuelito Canyon follows structure and in its lower reaches becomes a strike valley. Both of these drainages and the Big House Canyon provide excellent exposures of Upper Jurassic and Cretaceous rocks.

Previous work in the area includes that of Darton (1910), who described the Zuni Basin in the course of a regional study, Sears (1925), who studied and reported on the Cretaceous stratigraphy and coal resources of the Gallup–Zuni Basin, and Shomaker et al. (1971), who included the Gallup–Zuni Basin in a regional evaluation of strippable coal resources. Most recently, Molenaar (1983) and Hook et al. (1983) described in detail the Cretaceous stratigraphy of the Zuni Basin and added greatly to our knowledge of the intertongued marine–nonmarine sequence.

ACKNOWLEDGMENTS—This geologic mapping project is the result of encouragement from Frank Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources, to extend investigations of Cretaceous rocks and associated coal resources northwestward from the Pinehaven area to the Manuelito area. The New Mexico Bureau of Mines and Mineral Resources provided the support for the field work. Special thanks go to William A. Cobban of the U.S. Geological Survey for his help in fossil identification and for helpful suggestions, to Donald L. Wolberg and Spencer G. Lucas for reviewing and improving the text, to Richard M. Chamberlin for reviewing the map and cross sections, and to Lynne McNeil, who typed the manuscript. Special thanks go to Mr. John Taylor, Superintendent of the Chichiltah and Jones Ranch BIA schools for permitting the New Mexico Bureau of Mines and Mineral Resources to park a living-quarters trailer on the school grounds for the duration of the field work in 1985.

STRUCTURE

The Piñon Springs anticline trends N40°W across the Jones Ranch School quadrangle and is the major structure. Dips on the southwest flank tend to be steeper, ranging up to 29°; however, a maximum dip of 21° was recorded on the northeast flank in the SE1/4 sec. 11, T12N, R20W. The structure is subparallel to the Nutria monocline, which lies 18 mi to the east and trends slightly more northerly.

text continued on back

A reverse "S" curve or a kink is very evident in the axis of the Piñon Springs anticline at the southeast corner of the quadrangle, and it is this portion of the structure that is breached by Whitewater Arroyo. This sinuous trace of the axial plane is a feature that the Piñon Springs anticline has in common with other northwest-trending folds in the Zuni Basin, for instance the Atarque and Galestina monoclines (Anderson, 1987). However, these narrow, sharply flexed folds are more appropriately termed monoclines and thus differ vastly in cross section from the Piñon Springs anticline. Moreover, the anticline is flanked on the southwest by a syncline as it exits the quadrangle to the northwest. The syncline, here termed the Lupton syncline, can be traced across the adjacent Lupton quadrangle and into the Surrender Canyon quadrangle near the southern end of the Defiance monocline.

Structural relief on the anticline is estimated at 1200 ft from cross sections. The cross sections also show the presence of a double bend in the northeast flank of the anticline, at least in the southeast corner of the map. This double bend adds to the structural relief because it extends the flank of the anticline northeastward in the direction of regional dip; including this feature, the structural relief on the northeast flank may approach 1700 ft. The anticline affords the only exposures of the Chinle Formation in the quadrangle.

The nature of the controlling basement faults is not well constrained. The cross section B–B′ illustrates two opposed, or outward-facing, high-angle reverse faults followed by another to account for the double bend in the northeast flank; however, other interpretations may be equally acceptable. Several deep tests that penetrate the basement or some detailed seismic lines are necessary to understand completely the basement faulting in the Zuni Basin and along the Nutria monocline.

STRATIGRAPHY

The composite stratigraphic column (Fig. 2) illustrates the Triassic through Tertiary units exposed in the quadrangle. It is based on measured sections made at 10 localities and on one petroleum test drilled in the south-central part of the quadrangle. Emphasis was on the Gallup Sandstone and the overlying coal-bearing Crevasse Canyon Formation, but thicknesses were established for all units except the Zuni Sandstone, for which only an estimate is given.

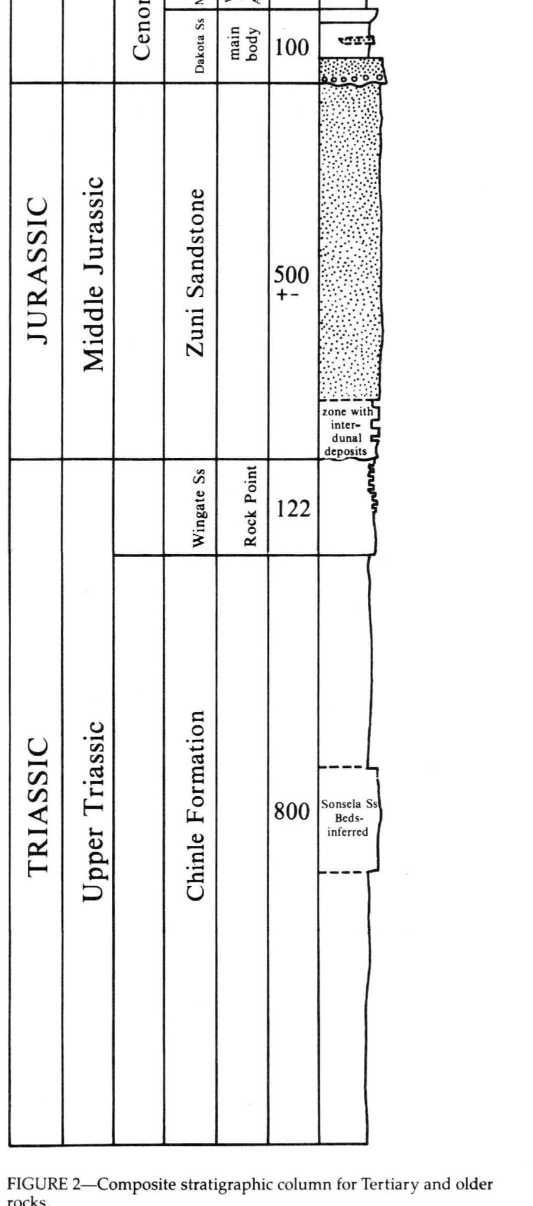


FIGURE 2—Composite stratigraphic column for Tertiary and older rocks.

Triassic rocks

The Triassic System is represented by the Chinle Formation (Ŧc), the oldest rocks exposed in the quadrangle, and the overlying Rock Point Member of the Wingate Sandstone (Ŧwr; both Upper Triassic). The petroleum test in the NW1/4NE1/4 sec. 16, T12N, R20W (drilled by Seco–Yates, 1981) penetrated 800 ft of Chinle Formation. The test continued down through Paleozoic rocks for another 2300 ft and encountered Precambrian basement at a depth of 3540 ft. Chinle Formation exposures in secs. 13, 14, 23, and 24, T12N, R20W reveal that the upper part consists of dusky- to grayish-red and purple mudstone and shale with very minor amounts of siltstone and fine-grained sandstone. A low-energy environment of deposition is indicated, probably an extensive floodplain dotted with small lakes in a very low gradient, westward-flowing fluvial system. Cooley and Davidson (1963) briefly discussed this Late Triassic depositional system and suggested that the bulk of the sediments were derived from the Uncompahgre highlands to the north and northeast. However, they also showed the southwestern limit of sandstone beds within the upper part of the Chinle to be just east of the Jones Ranch School quadrangle, a conclusion that is consistent with my observations of Chinle lithologies. The extensive floodplain environment described above was associated with the axial stream and not with the somewhat higher-gradient tributaries coming off the bordering highlands—the Uncompahgre to the north and a lesser source area, the Mogollon, to the south.

The Rock Point Member of the Wingate Sandstone (*Ŧwr;*) conformably overlies the Chinle. It is a flat-bedded unit, sometimes referred to as "board-bedded," consisting of 122 ft of reddish-brown to moderately reddish brown intercalated very fine grained silty sandstone, sandy siltstone, and silty mudstone. Ripple marks in the thicker, sandier units are symmetrical and trend north to N10°E (center sec. 25, T12N, R20W). A ripple index of approximately 4 (wavelength of 2.5 inches) suggests that they are wave ripples (Reineck and Singh, 1980). This is consistent with an interpretation by Harshbarger et al. (1957) that the eastern margin of a lagoon, Rock Point Lagoon, trending approximately N20°E, extended across this area. No fossils were found in the member; however, some bedding planes exhibit burrowlike forms. Most of the unit is slightly calcareous.

Some of the thicker sandstone beds contain low-angle crossbeds and, in contrast with the rest of the unit, may be pinkish gray on a fresh exposure. Mud cracks filled with sandy mudstone are common in the finer-grained horizons, indicating a depositional environment that was periodically subaerially exposed.

Flagstone, building stone, or patio stone could be quarried from the flaggy- to slabby-bedded sandstone units, but the market would be extremely limited. Many residential and commercial structures in Zuni Pueblo 12 mi to the south were built with Rock Point Sandstone slabs. Modern construction, however, tends to avoid these high-weight–high-density materials.

No major depositional break exists between the Chinle and the Rock Point Member, and the contact is placed at the base of the first significant sandstone bed, which is generally marked by a color change. Rock Point lithologies are not significantly different from those encountered in the lower portions of the Chinle Formation, and thus it would seem more logical to include the Rock Point as a member of the Chinle Formation rather than the Wingate. Stewart et al. (1972) arrived at a similar conclusion. Regional correlations have shown (Lucas et al., 1985) that the Rock Point Member is the equivalent of the Church Rock Member of the Chinle Formation in southeast Utah.

The upper contact of the Rock Point Member is somewhat more difficult to identify because some bleaching of the upper part of the Rock Point has produced colors similar to those of the overlying Zuni Sandstone. However, the Zuni has higher-angle crossbeds in thicker sets, is more massively bedded, and tends to be more friable than the Rock Point.

Jurassic rocks

The Zuni Sandstone (*Jz*; Middle Jurassic) unconformably overlies the Rock Point Member with little evidence of a depositional break; however, regional stratigraphic relationships indicate that all of the Lower Jurassic and some of the Middle Jurassic are missing here. The Zuni consists of a white to pinkish-gray, very fine to fine-grained, crossbedded quartzose sandstone sequence up to 500 ft thick. This massive section of sandstone, characterized by thick sets of high-angle crossbeds that dip to the east–southeast, south, and southwest, is interpreted to be of eolian origin. Locally, at the base the lithology is a bit more varied with several beds of reddish-brown, sandy mudstone up to 20 ft thick interbedded with the white sandstone. These red interbeds may be seen near the east quarter corner of sec. 30, T13N, R20W. They are interpreted to be interdunal deposits and do not represent intertonguing with the underlying older Rock Point Member.

The Zuni Sandstone, as mapped here, is probably the undivided equivalent of the Entrada Sandstone and the overlying Cow Springs Sandstone of Harshbarger et al. (1957). The area of this report lies just beyond the southern margin of the Todilto Basin, and thus no Todilto Limestone break is present to divide the sand lithosome into a lower (Entrada) and an upper (Cow Springs) part. Locally, a notch (Anderson, 1983) is developed near the middle of the Zuni Sandstone and is well exposed near Zuni Pueblo, but in this quadrangle no persistent, easily recognizable break or notch occurs. Just to the northwest in the Lupton quadrangle, Condon and Huffman (1984) recognize an eolian tongue of the Recapture Member of the Morrison Formation at the top of the Zuni Sandstone, but this unit is not recognized within the Jones Ranch School quadrangle.

Upper Cretaceous rocks

Dakota–Mancos sequence

The Dakota Sandstone (*Kd*; Cenomanian) forms the base of the Upper Cretaceous sequence in the Zuni Basin. Very good exposures of the Dakota exist along the top of the southwest-facing escarpment in secs. 21, 17, and 18, T13N, R20W. Here the typical sequence, in ascending order, is: (1) a basal 15–35-ft-thick upper fine- to medium-grained, crossbedded sandstone with a chert- and quartzite-pebble conglomerate at the base; crossbed-dip directions run from due north to east–southeast; relief on the basal surface reaches a maximum of 20 ft; (2) 40–55 ft of interbedded fluvial-channel sandstone and paludal mudstone and shale; the mudstone has carbonaceous zones; and (3) as much as 30 ft of thin- and flat-bedded, fine-grained sandstone with a thin mudstone or coaly, carbonaceous mudstone near the base and a sandy shale near the top. The base is sharp and shows some flaser bedding and clay drapes, trough crossbedding, and burrowing. This suggests tidal influence, perhaps deposition in a tidal basin or on tidal flats. Ripple marks in this upper unit commonly trend north to N30°E. At the very top are several very thin beds (0.5 ft) that contain abundant shells of the oyster *Exogyra levis* and some *Turritella* and other unidentified gastropods. The stratum containing the *E. levis* is probably the age and lithogenetic equivalent of the Paguate Tongue of the Dakota in the Atarque area. See Hook et al. (1980) for description of Paguate Tongue.

Also characteristic of the upper part of the Dakota, the portion considered to be marine or marginal marine, are small-diameter, smooth-walled burrows in the thin-bedded sandstone intervals. These trace fossils were identified as *Skolithos* and perhaps *Thalassinoides*, ichnofossils that exhibit a tolerance for a broad range of substrate and salinity conditions (Ekdale et al., 1984).

This tripartite Dakota—a basal, cliff-forming, fluvial sandstone unit, a middle mudstone and thin fluvial-channel sandstone unit, and an upper, thinly bedded marine and marginal-marine sandstone—is very typical of the western San Juan Basin, the Zuni Basin, and the Acoma Basin. Lateral variations are the rule, however, and locally, a 60-ft-thick sandstone may be found within the Dakota, and in this and adjacent quadrangles, the basal portion of the Dakota may be a coaly carbonaceous mudstone.

In the northwest and north-central part of the quadrangle, small patches of the overlying Whitewater Arroyo Tongue of the Mancos Shale (*Kmw*) are preserved on the dip slope of the Dakota Sandstone. The broad alluvial-valley floor of Manuelito Canyon is developed on and largely covers the Whitewater Arroyo shale in this area, but excellent outcrops may be found just west of the canyon in sec. 23, T13N, R20W.

Owen (1966) named the Whitewater Arroyo Tongue from exposures along the west side of Whitewater Arroyo water gap in the adjacent Vanderwagen quadrangle. He described it as 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." He measured 80 ft of "gray to olive gray silty, oyster bearing shale." The present investigation supports most of Owen's description, although the oyster *Exogyra trigeri* occurs only as widely scattered fragments, and thicknesses as low as 39 ft were measured (NW1/4SE1/4 sec. 26, T13N, R20W). Maximum thickness in the quadrangle was estimated to be 50 ft in the W1/2 sec. 26, T13N, R20W. Thin, orange-weathering bentonite beds are common in the middle part of the unit.

The Whitewater Arroyo Tongue represents deposition in a deeper-water, open-marine environment, out beyond the transition zone, in a transgressive sequence. But the transgression was interrupted near the end of Cenomanian time by the deposition of a shelf sandstone—the Twowells Tongue of the Dakota Sandstone (*Kdt*).

The Twowells overlies the Whitewater Arroyo Tongue with a base gradational from silty shale to silty fine-grained sandstone through a 10-ft interval. Above this are 30–35 ft of generally flat-bedded, coarsening-upward quartzose sandstone. Primary bedding features have been destroyed by bioturbation in the lower third to half of the unit; however, some planar and trough crossbedding with south and southeast dip directions is preserved in the upper beds of lower medium-grained sandstone. Also, in the upper beds are numerous burrows, including *Ophiomorpha*. Ripple-laminated beds may be found locally in the lower and middle parts of the unit; these and the relatively coarse grain size as well as the burrows indicate a shallow-water shelf environment. During this depositional event, sand was distributed as far as 50 mi seaward from this locality to near Grants, with no significant regression of the shoreline

Overlying the Twowells Tongue is a 350–400-ft-thick, gray marine shale that is slightly calcareous in the lower half. The sharp basal contact suggests a rapid return to deep-water, open-marine conditions following deposition of the Twowells Sandstone. The sudden transgression apparently was triggered by a eustatic rise in sea level and represents a major and final pulse during the Greenhorn cycle of sedimentation. The name Rio Salado Tongue of the Mancos Shale (*Kmr*; Hook et al., 1983) is used for this shale tongue even though here the upper boundary is formed by the Gallup Sandstone, not the Tres Hermanos Formation as is the case in the type area. This, however, is just a matter of nomenclature change related to the pinchout of the Pescado Tongue of the Mancos Shale and is not the result of an abrupt lithostratigraphic change that materially affects the upper boundary of the Rio Salado Tongue.

In the SE1/4 sec. 36, T13N, R20W and in adjacent sec. 1, T12N, R20W, a fossiliferous bed containing the oyster *Pycnodonte newberryi* is present approximately 20 ft above the Twowells Tongue of the Dakota. Also present are forms transitional between *P. newberryi* and the older *P. kellumi*, but these are in the minority. Approximately 15 ft above this oyster bed, for a total of 40 ft above the Twowells Tongue, calcareous beds equivalent to the Bridge Creek Limestone Member of the Greenhorn Formation are present. Near the middle of the S1/2 sec. 25, T13N, R20W tabular pieces of platy limestone up to 4 inches thick weather out of the Greenhorn beds, and some of the pieces were found to contain *Mytiloides mytiloides*. Cobban (1984) noted that this species occurs abundantly in the ammonite zone *Mammites nodosoides* of latest early Turonian age; *Mytiloides mytiloides* is considered to be a guide fossil to the Upper Cretaceous Turonian rocks in New Mexico. Other inoceramid debris is present in the Bridge Creek beds locally but is too fragmented to permit identification. The significance of the limestone beds is that they represent deposition during or immediately following the time of maximum transgression of the Greenhorn cycle of sedimentation, which has been established as an early Turonian event (Hook and Cobban, 1977). The northwest-trending shoreline passed through central Arizona into the southwestern corner of Utah (Cobban and Hook, 1984), and, as a result, the Zuni Basin area was as much as 130 mi offshore during this transgressive maximum.

Exposures of the Rio Salado Tongue are limited because it is a slope-forming unit; however, approximately 80–100 ft above the Bridge Creek Limestone beds, the calcareous aspect of the shale is lost, and the upper part becomes a darker-gray noncalcareous sequence. The thin, fossiliferous sandstone beds within the upper 100 ft of this noncalcareous shale, which were referred to as the Tres Hermanos beds (Anderson, 1988) in the adjacent Vanderwagen quadrangle, are not well exposed and were not mapped. One such outcrop containing the thin fossiliferous sandstone beds was found in the NE1/4SE1/4 sec. 19, T13N, R19W (Fig. 3). In addition, the light-colored slopes across the central part of sec. 31, T13N, R19W are covered by float derived from these sandstone beds. These sandstone beds have yielded specimens of *Collignoniceras woollgari* 1.5 mi to the east in the Vanderwagen quadrangle (Anderson, 1988). *C. woollgari* is indicative of a middle Turonian age (Hook et al., 1983).

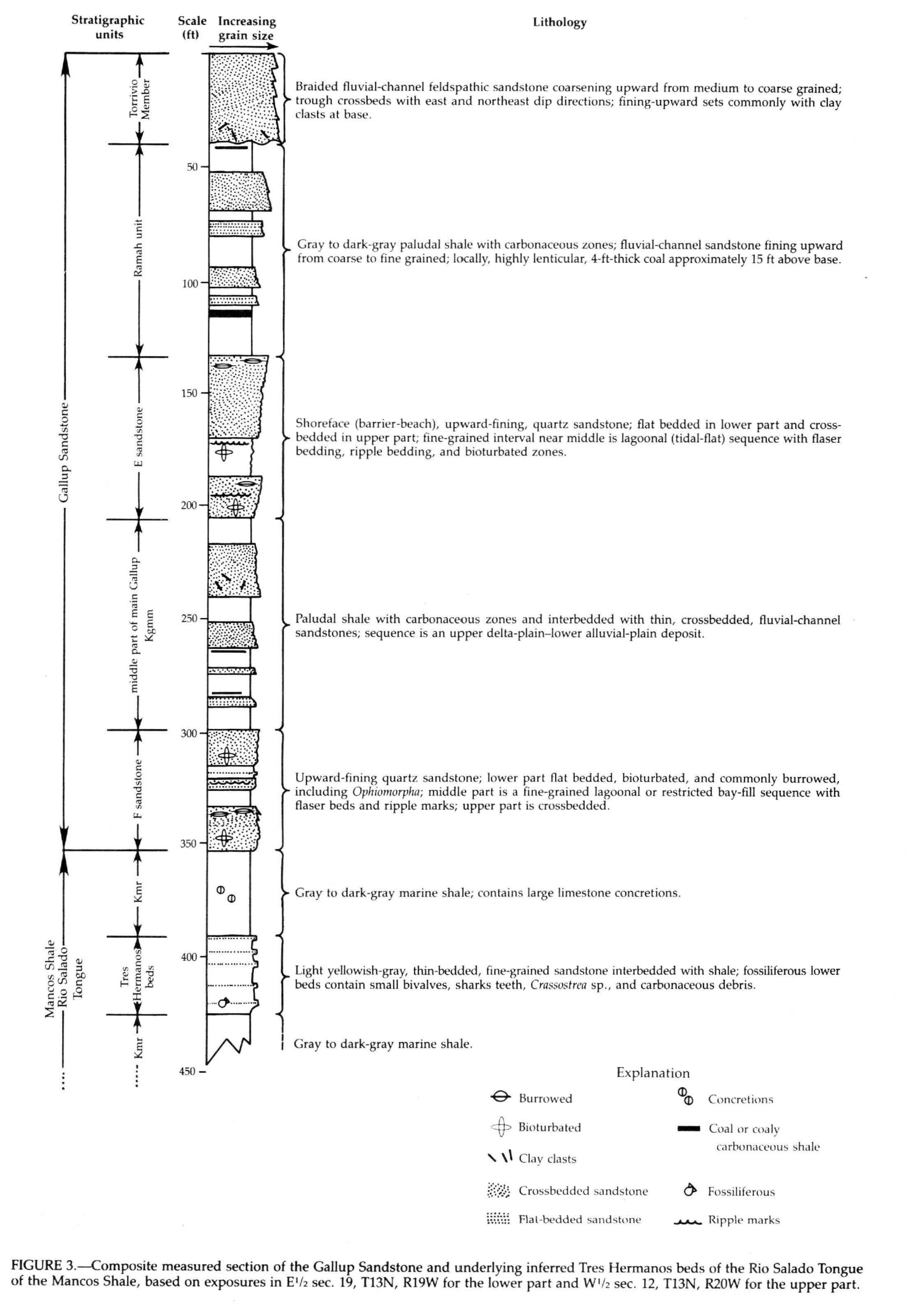


FIGURE 3.—Composite measured section of the Gallup Sandstone and underlying inferred Tres Hermanos beds of the Rio Salado Tongue of the Mancos Shale, based on exposures in E1/2 sec. 19, T13N, R19W for the lower part and W1/2 sec. 12, T13N, R20W for the upper part.

Gallup–Crevasse Canyon Formations

Overlying the Rio Salado Tongue of the Mancos Shale is the Gallup Sandstone. The Gallup consists of as much as 220 ft of marine and marginal-marine sandstone, siltstone, mudstone, and shale (*Kgm*), overlain by a nonmarine section as thick as 180 ft, which includes the reddish-brown, coarse-grained, feldspathic Torrivio Member at the top. The lower, mostly marine, 220-ft section (*Kgm*) is an alternating sequence of shoreface, tidal-channel, or distributary-channel sandstones interbedded with lagoonal, bay-fill, or coastal-swamp (paludal) mudstone, siltstone, and shale. Some of the fine-grained intervals have coaly zones (Fig. 3), but no coal resource exists (beds 14 inches) in this part of the Gallup.

The entire 220-ft section represents deposition and accumulation along a segment of the coast that was subject to minor oscillations of the shoreline; some of the sandstones in the lower part are "doublets" that may have regressive and transgressive components. The sandstones are burrowed, including *Ophiomorpha*, and commonly have bioturbated zones at their bases. Ripple marks in the sandstones trend between N20°W and N65°W; within the finer-grained sequences, such as the flaser-bedded lagoonal–tidal-flat sequences, more variation can be found in the trend of ripple marks. This greater variation in trend and the shorter wavelength of the ripples reflect the oval–elongate configuration and the shallow water, respectively, of the lagoon. In contrast, more uniform-trending ripple marks are found in the shoreface–barrier-beach environment. These sequences are the age equivalent of the upper part of the Tres Hermanos Formation and the Pescado Tongue of the Mancos Shale in the Pescado Creek area (Anderson, 1988).

In a very small portion of the quadrangle, specifically secs. 29 and 30, T13N, R19W, the basal 220 ft of marine-dominated sediments (*Kgm*) are divided into three parts, as they were in the adjacent Vanderwagen quadrangle (Anderson, 1988). These three divisions are: (1) a basal 50–55-ft-thick marine sandstone called the F sandstone (*Kgf*); (2) a medial paludal and fluvial unit as much as 90 ft thick, with several carbonaceous and coaly intervals (*Kgmm*); and (3) an upper marine, tidally influenced sandstone called the E sandstone (*Kge*). Commonly in two parts and a bold cliff former, it ranges up to 85 ft thick and contains *Inoceramus dimidius*, which indicates a Juana Lopez age. The F sandstone and E sandstone terminology is after Molenaar (1983), who used letter designations F through A to designate marine (shoreface) sandstone units built up during minor reversals of the strandline in an overall regressive sequence. In the remainder of the quadrangle, these three divisions are not so easily seen, and the lower or main Gallup is mapped as an undivided unit (*Kgm*).

Overlying this prominent cliff-forming marine Gallup is a nonmarine, slope-forming unit ranging from 95 to 130 ft thick, which was referred to informally as the Ramah unit (*Kgr*) by Anderson and Stricker (1984). This is the coal-bearing part of the Gallup, and it represents deposition in a lower alluvial-plain environment following the withdrawal of the Gallup seaway. The coal, however, is highly lenticular. A coal bed occurs 15 ft above the base of the unit in Big Falls Canyon in the SW1/4 sec. 17, T13N, R19W on the eastern boundary of the quadrangle. This bed is 4.0 ft thick and includes a 1-inch-thick tonstein near the top, but the coal cannot be traced laterally. This bed does not show up in outcrops to the northwest in secs. 12 and 13, where multiple fluvial-channel sandstones 5–15 ft thick, with the thicker sands nearer the top, dominate this interval. Fluvial sandstones in the Big Falls Canyon area at the quadrangle boundary are even thicker, reaching a maximum of 30 ft, and contain coarse-grained lenses. These Ramah sandstones resemble lithologies in the overlying Torrivio Member (*Kgt*); however, they do not become as coarse grained, nor do they develop the deep reddish-brown oxidized colors characteristic of the Torrivio. A 10–15-ft-thick, slightly carbonaceous, locally coaly mudstone forms the uppermost part and may have served as an aquatard or aquafuge restricting the downward movement of the oxidizing waters in the Torrivio.

The base of the overlying Torrivio is sharp and, at most localities, is a slightly scoured surface developed on carbonaceous mudstone (Fig. 3). The Torrivio is highly crossbedded, medium to coarse grained, and feldspathic, with grain size ranging to 4 mm or more. The crossbedding is of the trough and planar type (the thinner sets are planar) with the dominant dip directions to the east and northeast, with north subdominant. Clay galls and wood fragments or impressions are common at the base of fining-upward depositional packets. Thickness ranges up to 45 ft, and excellent outcrops may be found in secs. 17 and 20, T13N, R19W and in sec. 12, T13N, R20W in the northeast corner of the quadrangle. For a discussion of the tectonic implications of the Torrivio, see Anderson (1988) or Hayes (1970). Stratigraphically and lithogenetically, the Torrivio is unrelated to the main (marine) Gallup Sandstone in the Zuni Basin. The Torrivio represents only a distinctive fluvial unit within the nonmarine Crevasse Canyon Formation, and the informal Ramah unit is merely a lower tongue of the Crevasse Canyon. In the hogback area just east of Gallup, where Sears (1925) originally named the Gallup Sandstone, the Torrivio Member rests stratigraphically much closer to the main body of the Gallup, and thus a formation name for the entire sequence seemed logical there. It does not appear equally logical towards the center of the basin.

Named by Allen and Balk (1954) for exposures in the Tohatchi quadrangle 25 mi to the north of the Jones Ranch School quadrangle, the Crevasse Canyon Formation (*Kcc*) overlies the Torrivio Member of the Gallup Sandstone. The Crevasse Canyon is predominantly a nonmarine unit (entirely nonmarine in the Zuni Basin) composed of shale, mudstone, lenticular fluvial-channel sandstones, carbonaceous mudstone, and minor coal. The distribution, morphology, and grain size of the sandstone bodies and the fact that they are encased in the fine-grained sediments of the flood basin or backswamp suggest an abrupt return to a meandering fluvial system following deposition of the Torrivio braid plain.

Dips are gently northeastward 3°–4°, and, as a result, the unit has been eroded from all but the very northeastern corner of the quadrangle. It thickens from a feather edge in secs. 13 and 18 to perhaps as much as 300 ft in the subsurface at the extreme northeast corner. The cross section A–A′ shows these structural and stratigraphic details.

Large sandstone concretions commonly weather out of the fluvial-sand units; the concretions generally have a darker color than the encasing sandstone and show some hematitic oxidation. Anderson (1988) stated that in the Vanderwagen quadrangle the bases of the sandstone units are generally not scoured surfaces, an observation that may suggest rather high rates of sedimentation. The only good exposures of the unit are in the SW1/4 sec. 17, T13N, R19W, and no significant coal beds are present in the basal 150 ft of the section exposed here.

Tertiary

An upper Tertiary sedimentary unit unconformably overlying the Crevasse Canyon Formation is preserved only on the higher surfaces in the central part of the Zuni Basin but becomes much more widespread westward into Arizona. Named the Bidahochi Formation (*Tbu*) for exposures near the village of the same name by Reagan (1924), it was subsequently subdivided into three members by Repenning and Irwin (1954). The three members were designated: (1) the lower member, dominated by mudstone and sandstone with some lacustrine facies; (2) the volcanic member composed of basalt and basaltic lapilli tuff ranging from 2 to 50 ft in thickness; and (3) the fluvially dominated upper member, approximately 270 ft thick. The Zuni Basin occurrences have been assigned to the upper member by most authors, including Repenning et al. (1958).

The Bidahochi Formation remnants in the Jones Ranch School quadrangle consist of moderately reddish brown to light-brown argillaceous sandstone with numerous beds of nodular pedogenic carbonate. The color, texture, and lithology of the sandstone suggest that the major sources of these sediments were the Permian and Triassic rocks of the Zuni uplift 18 mi to the east with lesser amounts provided by the Jurassic and Cretaceous section. Reworked Cretaceous molluscs can be found locally in the Bidahochi (Anderson, 1988). The only good exposure of the Bidahochi in the Jones Ranch School quadrangle is in the SW1/4SW1/4 sec. 10, T12N, R20W. Elsewhere it is covered with modern windblown sand.

MINERAL RESOURCES

The mineral-resource potential of this quadrangle is extremely limited given the relatively simple geologic history of the area. It is an area dominated by Mesozoic clastic rocks with no complex structure, no local or regional metamorphism of the supracrustal rocks, and no mineralization in the classical sense. The following categories of mineral resources are discussed because they are either present in very limited quantities (coal) or a limited possibility for their presence exists (petroleum and natural gas).

Coal

Coal resources for this quadrangle can be considered nil. Less than 50% of the quadrangle is underlain by Cretaceous rocks, and most of that is due to the presence of the Dakota Sandstone, which has very low coal potential in this area. Only approximately 6% of the quadrangle is underlain by Cretaceous rocks of moderately good coal potential, and coal was found in only one outcrop, a 4-ft-thick bed in the Gallup Sandstone on the eastern boundary of the quadrangle. No coal resources were calculated based on this one exposure.

Petroleum and natural gas

No oil or gas show was reported in the 1981 test well drilled in the NW1/4NE1/4 sec. 16, T12N, R20W (a state-owned section). No drill-stem tests were run. The well was reported to have penetrated 30 ft of unnamed Pennsylvanian strata before going into basement rock (New Mexico Bureau of Mines and Mineral Resources petroleum library).

Building stone

Flaggy to slabby sandstone beds in the Rock Point Member of the Wingate Sandstone have been used locally for building stone. Numerous structures in Zuni Pueblo 12 mi to the south also were built with this sandstone. Any future market appears to be unlikely, but it may find application as patio or landscaping stone.

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