# GEOLOGY AND COAL RESOURCES OF THE ATARQUE LAKE QUADRANGLE, CIBOLA COUNTY, NEW MEXICO

NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

OPEN-FILE REPORT 167

by

ORIN J. ANDERSON

June, 1982
(revised, 1983)

Contents: (1) Discussion of Geology and Coal Resources (attached)

(2) Geologic map with cross sesction (accompanying)

Table of Contents

# GEOLOGY

## General

The Atarque Lake quadrangle lies in the southwestern part of the Zuni Basin, a broad, shallow structural element that extends southwestward from the Zuni Mountains of New Mexico into east-central Arizona. As such it lies near the southeastern margin of the Colorado Plateau. The regional dip in the study area is very gently northeastward toward the Gallup Sag which comprises the northeastern part of the Basin. There are, however, broad, gentle NW-SE trending folds which result in local southwestward dips, and at least two abrupt monoclinal flexures, up on the northeast side, (opposed to regional dip) that clearly define the NW-SE structural grain of the area, as well as minor faulting.

These structural trends parallel the axis of the Zuni Uplift, but perhaps more importantly they appear to represent the southeastward extension of the structural axes that wrap around the southern end of the Defiance Uplift, as shown by Davis and Kiven (1975), and they also align very well with the northwest-trending dike system in the Fence Lake (the Dyke quadrangle), Techado, Adams Diggings, and Pietown areas.

Of the three structural features mentioned - broad folds, monoclines and faulting - monoclines are the most pronounced and significant not only locally, but in a much broader context. As Kelley (1955) stated, "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 tied to the concept of northeast-southwest horizontal compression

of the Colorado Plateau during the Laramide. As a response to the regional compression, discrete, individual basement blocks were uplifted by reverse movements 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 over 100 miles in length, have been attempted on the basis of similarity of trends, which when related to the fracture zones serve to subdivide the Precambrian basement into a mosaic of crustal blocks.

The area under consideration is underlain by (1) Cretaceous sandstone and shales that may exceed 500 ft in thickness where the Moreno Hill Formation (new name) is present, (2) highly cross bedded eolian sandstone of the Jurassic that total about 140 ft in thickness, and (3) the Triassic shales, mudstones, siltstones, and sandstones that make up the Chinle Formation, which is estimated to be 800 to 1000 ft thick in this area. A 6 ft thick flat bedded silty sandstone and sandy siltstone present at the top of the Chinle Fm crops out at one locality and is thought to represent the Rock Point Member of the Wingate Sandstone which is present as a much thicker unit both to the north and southeast.

In addition a 1400 ft section of upper Paleozoic rocks capped by the San Andres Limestone occurs in the subsurface locally as indicated by an oil test 10 miles to the north of the Atarque Lake quadrangle. (Hole is in NE 1/4 sec. 5, T 9N R 18W, drilled in 1963 by Cities Service Oil Co.; Maxwell and Nonini, 1977). This results in a cumulative sedimentary section of approximately 2900 feet overlying the Precambrian basement in

those areas where the Moreno Hill Formation is present.

Major unconformities in the section occur at the systemic boundaries - the Jurassic/Triassic, and the Cretaceous/Jurassic. The Upper Jurassic Zuni Sanndstone is an eolian and partly fluvial unit deposited unconformably on the Rock Point Member of the Wingate Formation. The overlying Dakota Sandstone forms the basal Cretaceous rocks which consist of the nonmarine, marginal marine, and marine sandstones and shales that were deposited in front of and immediately behind the shoreline of the advancing Western Interior Seaway. In this area the Dakota rests unconformably on the Zuni Sandstone, but southward it rests on progressively older rocks; in the Zuni Salt Lake area the Dakota rests on the Chinle Formation.

Scattered remnants of the Upper Tertiary Bidahochi Formation area present throughout the area from the north side of Carrizo Creek on the south to Pinehaven on the north. It represents an apron of alluvial material deposited along a northwest trending fluvial axis in the upper reaches of the ancestral Little Colorado River drainage basin. In the Atarque Lake area the formation consists of sandstones and coarse conglomerate composed largely of volcanic material derived for the most part from the Datil, Mangas, and Gallo Mountains south and east of Quemado, as well as some reworking of older coarse grained fluvial deposits on the Zuni Plateau and Santa Rita Mesa. North of the village of Zuni and in the Pinehaven area the presence of granitic debris in the Formation indicates a source area in the granite cored Zuni Mountains (Repenning, et. al., 1958).

## Study Area

### Structure

The narrow, linear zone of deformation that trends northwestward through the southwestern corner of the Atarque Lake quadrangle can be traced for a distance of about 15 miles and is the most prominent and significant local structural feature. It has been interpreted as a fault by various investigators (see Sears, 1925, p. 23) and is shown as a fault on the Geologic Map of New Mexico (Dane and Bachman, 1965), upthrown on the east bringing Triassic Chinle against Cretaceous rocks. The present investigation has shown, however, that there is more than 100 feet of Jurassic sandstone cropping out in a hogback sequence that dips from 14° to 46° to the southwest and defines the zone of maximum deformation; the dips decrease rapidly to the NE and SW. At the base of the hogback sequence the upper part of the Chinle Formation and the Rock Point Member of the Wingate Formation are exposed. The contact with the overlying Jurassic Zuni Sandstone is a depositional one, not a fault contact. Therefore, the structure is interpreted as an abrupt monoclinal flexure - herein named the Atarque Monocline, related to a high angle reverse fault along a northwest trending fracture pattern in the Precambrian basement (see cross section A-A' on map). In the southern and western part of sec. 10, T. 6N, R 19W, an abrupt change in strike of the monocline from N 75°W to N N 20°W takes place in a very short distance; one mile to the southeast of this strike change the monocline is buried under a basalt flow and does not appear again as a distinct feature.

The southwest-facing Atarque Monocline is opposed to the regional dip. As the upper (anticlinal) limb has been eroded off and the lower limb is concealed, the axis of the feature, as shown on the accompanying map, is arbitrarily placed at or near the base of the Zuni Sandstone. The axis of the monocline converges with a synclinal axis to the southeast. This may indicate the structure is dying out in that direction, however, the dips are not decreasing where the monocline passes under the basalt flow. McLelland, Haschke, and Robinson, (1981) have indicated extensive faulting within and south of this basalt flow on the Rincon Hondo quadrangle.

Other notable aspects of the monocline are its sinuosity and the presence of cross folds. The axes of these cross folds are more or less normal to the monoclinal axis and appear to extend across the monocline, but are much more in evidence to the west on the Venadito Camp quadrangle (Anderson, 1982a). These cross folds probably represent deformation along basement fractures of a divergent trend. In discussing the cross folding and sinuosity characteristic of the Colorado Plateau monoclines, Davis (1978) stated that the inherent nature of basement fracture zones envisioned for the Plateau, coupled with the recurring nature of movements within the system would tend to favor the phenomenon of cross folding in the vicinity of fracture zone intersections. Folds created by movement along one fracture zone may be transformed into domes, saddles, or doubly plunging folds by superposed or contemporaneous movement along a fracture zone of different strike.

In the adjacent Venadito Camp quadrangle the cross folding associated with the monocline and its associated depression on the downwarped side has produced a series of structural basins and saddles. In the Atarque Lake quadrangle the largest topographic feature produced by the cross folding is the west facing mesa in the S 1/2 sec. 5 and the SE 1/4 sec. 6, T 6N R 19W. This mesa offers the only exposures of the Rio Salado Tongue of the Mancos Shale on the quadrangle.

Mesa Colorado in the northeast corner of the quadrangle does not appear to be related to cross folding; rather it represents a part of the southwest limb of a syncline that parallels the predominant NW-SE structural grain of the area. The morphology and relief on the mesa itself is partly the result of local variation in thickness of the Zuni Sandstone. The sinuous nature of fold axes is evident in this northeast area; the axis of the syncline northeast of Mesa Colorado and the monoclinal axis to the southwest in secs. 13 and 14 are both curved, but are of divergent trend, indicating they are separate structures.

Faulting on the quadrangle is limited to the minor north-south trending normal fault at the southwest corner of the Mesa Colorado. Here the west block has moved up 30 to 40 ft relative to the east and the middle shale unit of the Dakota Sandstone has been juxtaposed against the upper marine sand unit of the east side. The sense of movement along the fault is easily confused from a distance.

In addition minor faults are likely in the highly fractured area in the E 1/2 sec 10, T 6N, R 19W where the strike of the

Atarque Monocline changes abruptly. A 3 ft thick light greenish gray bentonitic clay found at one locality just west of the road in the SE 1/4 SW 1/4 sec 10 presents a stratigraphic problem that is probably related to faulting. Although the clay is included in an area of Atarque Sandstone outcrops because of scale limitations it is unlikely that it belongs in the Atarque. Outcrops are poor and structural relationships remain somewhat uncertain at this locality.

## Stratigraphy

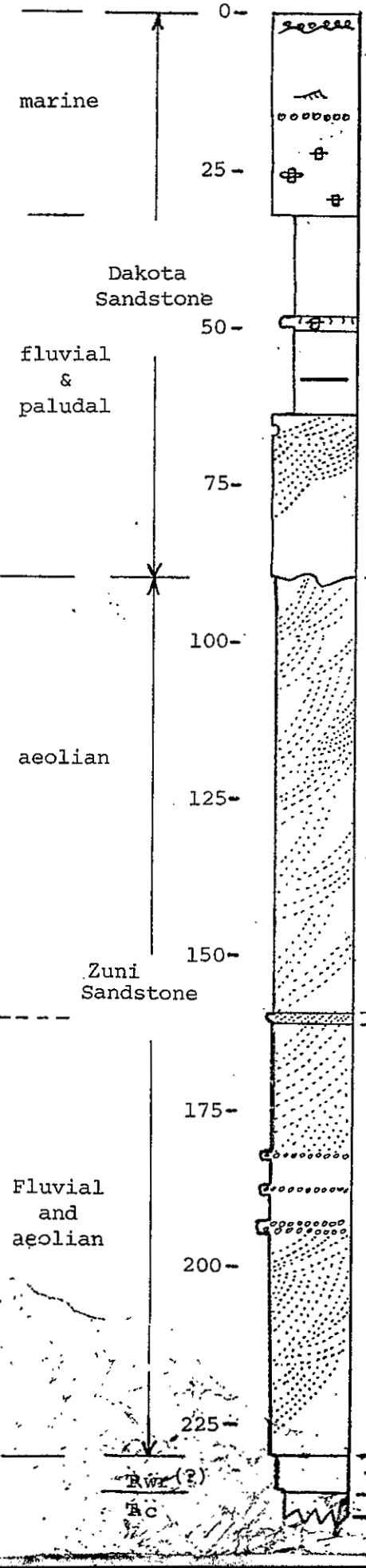
Although the Chinle Formation was mapped, this unit was not studied in detail. The upper part consists of purplish red, maroon, and gray siltstone, mudstone, claystone, and thin sandstones that are assigned to the Petrified Forest Member. Stewart, Poole, and Wilson (1972) described and measured sections of the Chinle at two nearby localities. At one locality north of St. Johns Ariz. between 34°42'N and 34°46'N, the upper part of the Petrified Forest Member is 591 feet thick within a total Chinle sequence that is 827 feet thick. At the other locality, near Zuni, New Mexico, 178 feet of Petrified Forest Member is present. The thickness of the Chinle on the Atarque Lake quadrangle was not determined in the present work, but is estimated to be 800 to 1000 ft thick, based on breadth of outcrop and inferred dips on the upper limb of the monocline, and the absence of San Andres Limestone outcrops. O'Sullivan (1977) showed the 400 m (1320 ft)isopach of the Chinle passing a few miles to the north of the Atarque area; the Chinle is thinning to the south in this area.

As previously mentioned, a 6 ft thick bed of reddish brown, flat bedded, silty sandstone is exposed at the base of the south end of Mesa Colorado in sec 18 T 7N, R18W, resting on Chinle Formation mudstones and shales with no apparent break in deposition. It is considered to be the equivalent of the Rock Point Member of the Wingate Sandstone described by Harshbarger, Repenning, and Irwin, (1957, p. 8) as a pale reddish brown silty sandstone and sandy siltstone at the type locality near Rock Point, Arizona. They further described 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 is shown extending across the New Mexico state line in the Zuni-Atarque area.

Southeastward from the Mesa Colorado exposure the Rock Point Member thickens before pinching out. An area of excellent exposures called Los Pilares at the boundary between the Mesita de Yeso and Fence Lake quadrangales is described as having nearly 30 ft of the flat bedded silty sandstone comformably overlying the Chinle and overlain by the largely eolian Zuni Sandstone (Anderson, 1982b).

The white, fine-grained, highly cross-bedded sandstone comprising the uppermost Jurassic rocks and outcropping in the monocline is considered to be the Zuni Sandstone. The Zuni Sandstone, as redefined by Anderson (1983), consists of the undivided equivalents of the Entrada and Cow Springs Sandstones. The name Cow Springs was proposed by Harshbarger et al, (1951),

Fig. 1 Measured section Zuni Sandstone and Dakota Sandstone in E½ NW¼ sec. 18, T 7N R 18W




Pale yellowish brn to pale red. brn, up fn to med. gr. ss, with thin pebble cgl. zones; burrowed & bioturb. in low. part; 10 ft thick white & purple well indurated ss in upper part overlain by erosional surface with pebble cgl.

Lt gray & lt. gray. brn, paludal shales, arenaceous shales and siltstones, and carbonaceous clay; interbedded fn sandy siltst and silty clay in lower part overlain by carbonaceous zone; 2 ft thick burrowed and root penetrated sandstone near middle.

Lt. brn to pale yell. brn up fn - low medium gr ss; trough cross bedding and channel scours; clay galls in lower part.

White to pinkish gray and grayish orange pink, lower fn gr ss; thick sets of trough and planar cross bedding; cross bed dip directions highly variable but gen. southward.

1 ft thick, med grained, planar cross bedded ss, with pitted-grooved surface; ledge former

Pinkish gray and grayish orange pink lower fn gr ss; planar and trough cross bedded except for extreme basal portion; thin conglomeratic zones in fining upward channel fill sequences in middle and lower parts.

Explanation

- burrowed
- bioturbated
- root tube
- ripple marks
- cross bedding
- carbonaceous zone

Rock Point Member, reddish brown silty ss; flat bedded.

base covered

for the greenish gray to light yellowish gray, fine grained, cross bedded sandstone that weathers to grayish white rounded cliffs. At the type section 4 miles east of Cow Springs, Arizona, it is 342 ft thick and is unconformably overlain by the Dakota Sandstone. Additional work by Harshbarger, et al (1957), extended the Cow Springs terminology into the Zuni Reservation of New Mexico and a 449 ft thick section at Black Rock was designated as Cow Springs Sandstone, unconformably overlain by the Dakota Sandstone. On the Zuni Reservation and southward it becomes difficult to distinguish the Cow Springs from the underlying Entrada Snadstone and thus the name Zuni Sandstone (first used by Dutton, 1885) has been applied to this interval by Anderson (1983). The Zuni sandstone, which commonly has a medial notch, may be traced in outcrop southward through the Plumasano Basin quadrangle to Mesa Colorado on the Atarque Lake quadrangle, although it thins considerably at two localities - sec. 35 T 9N R 19W and sec 31 T 8N R 18W. From the Lupton, Arizona area southward the contact between the Cow Springs and the underlying Entrada was reported by Harshbarger, et al (1951) as "unidentifiable." Hackman and Olson (1977) used the term Cow Springs-Entrada (Jcse) for this interval in the Zuni area.

Northwest of the study area toward Fort Defiance and Black Mesa the Summerville and the Bluff Formation are present and serve to divide the Zuni into its component parts - Entrada and Cow Springs. Northward and northeastward near Todilto Park, the upper part of the Zuni, i.e. Cow Springs, 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, et.al., 1957, p. 5Ø).

In the Atarque Lake area the "medial notch", which is thought to represent the break between the Entrada equivalent and the Cow Springs equivalent, is not as well defined as it is at Zuni Pueblo. It can, however, be identified at the north end of Mesa Colorado in the NW1/4 sec 6, T 7N R 18W, and to a lesser extent at the south end in sec 18, T 7N R 18W. At this southern location the medial break is represented by a 1 ft thick, cross bedded ledge forming sandstone, somewhat coarser grained than the adjacent units (Fig. 1).

The lower portion of the Zuni (below the medial notch or break) contains scattered conglomeratic zones at the base of thin channel fill sequences (Fig. 1). It also contains a well rounded chert and quartzite pebble conglomerate that is well exposed in the NE1/4 sec 6, T 7N R 18W. The conglomerates represent atypical facies for Entrada equivalent rocks, but fluvial facies are not unknown in the Entrada. These conglomerates are probably related to streams which originated in the Mogollon Highland and traversed this area of largely eolian sedimentation on a northward course toward the embayment or lagoon in which the medial silty member of the Entrada had been deposited (Harshbarger and others, 1957, p. 44-46).

Cretaceous rocks in the area 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 (new name), the Atarque Sandstone (new name), and the coal-bearing Moreno Hill Formation (new name). The rocks called

the main body of the Dakota Sandstone are the marine, marginal marine, and non-marine rocks tha 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 comprised of a basal cross-bedded, fluvial sandstone of varying thickness, a paludal shale sequence containing carbonaceous shale and very thin coal beds, and marginal marine and marine sandstones that form the upper 25 ft of the unit (fig. 1). Fossils collected locally in the upper marine sands include the bivalves Pycnodonte cf. P. kellumi and Exogyra levis, and Turitella sp, and various other gastropods. The Dakota is overlain by the lower part of the Mancos Shale, an 18-foot-thick arenaceous shale that is exposed only in the west-central portion of the quadrangle; elsewhere it is covered or unrecognizable. This shale tongue is probably eqivalent 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 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 (Hook, Cobban, and Landis, 1980).

Overlying this shale is the Paquate Tongue of the Dakota Sandstone; it consists of a 20-foot-thick, massive, cross-bedded, coarsening upward sandstone unit that commonly has a fossil hash zone at the top composed almost exclusively of Exogyra levis and Pynodonte cf. P. kellumi. Large brown ferruginous/calcareous

concretions may also be present in the upper part. The tongue characteristically weathers to a light tan or pale grayish orange color, but near the Atarque Monocline it may be reddish brown. Topographically, the Paguate is generally a small cliff former, but outcrops are very restricted on this quadrangle. Northward the unit merges with the main body of the Dakota, as the lower part of the Mancos pinches out. Near the village of Two Wells, 14 miles 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 (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 section 17 of T 12N, R 19W near the village of Two Wells, where it is 80 feet thick and described as a gray to olive-gray, silty, oyster-bearing shale. It does not crop out in the present study area but it consists of an estimated 55 feet of medium-to dark-gray fissile shale based on outcrops in adjacent areas, 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. Good exposures of the Whitewater Arroyo Tongue and the bentonite bed

occur on the adjacent Vennadito Camp quadrangle in the NE 1/4 sec 30, T 7N, R 19W, where it is protected by a cover of Twowells Sandstone. The bentonite bed has also been recognized 18 miles to the southwest on the Twentytwo Spring quadrangle, and 75 mi. to the east on D-Cross Mountain where it may be only 8 in. thick (Hook, Cobban and Landis 1980).

The Twowells Tongue of the Dakota Sandstone does not crop out in the study area. It also may be seen on the adjacent Venadito Camp quadrangle where it is about 30 feet thick and consists of (1) a lower very fine-grained, flat-bedded sandstone with a few burrows; (2) a middle very fine to fine-grained, intensely burrowed and bioturbated sandstone, locally quite friable; in at least one locality it has a flat-bedded, undisturbed, well-cemented, ledge-forming sandstone near the top of the bioturbated beds which in turn is overlain by a 10 ft covered interval probably composed of arenaceous shale or interbedded very fine sandstone and siltstone; (3) the upper part is an upper fine- to medium-grained, planar cross-bedded unit, generally 6 to 8 feet thick, containing clay clasts and, locally, moderate concentrations of burrows including Ophiomorpha. Both the Twowells and the Paguate Tongues are here considered to represent minor progradational events in the Dakota-Mancos transgressive sequence.

The Rio Salado Tongue of the Mancos Shale (new name) represents a return to open marine conditions or an interruption in sediment supply following deposition of the Twowells. It consists of up to 240 feet 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 Atarque Sandstone (new name).

The name Rio Salado Tongue is proposed in Hook, Molenaar, and Cobban (1983). It is defined as the shale tongue lying between the Twowells Tongue of the Dakota Sandstone and the Atarque Sandstone (the latter unit is also being defined by the same authors) and is coextensive with these two units.

The thin calcarenite and calcareous shale beds that occur 30 to 40 feet above the base of the Rio Salado in this area 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. They appear at only one locality on the map-the NE 1/4 sec 31, T 7N, R 19W. 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 Innterior Seaway. These beds form important marker horizons and also contain the guide fossil Pycnodonte newberryi (Stanton) in abundance at or just below this interval (Hook and Cobban, 1977). P. newberryi was collected in the NE 1/4 sec 31 and NW 1/4 sec 32 T 7N, R 19W and in the SW 1/4 sec 11 T 6N, R 19W. 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 feet above the Bridge Creek equivalent, limestone concretions appear in the section; examples may be found in the SE 1/4 sec 6 T 6N, R 19W. Associated with the concretions are the ammonites Mammites depressus, M. nodosoides, Proplacenticeras cummingsi, and Neoptychites cephalotus. Also found in association with the concretions are Ostrea sp., Veniella mortoni, Baculites sp., Turritella sp. and other gastropods. The interbedded shale and sandstone sequence at the top of Rio Salado Tongue can be seen at the same sec 6 locality.

The Atarque Sandstone (new name) is the redefined term proposed in Hook, Molenaar, and Cobban (1983) 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 transgression. As the shoreline had assumed a general NW-SE trend in this area the Atarque prograded northeastward into the Mancos Seaway. It is a diachronous unit that becomes younger to the northeast. Throughout 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, and coarsens upward from very fine to fine grained; and an upper cross-bedded unit, generally 15 to 20 feet thick that is lower to upper fine grained (see Fig. 2). Only the upper cross bedded unit is well exposed on the Atarque Lake quadrangle. These two units are similar to the lower and upper shoreface units of Molenaar (1973). The lower shoreface unit is thought to have been deposited offhsore beyond

the zone where wave action or longshore currents effected 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 are often present in the extreme lower and upper parts of the cross-bedded unit.

The Atarque Sandstone, present 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) 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 Sandstonne and as being separated from the Gallup by the Pescado Tongue of the Mancos Shale.

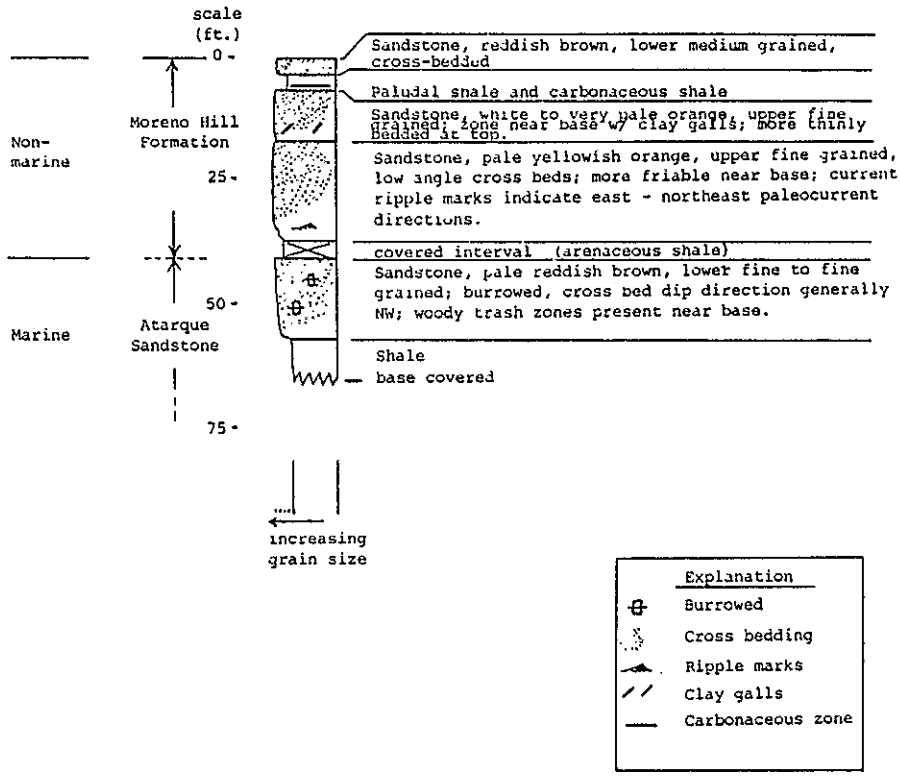
The Pescado Tongue is not present in the study area. Its southwesternmost occurrence is some 10 miles to the east on the Shoemaker Canyon Southeast quadrangle. Where present, the Pescado Tongue separates the Gallup Sandstone from the (older) redefined Tres Hermanos Formation (Hook, Molenaar, and Cobban, 1983). The base of their Tres Hermanos is the regressive marine sandstone for which they propose the name Atarque Sandstone Member of the Tres Hermanos Formation. In their regional stratigraphic framework a nomenclature change exists at the southwestward or landward pinchout of the Pescado Tongue; landward from the pinchout the Atarque is raised in rank from member to formation. Likewise the overlying nonmarine,

Figure 2

Measured section of Atarque Sandstone

and the Moreno Hill Formation near

the center of the S½ SW¼ sec 5, T 6N R 19W



carbonaceous shales, fluvial channel sanstones, and thin coals that Molenaar (1973) included in the Atarque Member of the Lower Gallup, are currently recognized as a separate stratigraphic unit that must also undergo the nomenclature change at the landward pinchout of the Pescado Tongue. The term proposed for that nonmarine section in Hook, Molenaar, and Cobban (1983) is the Carthage Member of the Tres Hermanos Formation in the area where the Pescado Tongue is present, and the Moreno Hill Formation in the area landward of the Pescado pinchout (McLelland, et. al., 1983).

The Moreno Hill Formation, as defined comprises the nonmarine carbonaceous shales, fluvial channel sandstones and minor thin coals that overlie the Atarque Sandstone and that locally represent the youngest Cretaceous rocks. The geographical area in the Zuni Basin in which these two new names (the Atarque Sandstone and Moreno Hill Formation) may be applied is roughly indicated by the area northwest of Quemado mapped as Mesaverde Group on the Geologic Map of New Mexico (Dane and Bachman, 1965).

Most of the Moreno Hill Formation has been eroded off in the Atarque Lake quadrangle. Exposures of the remaining section are limited to two areas in sec 5, T 6N, R 19W. The basal 25 ft consists of a cross bedded fluvial channel sandstone that rests on the Atarque Sandstone (see Fig. 2). An overlying paludal shale at this locality contains very thin coaly beds, 2 to 4 inches thick; this is the only coal occurrence on the quadrangle.

The light-gray and pinkish-gray fluvial sandstones and conglomerates that occur largely as isolated patches and remnants unconformably overlying the Cretaceous, Jurassic, and Triassic rocks are considered to be part of the Bidahochi Formation. 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 McCann (1938), Reiche (1941) and Hack (1942) established a correlation between the Bidahochi and the Tertiary sediments of the upper Little Colorado River drainage in the Zuni Basin. Repenning and Irwin (1954) established a reference section for the Bidahochi 15 miles east of the settlement of Bidahochi, Arizona and recognized three members, a lower largely lacustrine member, a middle volcanic member, and an upper member. The Zuni Basin deposits probably correlate with the upper member.

In the present study area the formation is locally well exposed but for the most part the topographic expression of the unit is gentle sandy slopes at places strewn with cobbles or boulders.

The coarser conglomerates in the unit are composed of cobble-and boulder-size fragments of vesicular basalts, basaltic andesites, minor rhyolite and other volcanic rock, with some quartzite and chert and are well exposed in the vicinity of the Atarque Monocline. Quartzite, chert, and jasper comprise a much larger proportion of the pebble conglomerates than they do of the coarser deposits; all have a calcareous cement. The sandstones associated with the conglomerates are white to very light gray,

medium to coarse grained, poorly sorted, rich in lithic fragments including chert, and jasper, and are generally very friable. Low angle cross bedding of highly variable directions is a common feature. The clast lithologies suggest a source area to the southeast in the Datil, Gallo, Mangas Mountains area and deposition was along a persistent northwest trending fluvial axis.

A finer grained, light brown to very light grayish brown, highly friable sandstone occurs in the north and north central parts of the quadrangle. These sandstones are not asociated with conglomerates, however, and tend to be more quartz rich than those that are. They rest on the more gentle topography developed on the Chinle Fm., but the base is nowhere well exposed. It is for the most part a fluvial deposit, but there may be aeolian facies near the top of the remaining section locally. In the SE 1/4 SW 1/4 sec. 2 T 7N R 19W a 25 ft thick white altered tuff was found resting on sandstone of the Bidahochi Fm. An x-ray analysis of the tuff at the New Mexico Bureau of Mines and Mineral Resources by Robert M. North identified feldspar and kaolinite as the principal constituents. In their discussion of the lithology and depositional features of the Upper Member of the Bidahochi Fm. Repenning et. al, (1958) stated the unit containned a few beds of white rhyolitic ash.

Another distinctive facies of the Formation is present and forms the resistant tops on the mesas in the E 1/2 sec 19 and the NE 1/4 sec 30 T7N R19W. It is a dense, calcareous sandstone, matrix and cement supported. A fresh surface is yellowish gray, but it weathers somewhat darker; thickness varies but may approach 20 ft in places; small root casts were noted at several

horizons and localities. The deposit may be related to a shallow impondment formed behind the hogback created by the truncated monocline or it may be in part pedogenic-a caliche caprock.

## COAL RESOURCES

The Atarque Lake quadrangle encompasses a small portion of the Salt Lake coal field. The field is essentially defined as that area lying for the most part south of the North Plains basalt flow and west of the continental divide, that is underlain by the Upper Cretaceous Moreno Hill Formation of McLelland, et. al, (1982) (in preparation). In effect it is delineated on the State Geologic Map (Dane and Bachman, 1965) as a Mesaverde Group outcrop area. A small portion of the field, however, lies north of the basalt flow; most of this "outlier" is on the Venadito Camp quadrangle in the triangular area bounded by the west trending flow and the northwest trending Atarque Monocline but a very small portion extends eastward for a few miles across the southwest corner of the Atarque Lake quadrangle.

The coal resources on the quadrangle are limited to the Moreno Hill Fm. outcrops in this southwest corner and are essentially nil. At the outcrop in the SE 1/4 NE 1/4 sec 5, T 6N R 19W several 4 inch thick coaly beds are present in a shale and carbonaceous shale section resting on the fluvial sandstones. The coal bearing sequence as noted and described on the adjacent Venadito Camp quadrangle (Anderson, 1982a) is higher in the section and has been eroded off here.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ATARQUE LAKE QUADRANGLE
NEW MEXICO—CIBOLA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)


Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1971. 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

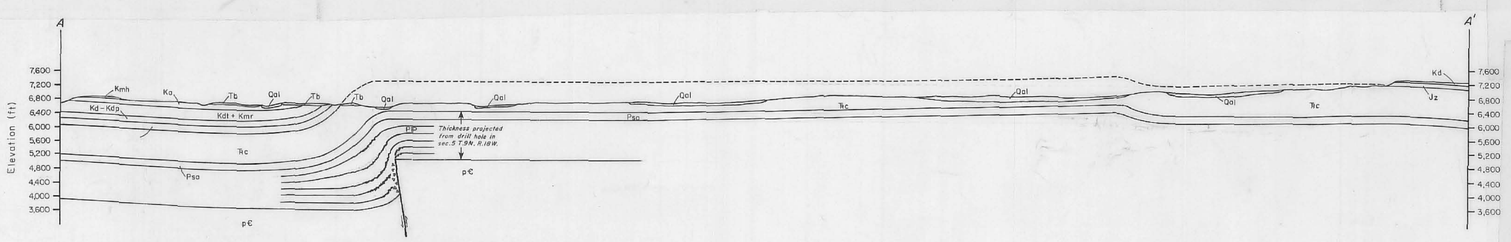
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

ROAD CLASSIFICATION
Primary highway, hard surface — Light-duty road, hard or improved surface
Secondary highway, hard surface — Unimproved road
Interstate Route · U.S. Route · State Route

QUADRANGLE LOCATION

ATARQUE LAKE, N. MEX.




## DESCRIPTION OF MAP UNITS

**Qal** Alluvial deposits undifferentiated; clay, silt, sand, and gravel in arroyos, through flowing stream beds, and on the gentle to moderate slopes formed on non-resistant strata.

**Qb** Basalt flows; originating from centers to the east in the North Plains Lava beds; olivine tholeite in composition with a K-Ar age of 1.41 m.y. (Laughlin, Brookins, Damon, and Shafiqullah, 1979); locally up to 80' thick.

**Tb** Bidahochi Formation (Pliocene); very light gray to pinkish gray and yellowish gray, fine to coarse grained poorly sorted sandstones, with sufficient red, brown, gray, and black lithic fragments to influence the gross coloration. Degree of cementation is highly variable ranging from the well indurated, dense, calcareous sandstone forming the flat top of the mesas in sections 19 and 30 T 7N R 19W at the western edge of the map, to the very friable, poorly sorted sandstone in the SE 1/4 section 9 and in section 10 T 7N R 19W. An altered tuff, strikingly white in color, forms the top of the bluff immediately north of Chalk Windmill in section 2, T 7N R 19W; the tuff overlies a yellowish gray to pinkish gray, poorly sorted friable sandstone. Additional isolated knobs capped with white tuff are present to the north on the Plumasano Basin quadrangle.

**Kmh** Moreno Hill Formation (Upper Cretaceous); fluvial channel and/or distributary channel sandstones, paludal shale and mudstone, and carbonaceous shale with minor coaly beds; the basal part of the formation consists of a 25 ft thick, upper fine grained, white to pale yellowish orange, fluvial sandstone that rests on a 3 ft thick covered (shaly) interval which forms a bench on the reddish brown, marine Atarque Sandstone; the sequence is well exposed in the SW 1/4 sec 5, T 6N, R 19W; the lower 14 ft of the fluvial sandstone shows strong low to high angle cross bedding, some opposed cross bedding, and current ripples oriented from S 5° E to S 60° E indicating northeast paleocurrent directions; the upper 11 ft of sandstone is a white, well indurated with siliceous cement, well sorted, thin to massive bedded, low angle cross bedded, cliff former with clay clasts in the lower part; overlying is a 4 ft thick paludal carbonaceous shale interval containing thin - 2 to 4 inch - coaly beds with good exposures in the SE 1/4 NE 1/4 sec 5 T 6N, R 19W in addition to the SW 1/4 sec 5; sequence is capped by a 2 ft thick pale reddish brown medium grained, cross bedded fluvial channel sandstone; thickness of incomplete section at B.M. 6870 in SW 1/4 sec 5 is about 34 ft.

**Ka** Atarque Sandstone (Upper Cretaceous); sandstone, pale yellowish orange to light brown and pale reddish brown, very fine to upper fine grained; lower part, not well exposed, is very fine grained, flat bedded with interbeds of shale; base is picked at the lowest, 2 ft thick sandstone in the interbedded zone that marks the transition from the underlying Rio Salado Tongue to the Atarque Sandstone. A medial arenaceous shale unit 8 - 12 ft thick is characteristic (not well exposed here) overlain by 16 ft of lower to upper fine grained trough cross bedded sandstone; these lower and upper sandstone units may correspond to the lower and upper shoreface sequence characteristic of regressive coastal barrier sandstones. Burrows, including Ophiomorpha, are present at the base of the upper sandstone, along with wood and plant casts. Best exposures are in sections 5 and 6, T 6N R 19W where the upper sandstone undergoes a color change becoming more reddish to the east; additional outcrops are found to the southeast in sections 9 and 10. As defined, unit is 35 ft thick locally, but appears much thicker where fluvial or distributary channel sandstones of the Moreno Hill Formation rest directly on the coastal barrier sandstones of the Atarque. (see accompanying measured sections)

**Kmr** Rio Salado Tongue of Manco Shale (Upper Cretaceous); medium to dark gray and light olive gray marine shale, silty shale, calcareous shale, and thin sandstones; weather to gentle or moderately steep slopes which are generally covered with colluvium, talus, and landslide debris; base is nowhere well exposed, nor are the calcarenites and nodular limestone beds that are the equivalent of the Bridge Creek Limestone Member of the Greenhorn Formation and are well exposed on the adjacent Venadito Camp and Mesita de Yeso quadrangles (Anderson, 1982). The upper 125 - 140 ft contains numerous limestone concretion zones with thinly interbedded shale and sandstone at the top of the sequence; associated with the concretion zones are the ammonites Mammites depressus, Mammites nodosoides, Proplacenticeras cuminsi, Neoptychites cephalotus, and Baculites sp; also found in the concretion zones were Veniella mortoni, Ostrea sp., various bivalves, Turitella and other gastropods. Thickness of formation estimated at 225 -240 ft.

**(Kdt)** Twowells Tongue of Dakota Sandstone (Upper Cretaceous); unit does not crop out within this quadrangle but exposures occur within .3 mi of the west boundary of the quadrangle in the S 1/2 sec. 30, T 7N R 19W; it is generally a yellowish gray to dusky yellow sandstone, very fine at base to upper fine and lower medium grained at top, commonly wavy bedded, cross bedded, and fossiliferous in upper part; unit generally about 30 ft thick.

**(Kmw)** Whitewater Arroyo Tongue of Mancos Shale (Upper Cretaceous); unit does not crop out within this quadrangle but exposures occur within .3 mi of the west boundary of the quadrangle in the S 1/2 sec. 30, T 7N R 19W; it is a dark gray, fissile, marine shale, with a characteristic white to orange weathering 15 inch thick bentonite bed about 22 - 25 ft below the top; the relatively large oyster Exogyra trigeri is common near the bentonite bed; estimated thickness of unit is 55 ft.

**Kdp** Paguate Tongue of Dakota Sandstone (Upper Cretaceous); locally a pale reddish brown to light brown, thin to massively bedded, fractured sandstone; coloration and fracturing are associated with the northwest trending monoclinal flexure zone (elsewhere the unit is characteristically yellowish gray to grayish orange and intact); coarsens upward from very fine grained at base to upper fine in the upper half, with a sharp break near the middle of unit; upper part is flat to low angle cross bedded in medium to thick sets, with very thin interbeds of shale and/or mudstone; internal scouring, sinuous crested and linguoid or cuspate ripple markings, and other sedimentary structures common; burrows scattered throughout unit but more common in upper half; sparsely fossiliferous, mainly Exogyra levis, in upper 6 ft.; exposures limited to western boundary of quadrangle in SE 1/4 SE 1/4 sec. 30, T 7N R 19W; thickness of unit about 20 ft.

**(Kml)** Lower Part of Mancos Shale (Upper Cretaceous); not shown because of map scale; is exposed at one locality - in the arroyo flanked by Kdp outcrops in the SE 1/4 SE 1/4 sec 30 T 7N R 19W; unit is a gray to medium dark gray, marine arenaceous shale; estimated thickness 18 ft.

**Kd** Dakota Sandstone, main body (Upper Cretaceous); the marine, marginal marine, and non-marine rocks that make up the lowest part of the Cretaceous sequence in west-central New Mexico (Hook, Cobban, and Landis, 1980); consists of 3 members, in ascending order; (1) a basal pale yellowish brown, lower medium grained, trough cross bedded fluvial channel sandstone complex, locally conglomeratic, that rests uncomformably on an erosional surface cut in the underlying Zuni Sandstone (Jz); thickness generally about 25 ft. but pinches and swells locally; (2) a 30 ft thick medium gray to light brownish gray paludal shale, mudstone, and carbonaceous clay unit; and (3) a light brown to grayish orange upper fine to lower medium grained, shallow marine sandstone; base is thinly bedded, burrowed, and locally bioturbated; upper part more massive, with very thin pebble conglomerates at two horizons, one at the base of a shallow channel fill sequence and the other at the very top; upper sand about 32 ft thick. Total thickness of formation at measured section on Mesa Colorado in the center E 1/2 sec 18 T 7N R 18W is 87 ft. Other good exposures of lower part of unit are found in the monoclinal flexure in the center sec 32, T 7N R 19W and in the N 1/2 SE 1/4 sec 10, T 6N R 19W, as well as elsewhere along the flexure.

**Jz** Zuni Sandstone, of Anderson,(1983),(Upper Jurassic); sandstone, white to pinkish gray and grayish orange pink, generally lower fine grained but with lower very fine grained, medium grained, and conglomeratic zones; thick sets of high angle trough and planar cross bedding are prevalent, especially in upper half, and indicate an aeolian orgin; a medial 1 ft thick planar cross bedded medium grained sandstone with a pitted and grooved surface forms a resistant stratum 70 ft below the top and divides the formation into upper and lower units of approximately equal thickness, particularly well displayed at south end of Mesa Colorado in sec. 18; the lower unit, although lithologically similar, has some low angle cross bedding in somewhat thinner sets, and also scattered conglomeratic zones commonly at the base of fining upward channel fill sequences, indicating a fluvial origin in part; locally the basal 20 ft ranges from a reddish orange fine grained sandstone, to a chert and quartzite pebble conglomerate (NE 1/4 sec. 6, T.7N R.18W); formation rests on a surface of moderate relief cut in the Triassic units and thickness varies from 90 ft in the NE 1/4 sec 6, T 7N R 18W, to 141 ft at the measured section on the south end of Mesa Colorado in center of N 1/2 sec 18; weathers to steep, white slopes or cliffs that contrast sharply with the overlying light brown and grayish orange Dakota.

**(Rwr)** Rock Point Member of Wingate Sandstone (Upper Triassic); pale to moderate reddish brown, flat bedded, sandy siltstone and silty sandstone; a mixture of coarse silt and lower very fine grained sand with a carbonate cement; at measured section on south end of Mesa Colorado in center of N 1/2 sec 18 T 7N R 18W, a 6 ft thick exposure rests conformably of the shale and mudstones of the Chinle Formation; it thins to 2 ft thick several hundred ft. to the west; not mapped because of scale limitations.

**Rc** Chinle Formation undifferentiated (Upper Triassic); maroon, purple, reddish brown, and green mottled clayey siltstone, mudstone, shale, and red and gray cross bedded fluvial channel sandstones, and minor conglomerate; with the exception of the sandstone it is generally a non-resistant, structureless sequence with limited outcrops; sandstones with low to moderate northeast dips are exposed in secs. 13, 14, and 24 of T 7N R 19W, where they are light gray and reddish brown, medium grained and cross bedded; white sandstone in two beds each 10 to 12 ft thick, separated by a 32 ft thick maroon and purple shale and mudstone, crops out in sec. 8, T 7N R 19W with good exposures 1/4 mi. northeast of Franciscan Windmill; at this locality there is also a greenish gray bentonitic clay exposed above the upper sandstone; in the arroyo south of Franciscan Windmill in NW 1/4 sec. 17, mounds of resistant, buff colored, calcareous siltstone and very fine grained sandstone account for irregular topography; mapped unit locally includes the overlying Rock Point Member of Wingate Sandstone.

( ) indicate unit is not mapped or is present in subsurface only

## MAP SYMBOLS

- Contact – dashed where approximate or inferred
- U / D — 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; dashed where existence uncertain, 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

# GEOLOGY AND COAL RESOURCES OF THE ATARQUE LAKE QUADRANGLE, CIBOLA COUNTY, NEW MEXICO


NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES
OPEN-FILE REPORT 167



BY ORIN J. ANDERSON



1982