GEOLOGY AND COAL RESOURCES OF THE VENADITO CAMP QUADRANGLE, CIBOLA COUNTY, NEW MEXICO

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by

ORIN J. ANDERSON

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

(2) Geologic map with cross sections, stratigraphic column, and references (accompanying)

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GEOLOGY

General

The Venadito Camp 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 also northwest-trending high-angle faults and at least one abrupt monoclinal flexure up on the northeast side (opposed to regional dip) that clearly define the NW-SE structural grain of the area.

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 area.

Of the three structural features mentioned - broad folds, high-angle faults, and monoclines - 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 600 ft in thickness where the Moreno Hill Formation (new name) is present, (2) Jurassic sandstones that total about 150 ft in thickness, and (3) the Triassic shales, mudstones, siltstones, and sandstones that comprise the Chinle Formation, which is estimated to be 800 ft thick in this area.

In addition about 1400 ft of upper Paleozoic rocks occur in the subsurface locally as indicated by an oil test 12 miles to the northeast of the Venadito Camp quadrangle. (Hole is in NE¼ sec. 5, T 9N R 18W, drilled in 1963 by Cities Service Oil Co.) This results in a cumulative sedimentary section of more than 2900 feet above 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 Cow Springs Sandstone is a fluvial and eolian unit deposited unconformably on the Chinle Formation. The Dakota Sandstone forms the basal Cretaceous rocks in the area 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 Cow Springs 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 Late Tertiary Bidahochi Formation are present throughout the area from the north side of Carrizo Creek on the south to Pinehaven on the north. It represents an apron of fluvial deposits in the upper reaches of the Little Colorado River drainage basin. 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 southeast of Quemado, as well as some reworking of older fluvial deposits locally referred to as the Fence Lake Formation, McLelland, et. al., 1982 (in preparation).

Study Area

Structure

The narrow, linear zone of deformation that trends northwestward through the northeast quadrant of the Venadito Camp quadrangle can be traced for a distance of about 15 miles and is the most prominent and significant structural feature locally. It has been interpreted as a fault by various investigators 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 150 feet of Jurassic sandstone cropping out in a hogback sequence that dips from 28° to 45° 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 crops out which here consists of a soft maroon claystone or clay-shale; the contact with the overlying Jurassic Cow Springs Sandstone appears to be a depositional one, not a fault contact. Therefore the structure is interpreted as an abrupt monoclinal flexure, probably related to a high angle or high angle reverse fault along a northwest trending fracture pattern in the Precambrian basement. At one locality, however, (SW¼ sec. 13, T 7N R 20W) slickensides were found on wastage blocks at the foot of the hogback. These are interpreted as bedding plane slippages within the Cow Springs and probably mark a zone of intense folding. No such features were found elsewhere along the hogback.

The southwest-facing 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 the base of the Cow Springs Sandstone. A synclinal axis that parallels the monocline on the downwarped side is present about one mile to the southwest. This may represent an earlier episode of movement of the basement block in an opposite sense (and of lesser magnitude) from that which produced the monocline. In the truest sense the overall structure represents a highly assymetric syncline (see cross-section A-A').

Other noteworthy aspects of the monoclinal flexure zone are its sinuosity and the presence of a series of cross folds. The axes of these cross folds are more or less normal to the monoclinal axis and at least one (the southernmost) appears to extend across the monocline. This southernmost one is itself a monocline, but is a much less abrupt flexure than the major northwest trending one (see map). 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 Venadito Camp quadrangle the cross folding associated with the monocline and its associated depression on the downwarped side has produced a series of basins, saddles, etc. that determine the outcrop pattern of the Cretaceous sandstones. Cross section D-D' on the accompanying map shows one of these basins formed by a cross fold; these localized basins should not be regarded as representative of the amount of downwarping adjacent to the northwest trending monocline.

Another structural feature worthy of note is an apparent high in the west-central portion of the quadrangle. Here the main body of the Dakota Sandstone crops out along a structural trend that is subparallel to the synclinal axis along the monocline. This structural high diverted to the west the Pleistocene stream valley, whose course was followed by the prominent basalt flow that originates to the east in the North Plains lava field. A stratigraphic problem arises in this area regarding the relationship of the Paguate Tongue to the main body of the Dakota; as the main body appears in the stratigraphic position where the Paguate is expected in the S½, SE¼ section 18 and no unequivocal Paguate can be found in outcrop, a local, abrupt down flexure may be present forming part of the north limb of the anticlinal structure shown on the map in section 19. Alternatively, the Paguate could be thinning locally.

Stratigraphy

Although the Chinle Formation outcrop pattern is shown on the accompanying map, this unit was not studied in detail. It consists of purplish red, maroon, and gray siltstone, mudstone, claystone, and thin sandstone comprising 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. John, 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 in the Venadito Camp quadrangle was not determined in the present work, but is believed to be about 800 ft.

The white, fine-grained, planar cross-bedded sandstone comprising the uppermost Jurassic rocks and forming part of the monocline hogback sequence is considered to be the Cow Springs Sandstone of Harshbarger, et. al. (1951). Northward and northwestward toward Fort Defiance and Black Mesa this unit grades laterally into the Summerville Formation and overlies the Entrada Sandstone. Northward and northeastward near Todilto Park it 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. 50). From the Zuni-Black Rock area southward the contact between the Cow Springs and the Entrada is unidentifiable and Hackman and Olson (1977) used the term Cow Springs-Entrada (Jcse) for this interval in the Zuni area. In the Venadito Camp area the lower half of the interval is a pale orange to reddish brown (see map legend), and a first reaction is to assume this lower reddish facies is an equivalent of the Entrada Sandstone. Closer inspection, however, reveals that for the most part it is coarser grained than the typical Entrada and that it probably represents a tongue of fluvial sediments that extends southward from the Morrison Formation and/or is related to streams which originated in the Mogollon Highland and traversed this area on a northward course toward the area of Morrison deposition (Harshbarger, et. al., 1957, p. 51).

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 (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 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 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 which form the uppermost 20-25 feet of the unit. Fossils collected in the upper marine sands include the bivalves Pycnodonte kellumi and Exogyra levis, and Turritella sp. and various other gastropods. The Dakota is overlain by the lower part of the Mancos Shale, an 18- to 20-foot-thick arenaceous shale that is well exposed only in the east-central portion of the quadrangle; elsewhere it is covered or unrecognizable. This shale tongue is probably equivalent to the Clay Mesa Tongue which has a type section designated in the Laguna, New Mexico area (as does most of the intertongued Dakota-Mancos sequence) (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 the shale is the Paguate Tongue of the Dakota Sandstone; it consists of a 20- to 25-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 Pycnodonte cf. P. kellumi. Large brown ferruginous/calcareous concretions may also be present in the upper part and these are particularly well developed in section 31, T 7N R 20W. The tongue characteristically weathers to a light tan or pale grayish orange color, but near the monocline zone hogback it may be reddish brown; topographically it is generally a small cliff former, but outcrops are very restricted on this quadrangle, the best ones being those along the drainage paralleling the south edge of the basalt flow. The unit may be thinning in a northwesterly direction, as mentioned earlier, because it does not appear in the stratigraphic position one would expect in the west-central portion; a small structure here could account for its seeming absence, however. Northward the unit merges with the main body of the Dakota, as the lower part of the Mancos pinches out; near the village of Twowells 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 Twowells, where it is 80 feet thick and described as a gray to olive-gray, silty, oyster-bearing shale. In the present study area it consists of 60 feet of medium- to dark-gray fissile shale containing the relatively large oyster Exogyra trigeri in its middle portion; also very near the middle is a distinctive white to orange-weathering 15-inch thick bentonite bed. This bentonite bed has been recognized 18 miles to the south on the Twentytwo Spring quadrangle, and 75 mi. to the east on D-Cross Mountain an 8-in. bentonite in a similar stratigraphic position was noted by Hook, Cobban and Landis (1980). Good exposures of the Whitewater Arroyo Tongue and the bentonite bed occur in the NE¼ section 30 T 7N R 19W where it is protected by a cover of Twowells Sandstone. Colorless tabular masses of selenite commonly weather out of the bentonite zone.

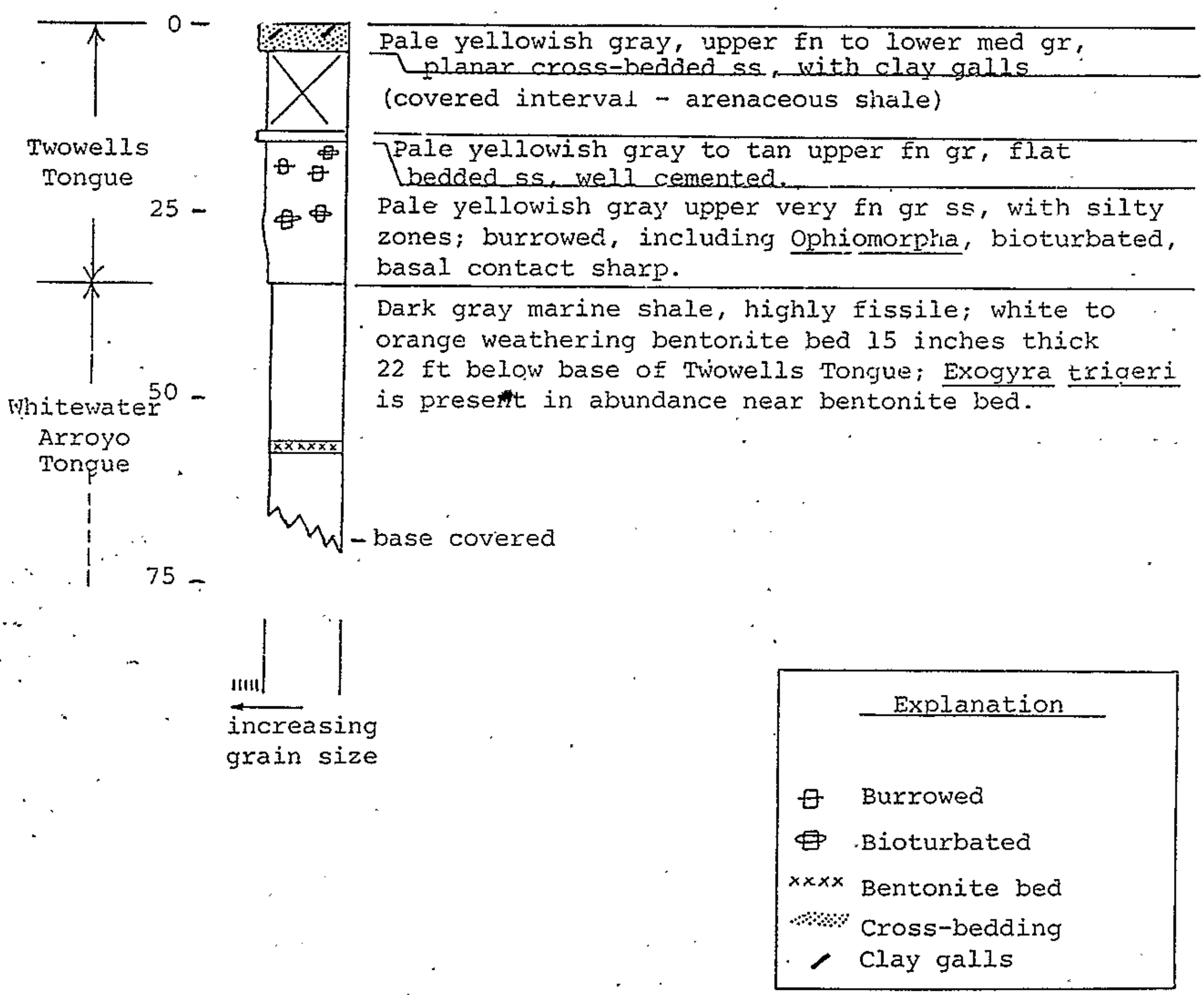
The Twowells Tongue of the Dakota Sandstone is recognized in this area as a tan to yellow and yellowish-gray-weathering sandstone that "comes and goes." The sporadic nature of the outcrops or surface expression of this unit is thought to be due to laterally varying (1) degrees of induration, (2) grain size, and (3) clay and silt content, and not to depositional thicknesses. It is about 30 feet thick in the study area 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 (see Fig. 1); (3) the upper part is an upper fine-to medium-grained, planar cross-bedded unit, generally 6 to 8 feet thick, with clay clasts and which locally may have moderate concentrations of burrows including Ophiomorpha. Cross bed dip direction is generally north or northeast, but in places the uppermost beds have north 30° west dip directions. Opposed cross-bedding is common, and symmetric ripple marks found in the E½NE¼ section 20, T 7N R 20W have a north-south orientation. No fossils were collected at any level in the unit; however, oysters occur in abundance at the very top a short distance to the east on the Mesita de Yeso quadrangle.

Although a wide array of cross bed dip directions were recorded (from N 30° W to N 25° E) it is felt the uppermost sets with the northwesterly dips may reflect long shore current directions paralleling the Late Cenomanian shorelines. The presence of clay clasts and the opposed cross-bedding with northeasterly trends is strong evidence of a tidal channel origin for a portion of this uppermost member of the Twowells locally; the lower part has been described by various authors as a northeastward prograding shallow marine sand body.

The Rio Salado Tongue of the Mancos Shale (new name) represents a rapid return to open marine deeper water conditions or an interruption in sediment supply following deposition of the Twowells. It consists of up to 240 feet of medium-gray and

Figure 1

Measured section of the upper part of the Whitewater Arroyo Tongue of Mancos Shale and the Twowells Tongue of Dakota Sandstone, in SW¼ SE¼ sec. 4 T 6N R 20W



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 (1982) (in preparation). It is defined as the westward-pointing 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 about 30 feet above the base of the Rio Salado are thought to 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. Origin of these beds is related to the concept of Seboyeta Bay proposed by the same authors to explain the thicker and older sequence of Cretaceous rocks in the southern Zuni Basin than in the Gallup Sag-southwestern San Juan Basin area. A westward protruding arm (Seboyeta Bay) of the Western Interior Seaway expanded into the southern Zuni Basin area until very late Cenomanian (Greenhorn) time when it merged with the main body of the Seaway. The merger represents a time of maximum transgression and was marked by the deposition of limestone beds throughout most of the Western Interior Seaway; this depositional interval is considered to be represented in west-central New Mexico by the lower part of the Bridge Creek Limestone Member of the Greenhorn Formation (Hook and Cobban, 1981). Nomenclature problems arise, however, when a member is placed within a tongue of some other unit (i.e., the Bridge Creek Member *in* the Rio Salado Tongue) and consequently the limestone beds are now being referred to informally as the equivalent of the Bridge Creek Limestone Member. The beds form important marker horizons at various localities in the quadrangle; also the guide fossil *Pycnodonte newberryi* (Stanton) appears in abundance at this interval (Hook and Cobban, 1977). In the subsurface the 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 concretion zones began to appear. Associated with the concretions are the ammonites *Mammites depressus*, *M. nodosoides*, *Proplacenticeras cumminsi*, 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 in the upper part is particularly well exposed in the SE¼ section 8, T 7N R 20W. It also offers a good view of the contact with the overlying Atarque Sandstone, which is here transitional through a vertical distance of 6 to 8 feet.

The Atarque Sandstone (new name) is the term proposed in Hook, Molenaar, and Cobban (1982) (in preparation) 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 in this area 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 youngs from southwest to 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 at the top; and an upper cross-bedded unit, generally 15 to 20 feet thick that is upper fine to lower medium grained (see Fig. 2). 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 offshore 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.

Above the cross-bedded unit is a covered, fine-grained interval that to the south on the Cantaralo Spring quadrangle (Anderson, 1981) is a paludal-lagoonal shale sequence containing carbonaceous and coaly zones. Overlying the covered interval and locally taken as the top of the Atarque is a thin, upper very fine to lower fine-grained, burrowed and root-penetrated sandstone (see Figs. 2 and 3). This has been interpreted as a restricted

Figure 2

Measured section of Atarque Sandstone

and the Moreno Hill Formation in NE¼ SW¼

and the SE¼ NW¼ sec. 9 T 7N R 20W.

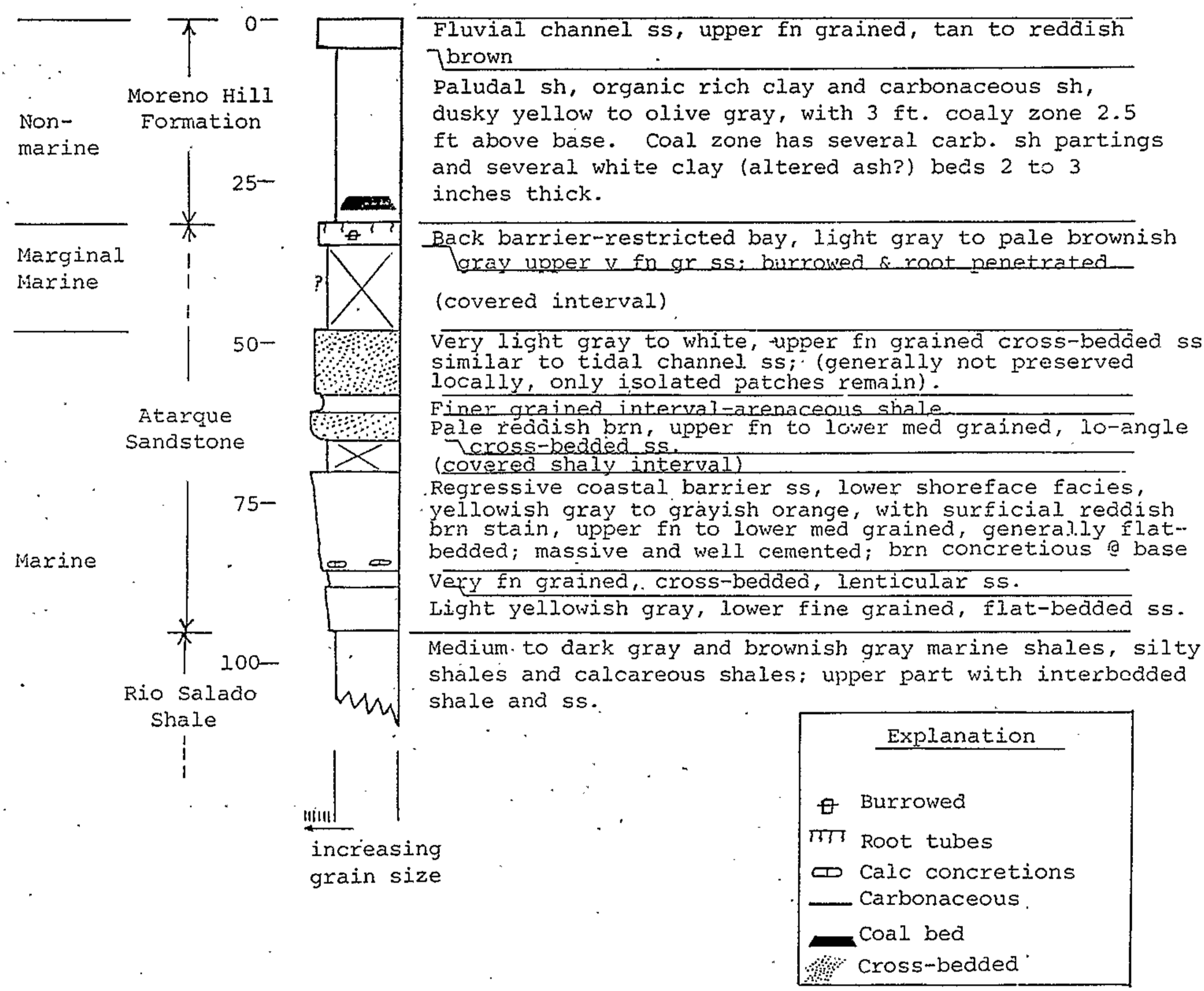
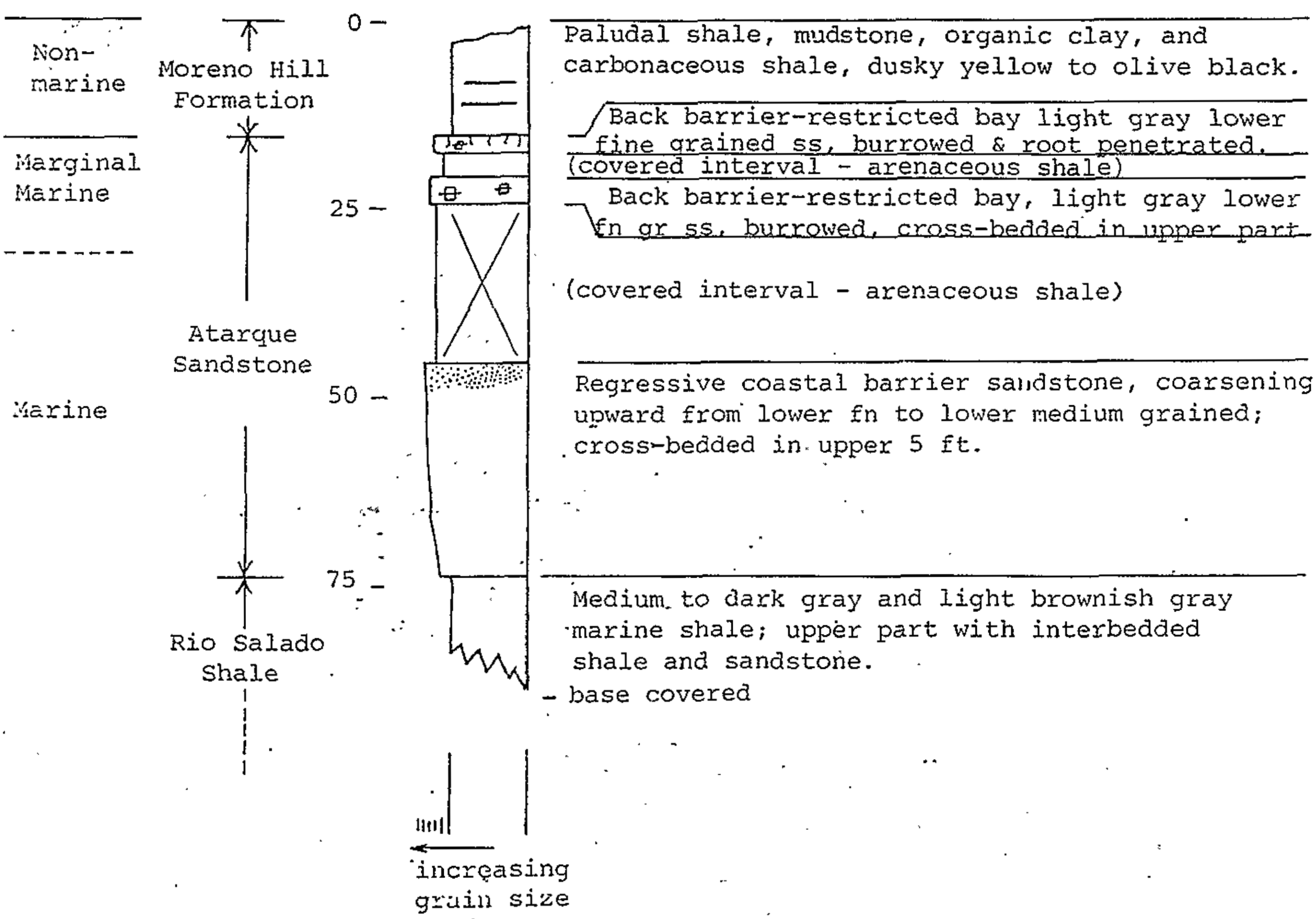


Figure 3

Measured section of Atarque Sandstone

and Moreno Hill Formation in center

of SE¼ sec. 15 T 7N R 20W



bay or back barrier sandstone, and is also recognized to the south on the Cantaralo Spring quadrangle, (Anderson, 1981).

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 (1982) (in preparation) 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 its associated underlying transgressive marine sandstone unit.

The Pescado Tongue is not present in the study area. Its southwestward pinchout occurs some 20 miles to the east on the Shoemaker Canyon Southeast quadrangle. Where present it defines the top of another new stratigraphic unit, the redefined Tres Hermanos Formation of Hook, Molenaar, and Cobban (1982) (in preparation). 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 there exists a nomenclature change 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, carbonaceous shales, fluvial channel sandstones, 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 (1982) (in preparation) 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., 1982) (in preparation).

The Moreno Hill Formation, as defined, comprises the nonmarine carbonaceous shales, mudstones, fluvial channel sandstones and minor thin coals that overlie the Atarque Sandstone and that locally represent the youngest Cretaceous rocks. The geographical area 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 study area and the remaining section being composed primarily of shale is poorly exposed. The exposures are limited to isolated patches in the northern half of the quadrangle and the best and the largest of these is in section 9, T 7N R 20W. Here a carbonaceous shale containing a three-foot-thick, high ash coal zone, overlain by a relatively thin fluvial channel sandstone is exposed (see Fig. 2). The dips are northeastward and a drill hole penetrated the coal at a depth of 150 feet in the northeast corner of the section (see map). Much of the area in adjacent sections 4 and the north ½ of section 5 is underlain by the Moreno Hill, but it is masked by the Tertiary Bidahochi Formation or by alluvial and aeolian material (Qae). It is probably also present northward under much of section 32, but it is thinning in this direction and exposures in the southwest corner of the adjacent Ojo Caliente quadrangle are minimal. The coal bed was also penetrated in the drill hole located in the NW¼NW¼ section 15, T 7N R 20W; here it was encountered at a depth of 130 feet, but the density logs indicate that ash content may be higher here. Coal resources are discussed in greater detail on the following pages. A type section has been specified for the Moreno Hill Formation in McLelland, et. al. (1982) (in preparation); it is in sec. 7 of T 4N R 18W on the Moreno Hill quadrangle.

The light-gray and pinkish-gray fluvial sandstones and conglomerates that occur largely as isolated patches and remnants 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 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, an Upper Member, a middle Volcanic Member, and a Lower Member. The Zuni Basin deposits probably correlate with the Upper Member.

In the present study area the formation is locally well exposed (shown by stippled pattern on map) but for the most part the topographic expression of the unit is gentle sandy slopes commonly strewn with cobbles or boulders; this suggests that the conglomerates, which form most of the good exposures, are in many places underlain by appreciable thicknesses of poorly cemented to non-indurated sand and gravel; drill hole data supports this interpretation of the section.

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. Quartzite, chert, and jasper comprise a much larger proportion of the pebble conglomerates than they do of the coarser deposits; all have a calcitic cement.

The sandstones associated with the conglomerates are white to very light gray, medium to coarse grained, are 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.

Carbonate deposits of various types are a characteristic of the Bidahochi Formation. In this area the carbonates range from white lenses and irregular masses within the sandstone and pebbly conglomerates to duricrusts composed of calcrete. In the NE¼ sec. 15 T 7N R 20W, the flat-topped hill at elevation 6,582 is capped by a calcrete, but in addition has several thin beds of wavy, laminated siliceous material herein called a silcrete after Goudie (1973).

COAL RESOURCES

The Venadito Camp quadrangle encompasses a 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 and most of this "outlier" is on the Venadito Camp quadrangle in the triangular area bounded by the west trending flow and the northwest trending monocline; it extends northwestward for a few miles across the southwest corner of the Ojo Caliente Reservoir quadrangle and on to the Zuni River.

The coal resources on the quadrangle were determined in the course of a detailed mapping project carried out in the spring of 1981 and with the help of drill hole information from seven holes drilled in the northern half of the quadrangle by one of the land and mineral holders in the area.

As mentioned under the discussion of the Moreno Hill Formation a three foot thick coaly interval was found in outcrop in the NW¼ of section 9, T 7N R 20W (see map legend). A carbonaceous shale parting and two white clay (altered ash) beds reduce the aggregate coal thickness to about 2.5 ft (30 inches). The interval is present at a depth of 150 ft in the NE¼ of the same section, where the coal is also 2.5 ft (30 inches) thick, but with a 1.5 ft carbonaceous shale above it followed by another coal bed about one ft thick. In the NW¼ section 15, T 7N R 20W a 2.5 ft coal zone was penetrated at a depth of 130 feet, but here the one ft thick rider bed was 4.5 ft above the main bed. The section 9 and section 15 were the only two drill holes in which coal was intersected.

No analyses of the coal were made; however, samples of weathered coal from what is considered to be the same interval on the Cantaralo Spring quadrangle (immediately to the south) yielded as-received Btu values ranging from 5000 to 9350 per lb. with ash contents of 14 to 44%. Fresh samples could be expected to run up to 30% higher. Campbell (1981) reported the average as-received Btu value for coals in the same formation 20 miles to the southeast as being 9920 per lb; his average moist, mineral-matter free value was 12869 Btu/lb. The coal was thus classified as a high volatile bituminous B rank; this rank is likewise assumed for the similar coal occurrences on the Venadito Camp quadrangle and accordingly a 14 in. thickness cut-off is used in calculating the demonstrated and inferred resources (U.S.G.S. Bull. 1450-B). The resource figures shown on Table 1 are based on the 1800 ton/acre foot weight estimate that is commonly used for bituminous coal.

The data does not permit accurate calculation of stripping ratios; however, this value is going to be greater than 10:1 for essentially all of the coal in both the demonstrated and inferred categories. For a large portion of the coal that lies near the axis of the syncline in sections 4, 9, 10, and 15 of T 7N R 20W the stripping ratios would be in the range of 60:1. This plus the limited resources and general inaccessibility of the area weigh heavily against any future development.

Additional information on this portion of the Salt Lake coal field will be available late in 1982 upon completion of a U.S. Geol. Survey mapping and coal resource evaluation project on the Ojo Caliente Reservoir quadrangle.

Table 1

Coal Resources of Venadito Camp Quadrangle

in millions of short tons
(acres upon which calculations made shown in parentheses)

	Measured*		Indicated*		Inferred*	
T 7N R 20W						
sec. 3	--		.36	(80)	--	
sec. 4	.36	(80)	.90	(200)	.36	(80)
sec. 5	--		--		1.44	(320)
sec. 6	--		--		.18	(40)
sec. 9	1.44	(320)	--		--	
sec. 10	.36	(80)	1.44	(320)	.36	(80)
sec. 15	.18	(40)	.86	(190)	.18	(40)
T 8N R 20W						
sec. 31	--		--		.36	(80)
sec. 32	--		--		.72	(160)
sec. 33	--		--		.18	(40)
Totals	2.34		3.56		3.78	

Total demonstrated resources (measured + indicated) = 5.90

*as defined in USGS Bull. 1450-B

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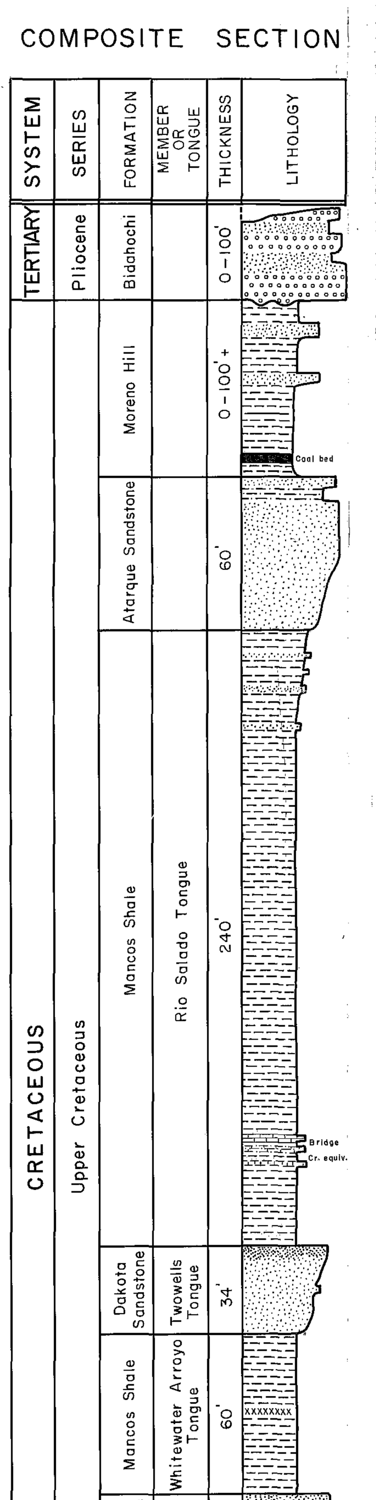
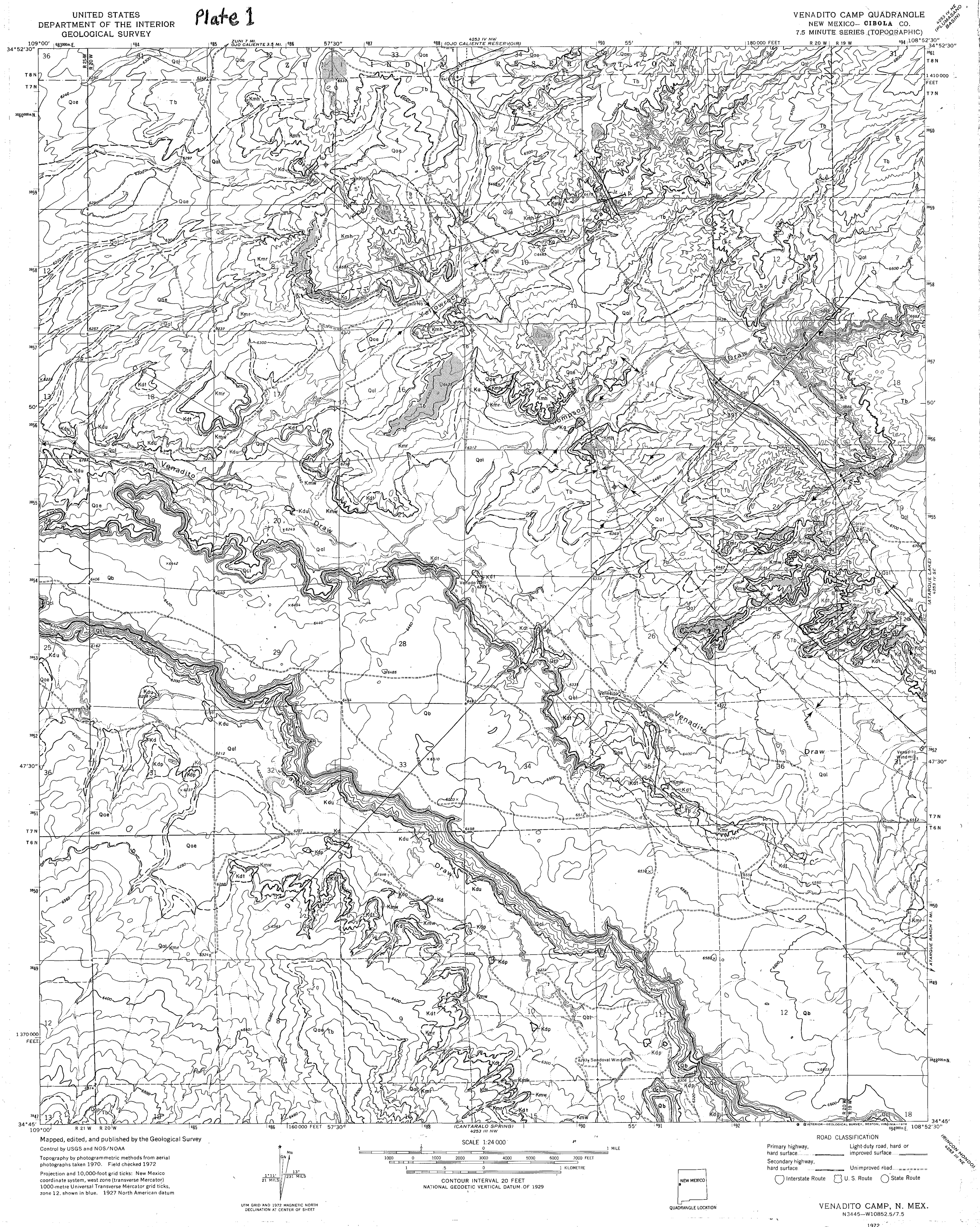
COMPOSITE SECTION



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Plate 1

VENADITO CAMP QUADRANGLE
NEW MEXICO—CIBOLA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



VENADITO CAMP, N. MEX.
N3445—W10852.5/7.5
1972

DESCRIPTION OF MAP UNITS

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

Qae Alluvial and aeolian deposits; silt and sand on intermediate or higher level surfaces, and on some of the broader interstream divides.

Qcl Colluvium and landslide masses; very coarse wastage, rockfalls, or toreva block slides on or at the base of the steep slopes surrounding the basalt flow that extends from the southeast corner to west-central portion of quadrangle.

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

Tb Bidahochi Formation (Pliocene); highly variable light gray sandstone and conglomerate, and light brown to light brownish gray unconsolidated sand; conglomerates are characteristically well indurated with calcareous cement and are composed of pebble to boulder size basalt and other volcanic rocks, quartzite, and minor chert; good exposures are indicated by stipling. In SW¼ sec. 24 T 7N, R 20W, residual patches of conglomerate beds appear to have a 6°-18° north-northwestward dip, very similar to the Cretaceous rocks; these probably have slumped on the soft underlying bentonitic shales of the Bridge Creek Limestone equivalent.

Kmh Moreno Hill Formation (Upper Cretaceous); fluvial channel sandstone, paludal shale and mudstone, carbonaceous shale, and minor coal. Sandstones range from lower fine grained (crevasse splays) to lower medium grained and locally may be reddish brown; shales range from dusky yellow to olive gray and olive black. A three foot thick, high ash, coal zone containing several thin carbonaceous shale beds and several white clay beds (altered ash?) lies a few ft. above the Atarque Sandstone. The coal zone crops out along stream banks 300-500 ft. northwest of center of section 9 and also in the center of N½, SW¼ of the same section T 7N R 20W; immediately underlying the coal is a fine grained sandstone, burrowed and root penetrated. The formation also crops out in adjacent sections 4, 5, 10, and 15, but nowhere is a complete section of the unit preserved; drill hole information indicates that more than 100 ft. is present in the N½ sec. 9 T 7N R 20W.

Ka Atarque Sandstone (Upper Cretaceous); light gray to yellowish gray and grayish orange, very fine to lower medium grained sandstone; well indurated massive, cliff former. Lower part is very fine grained and flat bedded; upper part is coarser grained and cross-bedded; these lower and upper units may correspond to the lower and upper shoreface sequence characteristic of regressive coastal barrier sandstone; burrows, including Ophiomorpha, are present though not abundant except in the back barrier or restricted bay fine grained sandstone that is taken as the top of the formation. Clay clasts and woody fragment impressions were found in upper part of the lower flat-bedded unit in the SE¼ SW¼ sec. 9, T 7N, R 20W. Small bivalves were also found in lower unit at the sec. 9 locality. Total thickness about 60 ft. (see accompanying measured sections).

Kmr Rio Salado Tongue of Mancos Shale (Upper Cretaceous); medium to dark gray and light brownish gray marine shales, silty shale, calcareous shale and thin sandstones; weathers to gentle or moderately steep slopes which are generally covered by colluvium, talus, or landslide debris; base is nowhere well exposed. In several localities the white to orange weathering calcareous shale, calcarenite and nodular limestone beds that are equivalent to the Bridge Creek Limestone Member of the Greenhorn Formation may be seen approximately 30 ft. above the top of the Twowells Tongue; the zone is identified by several thin bentonite beds and by abundant Pycnodonte newberryi (Stanton); the calcarenite beds, up to 3 inches thick, are comprised largely of P. newberryi debris, and can be found in the SW¼ SW¼ sec. 24 and S½ NE¼ sec. 26 T 7N, R 20W. The upper 100 to 125 ft. of formation contains numerous limestone concretion zones, with thin interbedded shale and sandstone at the very top; associated with the concretions in sections 8 and 9 T 7N, R 20W are the ammonites Mammites depressus, Mammites nodosoides, Proplacenticeras cumminsi, and Neotychites cephalotus; also found in concretion zone were Ostrea sp., various bivalves, Turritella and other gastropods. Thickness of Formation estimated at 225-240 ft.

Kdt Twowells Tongue of Dakota Sandstone (Upper Cretaceous); pale yellowish gray and tan, very fine to lower medium grained shallow water marine sandstone; lower part generally very fine to fine grained, burrowed and bioturbated; at top becomes upper fine to lower medium grained, is strongly cross bedded with dip directions commonly north-northeast, but north-northwest directions also noted; opposed cross bedding is common. Standing ripple marks found in E½ NE¼ sec. 20, T 7N, R 20W are oriented N 5° E; ripple marks also observed in center of sec. 5, T 6N, R 20W. Clay galls common in upper part in SW¼ SE¼ sec. 4, T 6N, R 20W (see accompanying measured section); up to 34 ft. thick.

Kmw Whitewater Arroyo Tongue of Mancos Shale (Upper Cretaceous); dark gray fissile, marine shale, soft slope former; contact with underlying Paguate Tongue nowhere exposed; approximately 22-25 ft. below base of the overlying Twowells Tongue is a 15 inch white to orange weathering bentonite bed; near the bentonite bed the relatively large oyster Exogyra trigeri is abundant; estimated thickness 55-60 ft.

Kdp Paguate Tongue of Dakota Sandstone (Upper Cretaceous); yellowish gray to grayish orange, massive, well indurated, marine sandstone; coarsens upward from upper very fine to upper fine grained; commonly cross-bedded throughout, though more prominent in upper part, with generally north-northeast dip directions but southeastward dips are not uncommon. Exogyra levis and Pycnodonte kellumi occur in abundance at top of unit, and may be seen particularly well in SW¼ NE¼ sec. 31, T 7N, R 20W; burrows common in upper part. Unit is not everywhere distinguishable from main body of Dakota; uncertain areas are mapped as Kdu. Estimated thickness 25 ft.

Kml Lower part of Mancos Shale (Upper Cretaceous); gray to medium dark gray marine arenaceous shale and shale, moderate slope former; a thin dark gray to black shale bed occurs about 6 ft. below the base of the Paguate Tongue at the only mapped outcrop, indicated by in sec. 30, T 7N, R 19W. Unit is unrecognizable elsewhere, and is included with Kd; thickness 18 ft.

Kdu Dakota Sandstone, undifferentiated (Upper Cretaceous); map unit used where the Paguate Tongue is not distinguishable from main body of Dakota Sandstone.

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). Good exposures of lower part of formation and contact with underlying Jurassic Cow Springs Fm. (Jcs) are found along the northwest trending fault in sections 2 and 11, T 7N, R 20W where drag folding has resulted in dips of 36° S 60° W; basal 20 ft. here consists of a flat to low angle cross-bedded fine grained fluvial channel sandstone which for most part is reworked Jcs; contact with Jcs is unconformable; overlying the sandstone is about 40 feet of poorly exposed purplish to reddish brown and gray mudstone, paludal shale, and thin carbonaceous shales, which is in turn overlain by a 5 ft. thick fluvial sandstone. Above is more poorly exposed mudstone, with sand increasing upward, which comprises another 25 to 30 ft. of section, for a total of 95 ft. Better exposures of this upper part may be found in west-central portion of quadrangle; in SW¼ SE¼ sec. 18, T 7N, R 20W, a gentle slope forming paludal shale sequence with thin carbonaceous shales and coaly beds is exposed overlain by a gray friable sandstone containing Exogyra levis and Pycnodonte cf P. kellumi; this is thought to be the marine facies near the top of the Dakota, but a structural upwarp here obscures relationship with the overlying Paguate Tongue; good exposures of same portion of section may be found in the NW¼ of adjacent section 19 and westward into section 24 of next township. In many areas a thin pebble conglomerate is present near top of unit.

Jz Zuni Sandstone (Upper Jurassic); white to pale reddish brown and pale orange very fine to lower medium grained quartzose sandstone; lower 75 ft. is pale reddish brown or orange upper fine to upper medium grained, with zones containing chert & feldspar particles that may exceed 1 mm; upper 100 ft. is a very fine grained, white, well indurated with a siliceous cement, cliff forming sandstone; lower coarser part typically has frosted grains, zones with calcareous cement, and is more friable than upper part. Only exposures are along monocline in sections 2, 11, 13, and 24 of T 7N, R 20W, and sections 19 and 30 of T 7N, R 19W. Sections 13 and 19 southwest of corral offer good exposures. Hackman and Olson, 1977, used the term Cow Springs - Entrada (Jcse) for this unit; rests uncomformably on the Rock Point member of the Wingate Sandstone (not mapped); total thickness of Zuni about 175 ft.

(Ꞧwr) Rock Point member of Wingate Sandstone (Upper Triassic); reddish brown, flat bedded, silty sandstone and sandy siltstone (not mapped because of scale limitations; crops out only in S 1/2 sec. 13, T. 7N R. 20W along monoclinal flexure).

Ꞧc Chinle Formation (Triassic); outcrops of this formation are restricted to the northest side of the fault zone; it was not mapped in detail but in general consists of purplish, maroon, red and gray mottled mudstones, siltstones and sandstone, with minor limestone beds. Sequence exposed here is part of the Petrified Forest Member (Stewart, Poole, and Wilson, 1972). A fault breccia zone with secondary calcite and siderite mineralization has been explored by a 20-25 ft. deep shaft in the NE 1/4 NE 1/4 section 13, t 7N, R 20W. In the SE 1/4 SE 1/4 sec. 34 T 8N R 20W irregular masses of pale yellowish brown silty limestone occur in "mounds" up to 10 ft thick; limestones characteristically have marble-size cavity fillings of chert.

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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

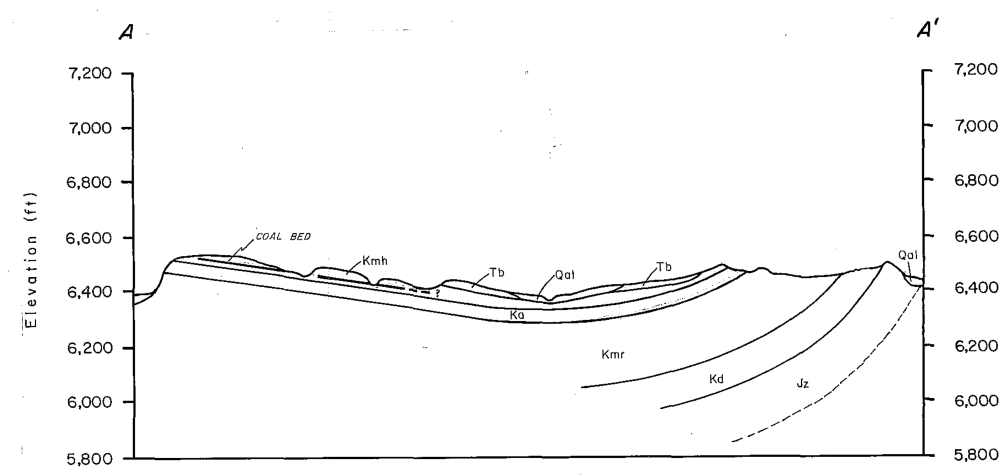
3° Strike and dip of beds

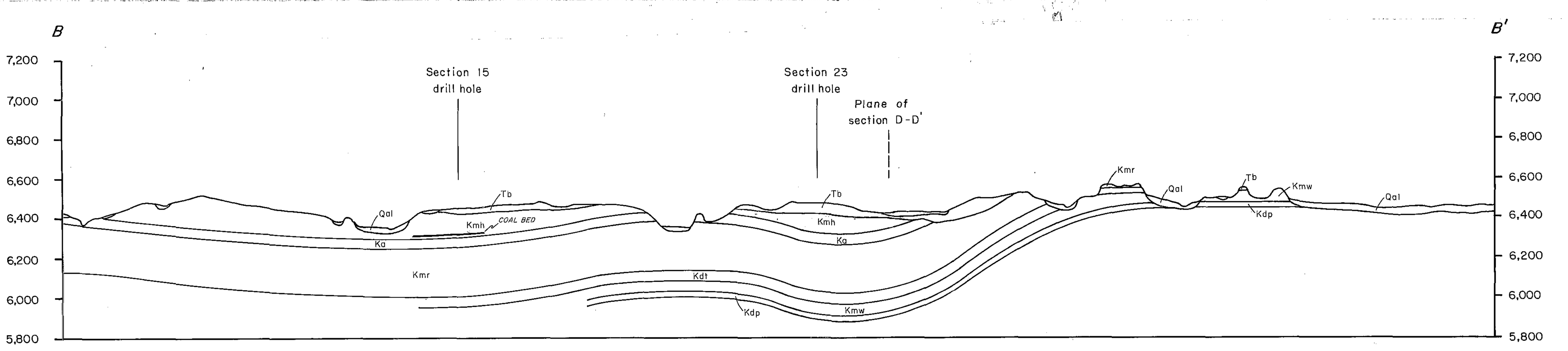
Areas of good exposures of Tertiary beds

Location of drill hole

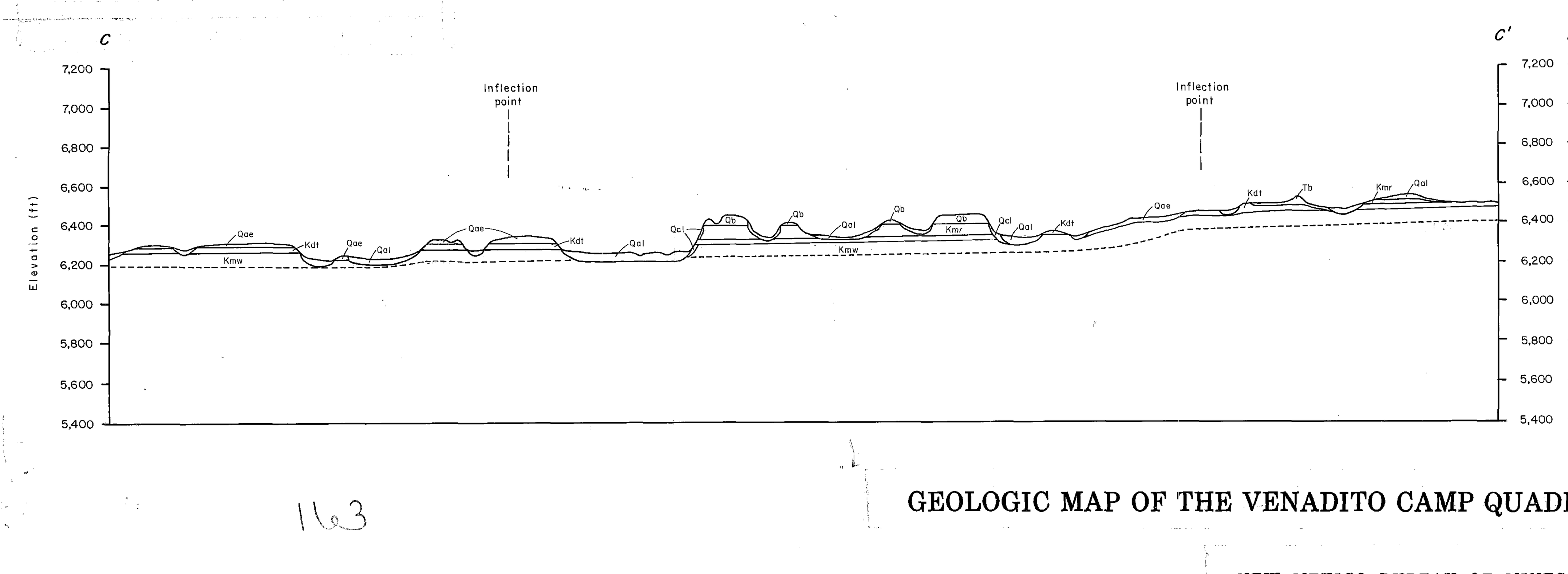
Abandoned mine shaft

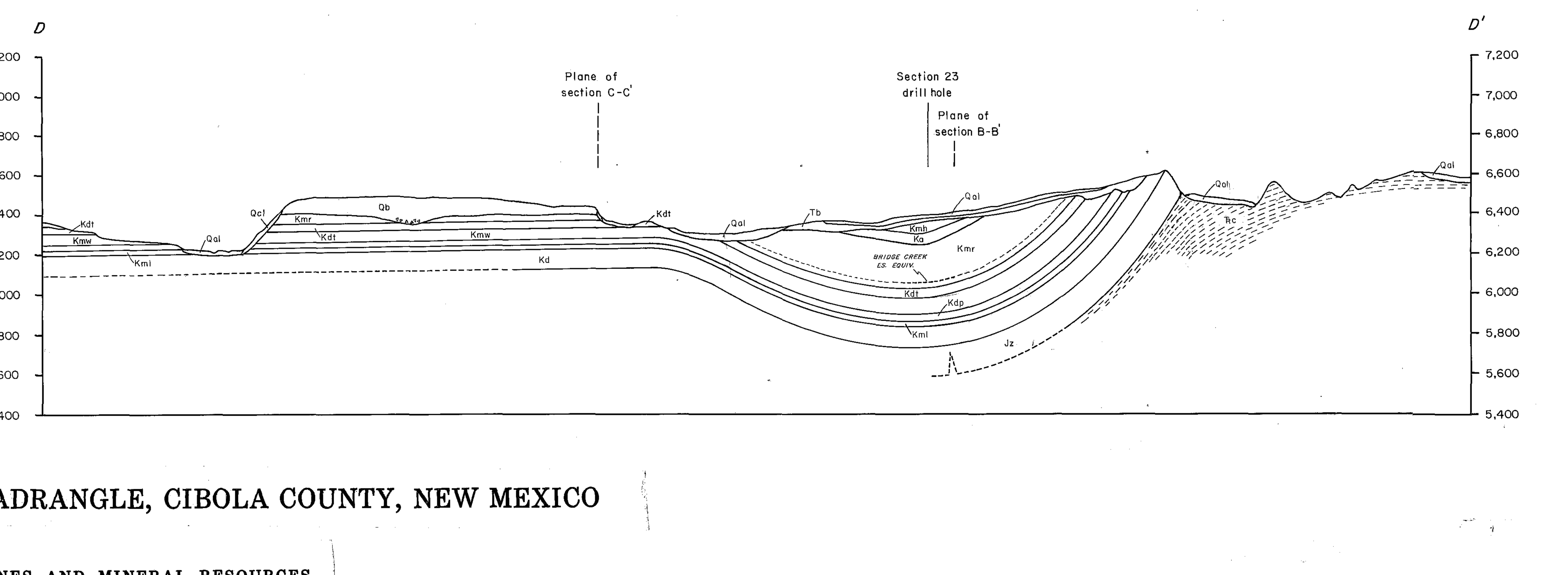
xxxxx Bentonite bed (stratigraphic column only)





ALL CROSS SECTIONS HAVE 5X VERTICAL EXAGGERATION





GEOLOGIC MAP OF THE VENADITO CAMP QUADRANGLE, CIBOLA COUNTY, NEW MEXICO

NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

OPEN-FILE REPORT 163 by ORIN J. ANDERSON

1982

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