# Environmental Characteristics of Menefee Coals in the Torreon Wash Area New Mexico

by David E. Tabet and Stephen J. Frost

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This report is the result of a cooperative project funded in part by the Conservation Division of the U. S. Geological Survey under grant 14-08-0001-448.

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Water Well Program Report

by

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Table of Contents

Table of Contents
(continued)

List of Figures

List of Figures
(continued)

List of Tables

## INTRODUCTION

### Previous Work

Various earlier workers have studied all or part of the Torreon Wash project area (Figure 1). Dutton (1885) conducted the first reconnaissance examination through the Torreon Wash area and outlined the geology, giving emphasis to the volcanic rocks. Schrader (1906) and Gardner (1909, 1910) traced the Upper Cretaceous coal-bearing rocks around the San Juan Basin south from Durango, Colorado and east from Gallup, New Mexico and described selected coal exposures. Hunt (1936) and Dane (1936) made more detailed examinations at the coal beds in the southern part of the Basin and attempted to correlate some of the thicker beds in an effort to classify the coal resources on public land. Shomaker and others (1971) include some general information about the study area in their discussion of low-sulfur, strippable coal resources for the entire San Juan Basin. Beaumont and Shomaker (1974) give a short summary of the geology and deep coal resources at the Cuba-La Ventana-Torreon area and the deep coal resources of the area are discussed at length and Shomaker and Whyte (1977).

Stratigraphic studies by Sears, Hunt, and Hendricks (1941) and Pike (1947) provide an explanation of the complex intertonguing of marine and nonmarine Cretaceous strata of the San Juan Basin. These workers conclude the

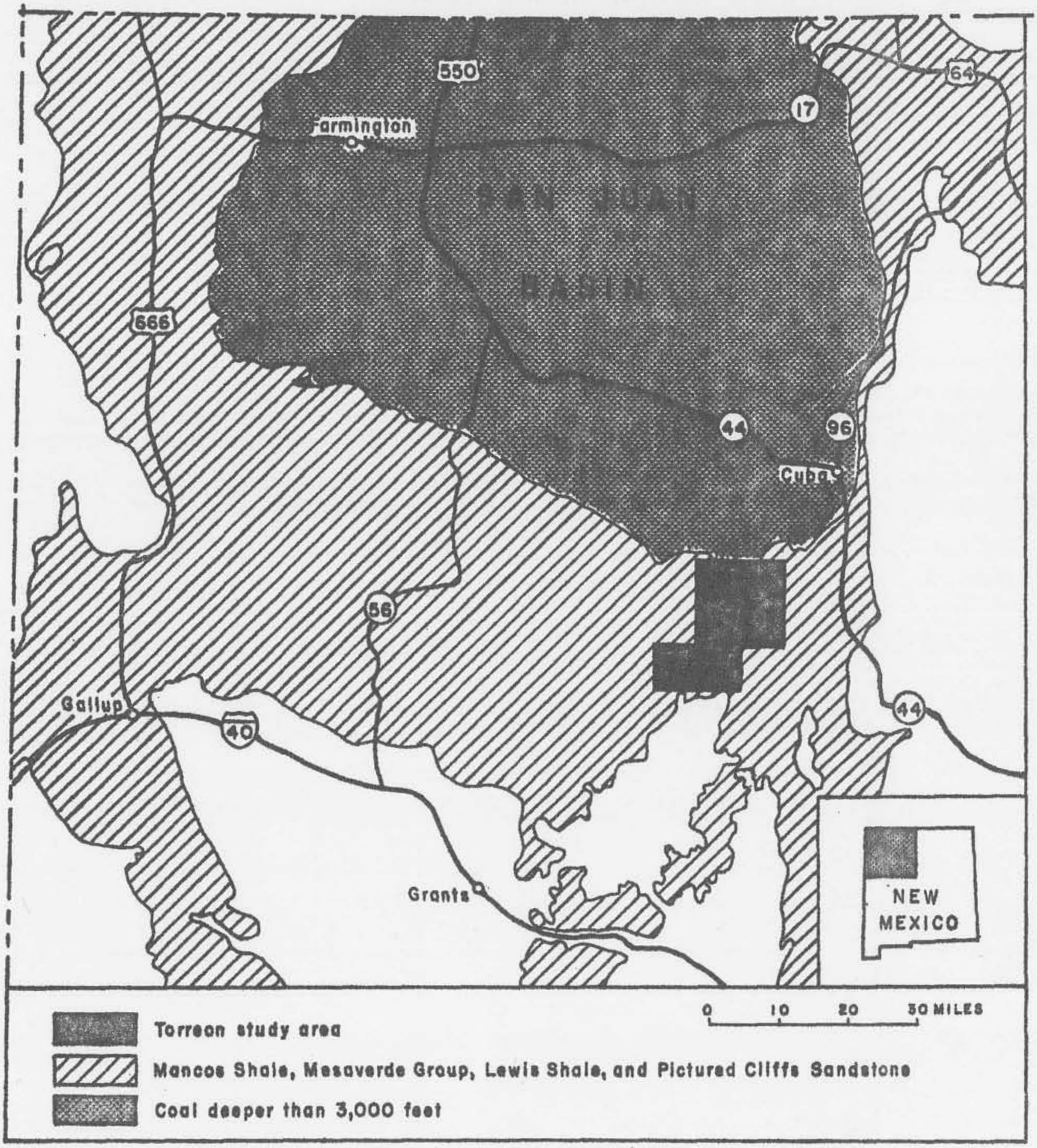



FIGURE 1 - Location map of the Torreon Wash study area.

intertonguing resulted from transgressive and regressive shoreline movements and the attendant shifts in depositional environments. The shoreline movements were caused by changes in the rate of sedimentation in a constantly subsiding basin. Further discussion of the transgressions and regressions of the Upper Cretaceous sea by Shomaker and others (1971) and Fassett and Hinds (1971) relates thicker coal deposits to slow migrations and stillstands of shoreline movement. Both studies also note that coal deposits are most continuous along trends paralleling ancient shorelines. The petrography and sedimentology of rocks deposited during the Point Lookout-Menefee-Cliff House regressive-transgressive cycle were investigated by Hollenshead and Pritchard (1961), Sabins (1964), Mannhard (1976), Shetiwy (1978) and Siemers (1977, 1978).

## Purpose and Scope

The increasing demand for coal to fuel electrical generation and industrial plants has created a clamor for new and better information about coal resources in New Mexico. The U.S. Geological Survey received a legislative mandate (Federal Coal Leasing Amendments Act) in 1975 to conduct exploration and research programs to determine the quantity and character as well as to evaluate the extent, location, and potential for development of the nation's coal deposits. This report is the result of a cooperatively funded program between the New Mexico Bureau of Mines and Mineral Resources and the Conservation Division of the U.S. Geological Survey. The goals of this study were to produce a detailed map of the coal geology and structure on an up-to-date base and to estimate coal resources in the area mapped. Emphasis was placed on delineating coal horizons and depositional patterns that would help in location of buried or hidden coal deposits. A limited drilling program (4 holes per township) was undertaken to provide information on the subsurface continuity of surface-identified coal beds, to aid in calculating resources, and to obtain fresh samples for coal analyses. In addition, the drilling program provided information important to coal development about water quality and quantity as a result of cooperation with the Water Resources Branch of the U.S. Geological Survey. Coal resource calculations use the parameters defined in U.S. Geological Survey Bulletin 1450-B.

## Acknowledgements

Various people deserve special thanks for providing information that was essential to understanding the stratigraphy and coal geology of the Torreon Wash area. Howard Nickelson, formerly supervising mining engineer with the U.S. Geological Survey Conservation Division Office in Farmington, New Mexico, allowed access to the expired coal lease and prospect files for the study area. Ray N. Warren of Pioneer Nuclear, Incorporated, Albuquerque, New Mexico, Dennis G. Storhaug of Tenneco Oil Company, Denver, Colorado, and Thomas Drought agent for the H.P. Drought Company, San Antonio, Texas, all kindly released drill-hole information for use in this report. John F. Murphy with the U.S. Geological Survey in Denver, Colorado, and William L. Chenoweth with the Department of Energy in Grand Junction, Colorado, provided information they had collected about the black sand deposit in sec. 34, T17N, R4W. John W. Shomaker and Edward C. Beaumont, consultants in Albuquerque, New Mexico, freely discussed ideas about coal in the study area based on their widespread experience in and around the area.

Certainly most important to the completion of this project was the funding provided by the U.S. Geological Survey, Conservation Division under grant number 14-08-0001-448 and the cordial working relationship that developed with the Conservation Division staff in New Mexico.

# REGIONAL STRATIGRAPHY

## Introduction

The stratigraphic relationships of the rocks at the Torreon Wash area are shown diagrammatically in Figure 2. These strata are made up of Upper Cretaceous marine and nonmarine rocks which have locally been intruded or overlain by Tertiary volcanic rocks related to the Mount Taylor center to the southwest. Coal is found in the Menefee Formation, which is composed of the basal coal-bearing Cleary Member, the middle Allison Member, a sandy unit, essentially devoid of coal, and the upper unnamed coal-bearing member. In the southern part of the area the Menefee Formation lies conformably on the Point Lookout Sandstone; to the east and northeast it intergongues with the La Ventana Tongue of the Cliff House Sandstone, and to the northwest it is overlain by the Cliff House Sandstone proper.

## Mancos Shale

Two tongues of the Mancos Shale, the Mulatto and Satan Tongues, are exposed in the southeastern part of the Torreon Wash area in parts of T16N, R4W, and T17N, R3 and 4W. These shales are the lowermost upper Cretaceous rocks exposed in the area. They consist of medium-gray, silty, laminated marine shale. The lower Mulatto and upper Satan Tongues of the Mancos Shale are separated by distal sands

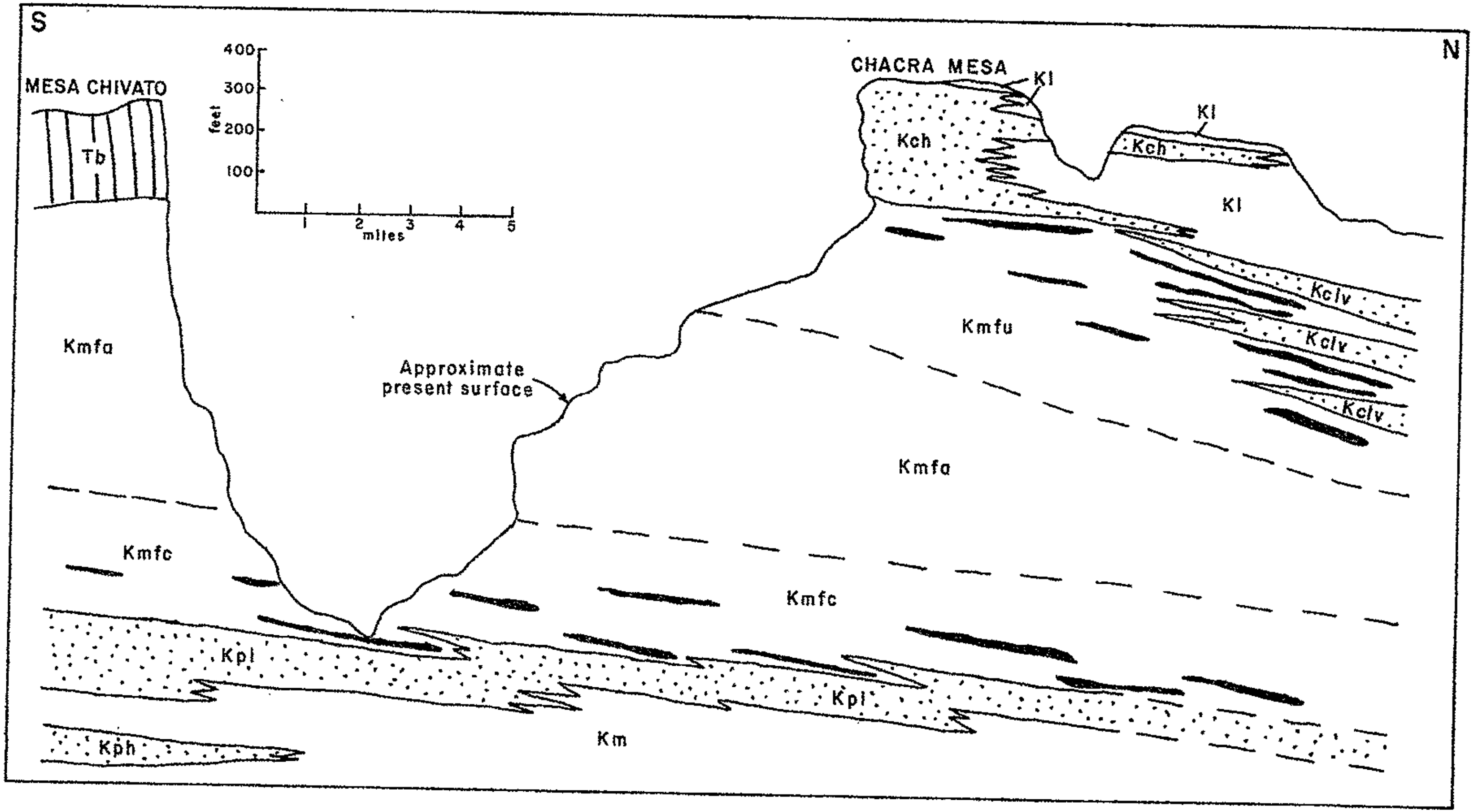



Figure 2. Diagrammatic cross section across study area. Km, Mancos Shale; Kph, Hosta Tongue of the Point Lookout Sandstone; Kpl, Point Lookout Sandstone; Kmfc, Cleary Member of the Menefee Formation; Kmfa, Allison Member of the Menefee Formation; Kmfu, upper coal member of the Menefee Formation; Kclv, La Ventana Tongue of the Cliff House Sandstone; Kch, Cliff House Sandstone; Kl, Lewis Shale; Tb, Tertiary basalt.

of the Hosta Tongue of the Point Lookout Sandstone. The Hosta Tongue thickens to the southwest. The main body of the Point Lookout Sandstone conformably overlies the Satan Tongue to the north.

## Point Lookout Sandstone

The regressive marine Point Lookout Sandstone has an alternating sand-shale transitional lower contact with the Satan Tongue of the Mancos Shale. The contact between these two units is characterized by a series of sand beds and intervening shales in which the sandbeds increase gradually in thickness upward at the expense of the shales until only a massive cliff forming sand exists (Figure 3). For the sake of mapping, this contact was drawn where sand predominates over shale. The Point Lookout crops out in a belt that runs southwestward through the southern part of T17N, R3W and T17N, R4W. This belt turns sharply south midway through the later township and extends southward through the central part of T16N, R4W along the east edge of Mesa Chivato.

Outcrops of Point Lookout Sandstone are very pale orange to light gray in color for the most part, although toward the top exposures may be very light gray to white. Bedding toward the base of the unit is generally less than 3 ft thick and has planar-lamination; bedding toward the top is thicker and has cross-lamination.

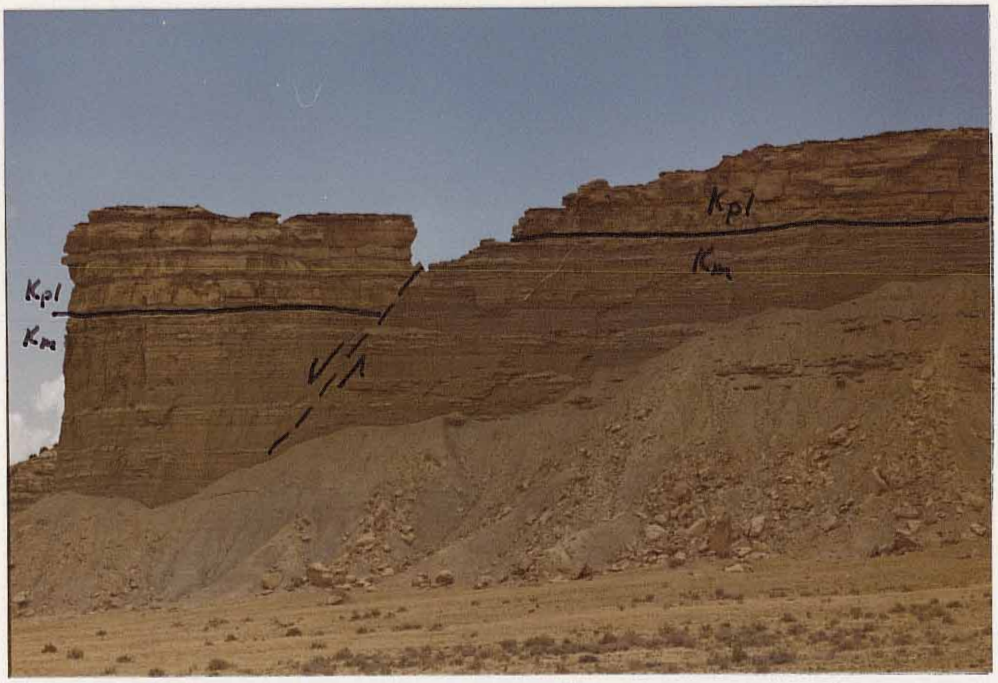



FIGURE 3 - Photograph of the transitional contact between the Point Lookout Sandstone and the Mancos Shale (NW$\frac{1}{4}$, sec. 12, T. 16 N., R. 4 W.). The contact is drawn in as mapped in the field. The sandstone to the left is lower due to local slumping.

Sand grains in the Point Lookout are subangular to subrounded and vary from very fine to fine grained. A general increase in grain size occurs from the base to the top of the formation (Shetiwy, 1978). Quartz is the dominant mineral in the Point Lookout, especially in the finer grained sandstones. Detrital grains of chert, feldspar, rock fragments, and organic debris are more common in the coarser sandstones of the upper Point Lookout (Sabins, 1964). Body fossils are not common in the Point Lookout although the trace fossil Ophiomorpha may be common in places

Examination of well logs across the Torreon Wash area shows the thickness of the Point Lookout Sandstone ranges from 75 ft to 260 ft (Figure 4). The thickness varies in a systematic way to form a series of west-northwest-trending ridges and troughs.

## Menefee Formation

### Introduction

The Menefee Formation consists of interbedded shales or mudstones, siltstones, sandstones and coals. The three members of the Menefee mapped in the Torreon Wash area were essentially divided on the basis of the presence or absence of coal. These members in ascending order are the coal-bearing Cleary Member, the sandy Allison Member, and an upper unnamed coal-bearing member, formerly considered part of the Allison Member. The upper coal member underlies or

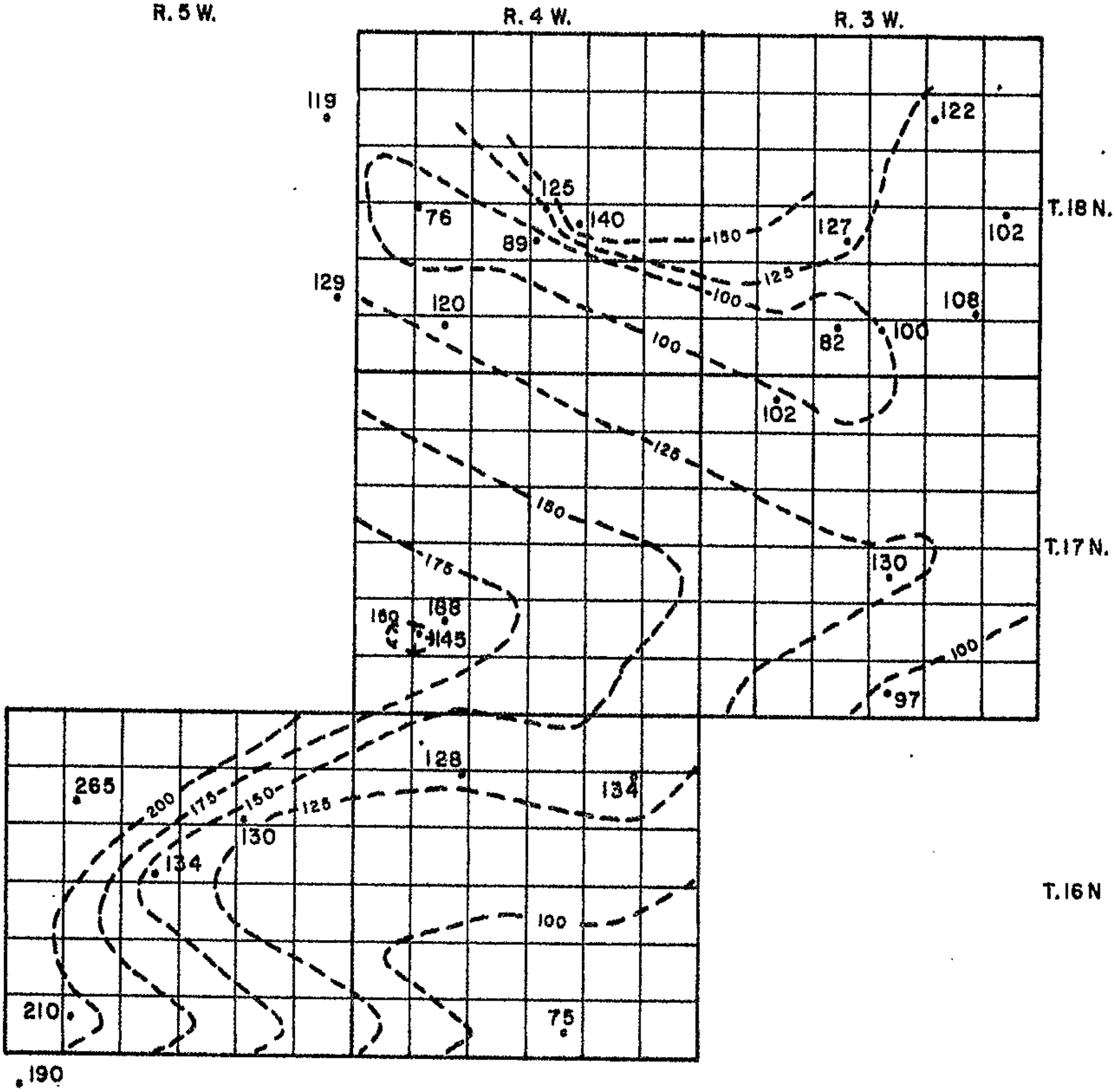



Figure 4. ISOPACHOUS MAP OF POINT LOOKOUT SANDSTONE
(contour interval 25 ft.)

intertongues with the Cliff House Sandstone and includes the Hogback Mountain tongue of Shomaker and Whyte (1977). The Hogback Mountain tongue was defined as one or more Menefee tongues that are laterally (to the south) equivalent and in part enclosed by the La Ventana Tongue of the Cliff House Sandstone.

These three members represent the gradational succession of depositional environments from a coastal swamp to a floodplain and back to coastal swamp. Since the succession is gradational, it necessarily follows that the contacts between units are gradational and not easily defined and thus are dashed on the maps. The contact between the Cleary and Allison members is drawn at the base of a thick, cliff-forming channel sandstone sequence which overlies the uppermost major coal horizon of the Cleary. The upper contact of the Allison Member with the overlying upper coal member is even less well defined. This contact is drawn where coals and brown to black carbonaceous shales, rarely found in the Allison Member, once again begin to predominate over drab-gray and tan mudstones.

## Cleary Member

The basal Cleary Member of the Menefee Formation has a conformable, transitional contact with the underlying Point Lookout Sandstone. This unit composed of palludal deposits is generally 200 ft to 300 ft thick. The Cleary

Member crops out in a northeast-trending belt running through most of T16N, R5W, the west half of T16N, R4W, the southern part of T17N, R4W, and the central part of T17N, R3W.

Lithologically the Cleary Member is dominated by finer grained palludal deposits composed of silt-clay size particles and abundant organic debris. At various horizons, more commonly in the lower half of the Cleary, organic debris accumulated to form coal beds (Figure 5). Occasional lenticular channel sandstone deposits and related splay and levee sandstone deposits make up a minor portion of the Cleary Member. These sands increase in abundance toward the top of the unit. Iron-rich concretionary layers or nodules composed of siderite are often associated with organic rich shales or mudstones. Abundant plant impressions and fragments ranging up to sections of logs are found along bedding planes but no macroinvertebrate fossils are found. The random orientation of the plant debris and the occasional presence of an upright stump indicate most of the organic debris accumulated in place. The coal is characterized by medium bands of vitrain with bits of amber along horizontal cleats.

## Allison Member

The Allison Member, composed of channel sandstones and barren silty mudstones and shales, overlies the Cleary

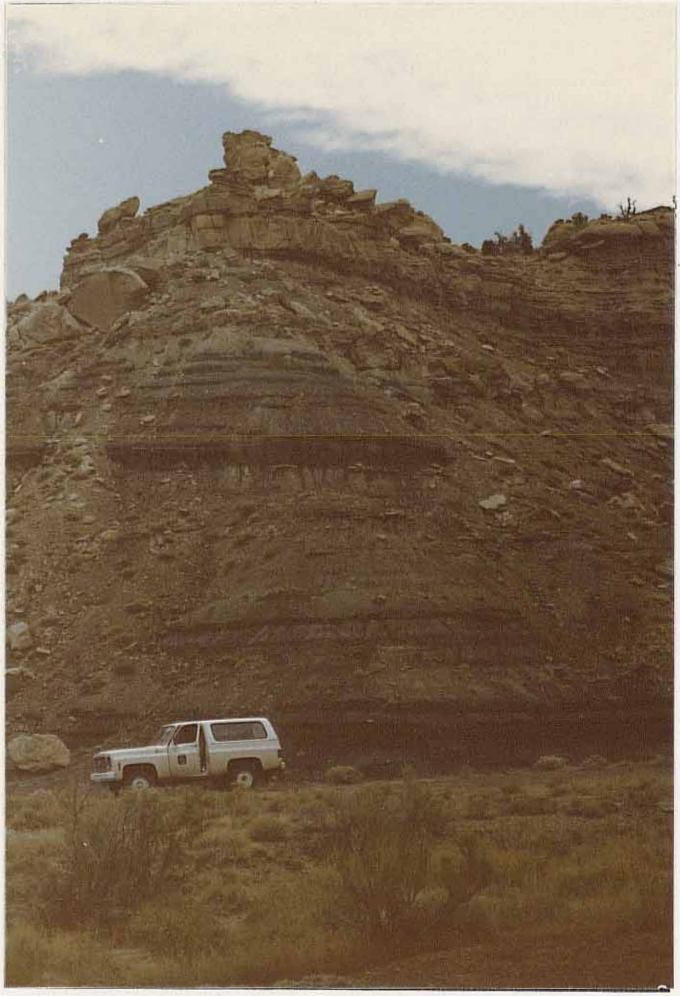


FIGURE 5 - Typical exposure of carbonaceous shale, sandstone, and coal of the lower part of the Cleary Member of the Menefee Formation ($NW\frac{1}{4}$, sec. 34, T.17 N., R. 4 W.).

Member with an irregular but conformable contact. This unit crops out mainly in the northern third of T17N, R3W, and the northern half of T17N, R4W. Small areas of exposures occur in the southern parts of the two northern townships and capping the higher mesas of the two southern townships. The Allison is roughly 400 to 550 ft thick.

Unlike the Cleary Member, rocks of the Allison Member are composed primarily of sand-silt sized particles and very little organic debris (Figure 6). Directly above the Cleary, the basal part of the Allison consists of a 200-ft-thick multi-story sequence of stacked channels. Above this basal sequence, channel sand units are common but do not occur in such thick stacked sequences. The channel sand units are characterized by sharp scour bases containing numerous clay clasts and wood fragments. A major part of these units has large sets of high-angle cross-stratification. The cross-sets generally decrease upward in size and thickness, then change to trough cross-sets and finally to ripple-lamination. Grain size in the channel units decreases generally upward from medium to very fine sand. In cross section the channel sandstones are thick lenticular units with a flat upper surface and a concave-upward lower surface.

Laterally associated with the thick channel sand units are thin, usually less than 3 ft, tabular bodies of fine, silty sand. These bodies commonly have ripple-lamination and numerous root tubes (Figure 7) along the upper surface and

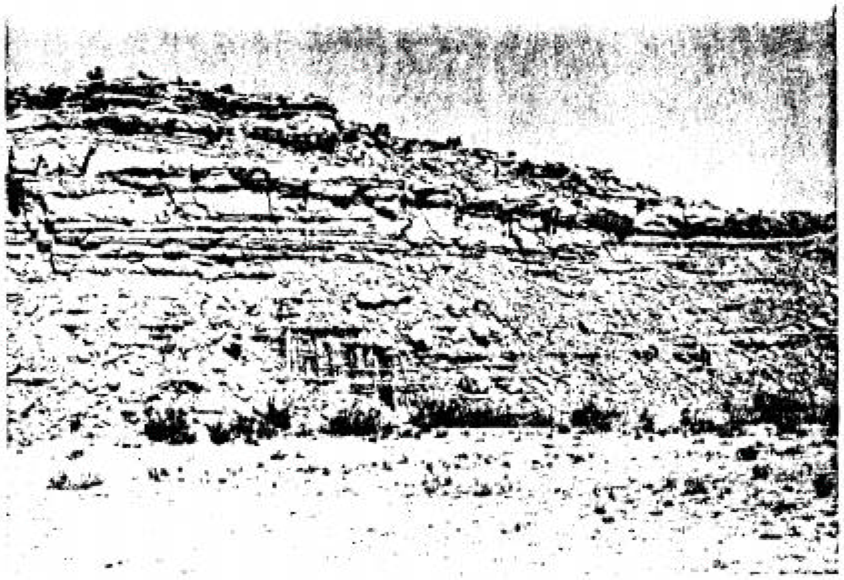


FIGURE 6 - Typical exposure of channel sandstones and barren gray shales of the Allison Member of the Menefee Formation, NE¼, sec. 21, T. 17 N., R. 4 W.

FIGURE 7 - Burrowed upper surface of a crevasse splay or levee sandstone deposit, NE¼, sec. 21, T. 17 N., R. 4 W.

represent splay and levee deposits marginal to the channels and extending into the floodplain deposits.

The floodplain deposits interstratified with the channel and marginal channel deposits are light gray or tan silty claystones and shales. These claystones and shales contain little organic material, probably as a result of an oxidizing, well-drained depositional environment. Locally thin coals and some brown humic shales occur, but they generally comprise less than 5% of the Allison Member.

### Upper Member

The upper unnamed member comprises as much as 650 ft of the Menefee Formation. It has a gradational lower contact with the Allison Member and it intertongues and is overlain by sand bodies of the Cliff House Sandstone (Figure 8). Lithologically the upper member is similar to the Cleary Member. Most of the thicker coal beds occur in the upper part of the upper member between sandstone tongues of the La Ventana. The upper coal member thins somewhat to the west, grading laterally into the Allison Member.

## Cliff House Sandstone

### Introduction

The Cliff House Sandstone proper and the stratigraphically lower La Ventana Tongue of the Cliff House overlie and intertongue with the Menefee Formation in T18N, R3 and 4W. Lack of detailed mapping or stratigraphic data caused earlier

FIGURE 8 - Illustration of the sharp contact between the upper coal-bearing member of the Menefee Formation and the La Ventana Tongue of the Cliff House Sandstone (top of hill). Note how the channel sandstone in the middle of the hill thins rapidly to the left (NW$\frac{1}{4}$, sec. 24, T. 18 N., R. 4 W.).

workers (Dane, 1936; Shomaker and others, 1971; and Beaumont and Shomaker, 1974) to postulate that the Menefee Formation in this area is directly overlain by the Lewis Shale. Marine sandstones of the Cliff House, albeit thin, are found between the Menefee Formation and the Lewis Shale at all exposures. This area is particularly complicated stratigraphically since only thin seaward (northeast) extending lenses of the Cliff House and thin landward (southwest) extending lenses of the La Ventana are found overlying most of the Menefee. The Lewis Shale, which intertongues with the thin Cliff House sands, pinches out rapidly to nothing at Chacra Mesa in sec. 5, T18N, R4W.

La Ventana Tongue

The La Ventana within the Torreon Wash area consists of several laterally persistent lenses of marine sandstone up to 40 ft thick that are interstratified with palludal deposits of the upper Menefee member. The uppermost lens of La Ventana separates the Menefee from the Lewis Shale through T18N, R3W, and the eastern half of T18N, R4W (Figure 9). The lower La Ventana lenses, which occur in T18N, R3W, thin and intertongue with the Menefee Formation to the southwest and thicken toward the main buildup of the La Ventana to the northeast.

The La Ventana sandstone lenses are characterized by sharp, generally planar to slightly undulatory upper and lower contacts with the brown humic shales or coals of the

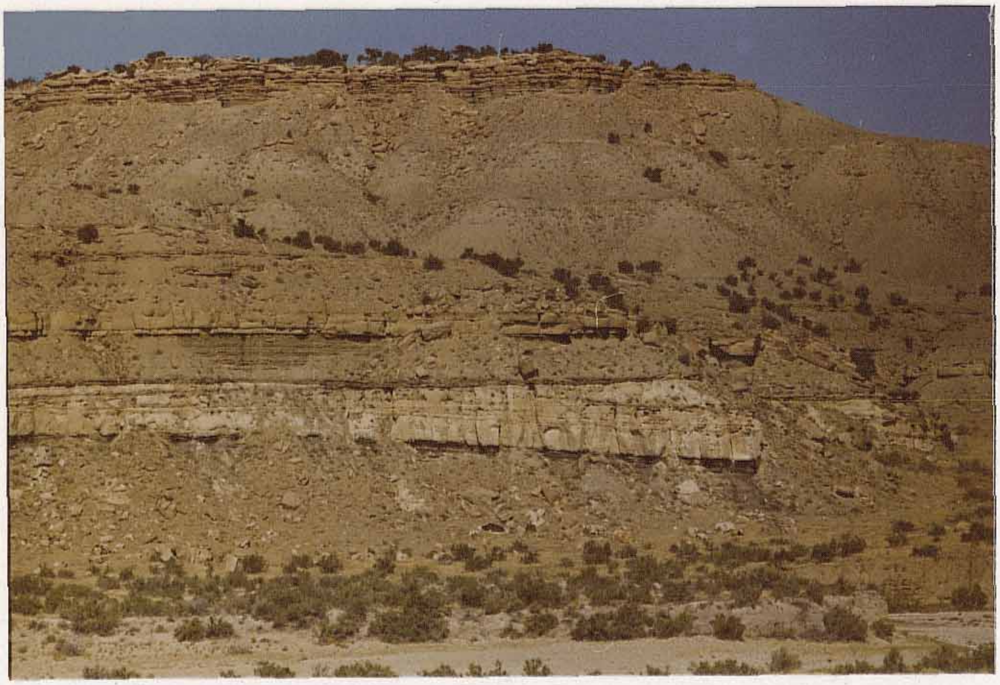


FIGURE 9 - The white La Ventana Tongue of the Cliff House Sandstone overlies the upper member of the Menefee Formation here in the SW$\frac{1}{4}$, sec. 10, T. 18 N., R. 4 W. To the southwest (left) this tongue thins and within a short distance is totally gone. Note the thin tongues of the main body of the Cliff House Sandstone in the Lewis Shale above the La Ventana Tongue. These tongues thicken to the southwest (left), coalescing into the thick cliff forming sandstone at Chacra Mesa.

upper Menefee. Load deformational structures and some reworked clasts of Menefee lithology are found along the lower contacts of these lenses. Internally, horizontal to very low angle planar cross-stratification may also be present. Iron-oxide-stained, knobby-walled Ophiomorpha trace fossils are sparse to very abundant and a key indicator of marine conditions for the La Ventana sands. The quartzose sands comprising the La Ventana units are tan to light gray, fine to very fine grained, and moderately well sorted.

Cliff House Sandstone, main body

The main body of the Cliff House Sandstone in this area was originally named the Chacra Sandstone by Dane (1936) for Chacra Mesa,which it caps,extending westward from T18N, R4W. The name "Chacra" was dropped by Beaumont, Dane, and Sears (1956) in favor of the name "Cliff House" when more work showed the continuity of this sandstone around the San Juan Basin. The name "Chacra Tongue" has been informally used for the portion of the Cliff House which caps Chacra Mesa (Shomaker and others, 1971; Beaumont and Shomaker, 1974; Beaumont and others, 1976; and Shomaker and Stone, 1977). Some subsurface work by Fassett (1977) indicates this sandstone may be the lowest of several tongues of the Cliff House and he suggests the informal name "Tsaya" for this tongue since the name "Chacra" has been used for other subsurface sandstones.

We prefer to use the term Cliff House until further work and formal naming clearly warrants the introduction of a new name.

Dane (1936) measured 310 ft of Cliff House Sandstone on Chacra Mesa in T18N, R4W. This thick cliff-forming unit undergoes radical changes just a short distance to the northeast. Surface exposures show a rapid seaward (northeast) thinning of the Cliff House and a significant increase in intertonguing with the marine Lewis Shale. Within the space of 3 mi , from Chacra Mesa northeastward to near the Torreon Trading Post, the Cliff House changes from a 310-ft-thick sandstone to an interval composed of upper marine sandstone approximately 45 ft thick, a medial tongue of Lewis Shale roughly 165 ft thick and a lower marine sandstone up to 25 ft thick (Figure 10).

The quartzose sands of the Cliff House are tan to light gray, very fine grained, well-cemented with occasional carbonaceous shale laminae. Sorting in these sands is generally poor to fair. Hollenshead and Pritchard (1961) list an average petrographic description from Cliff House core samples taken from 19 scattered wells as follows: quartz - 60%, feldspar - 10%, rock fragments - 5%, clay - 5%, and calcareous cement - 15%.

## Lewis Shale

Marine Lewis Shale overlies the uppermost La Ventana sandstone tongue in the northeast part of the Torreon area

FIGURE 10 - View northeastward from the SE$\frac{1}{4}$, sec. 10, T. 18 N., R. 4 W. showing the La Ventana Tongue of the Cliff House Sandstone (base of mesa) overlain by the Lewis Shale containing thin seaward-extending tongues of the main body of the Cliff House Sandstone.

Mollusca:

Bivalvia:

*Ostrea plumosa* (abund.)

*O.* aff. *O. tecticosta* (one)

*Inoceramus vanuxemi* (abund.)

*I.* aff. *I. barabini* (several)

*I. sagensis* (several)

*Crassostrea subtrigonalis* (several)

*Granocardium whitea* (several)

indeterminate veneridae (two)

*Pinna?* sp. (one)

*Nucula?* sp. (one)

Gastropoda:

*Aporrhais* sp. (abund.)

*Eoacteon* sp. (abund.)

*Anisomyon borealis* (several)

*Banis* cf. *B. siniformis* (several)

indeterminate turritelliform genus

Cephalopoda:

*Baculites perplexus*

*Placenticeras intercalare*

Trace Fossils:

*Gyrochorte*

Table 1. Macroinvertebrate faunal list from the Lewis Shale, sec. 8, T18N, R3W. Fauna listed in approximate order of abundance. (From Mannhard, 1976).

and interfingers with the main Cliff House sandstone to the northwest. Good exposures of the Lewis Shale are sparse and this unit was not studied in great detail. This unit generally consists of gray to olive-gray silty shale with common thin interbeds of silty sandstone. A persistent fossilliferous, thin, calcareous, silty sandstone occurs about 40 ft above the uppermost La Ventana sand in T18N, R3W. This unit contains numerous gastropods, bivalves, and ammonites, including Placenticeras intercalare. The thickness of the Lewis varies considerably over the area; it generally thickens to the north and east from the Chacra Mesa area.

## Tertiary Igneous Rocks

Tertiary igneous rocks related to the Mount Taylor volcanic center intrude and overlie the upper Cretaceous rocks of the Torreon Wash area. A series of thick columnar-jointed basaltic flows caps Mesa Chivato in the south. Abundant basaltic rubble forms talus slopes along the northern slopes of the mesa, obscuring the underlying Cretaceous rocks. Erosion has exposed several basaltic necks or plugs around the northern end of Mesa Chivato such as Bear's Mouth and Cerro Parido (Figure 11). Some smaller plugs are associated with north-south trending dikes in the southwestern part of the area in T16N, R5W. A series of en echelon dikes extends from T16N, R5W through T17N, R4W, and into T18N, R5W to the edge of Chacra Mesa. The dikes

FIGURE 11 - View looking southeast toward the Cerro Parido plug (middle ground) and the northwest tip of Mesa Chivato and the Bear Mouth plug (dark ridge and point in background) in T. 16 N., R. 5 W.

are generally 1 ft thick or less, yet can be traced along strike over a considerable horizontal distance. These igneous rocks have had little or no metamorphic effect on the enclosing strata.

## GEOLOGIC STRUCTURE

The basic structure of the Torreon Wash area can be depicted as a gentle northwestward-dipping block. The regional orientation of the strata has a northeasterly strike and a dip of $4^{\circ}$ to $5^{\circ}$ to the northwest. Dips greater than $5^{\circ}$ are generally the result of primary depositional slopes or disturbances along faults. Complicating the general picture of the northwest-dipping block are a series of northeast-trending normal faults, usually with the east side of the fault raised relative to the west side. These faults have relatively small amounts of displacement, generally only a few tens of ft, with a maximum displacement of up to 150 ft along the more predominant faults. Often the amount of displacement is dispersed northward along the faults as they splay into several lesser strands. Faulting is most prominently displayed along the Point Lookout escarpment across the southern part of the Torreon Wash area. The successive stepwise-rise of the fault blocks to the east is probably related to the sharp uplift of the eastern edge of the San Juan Basin along the Nacimiento front.

Basaltic dikes in the area also reflect the same northeast-trending fracture pattern. An en echelon series of thin dikes occurs along a discontinuous line 11 mi long from Coal Spring in sec. 15, T16N, R5W, northeast to the east edge of Chacra Mesa in sec. 29, T18N, R4W.

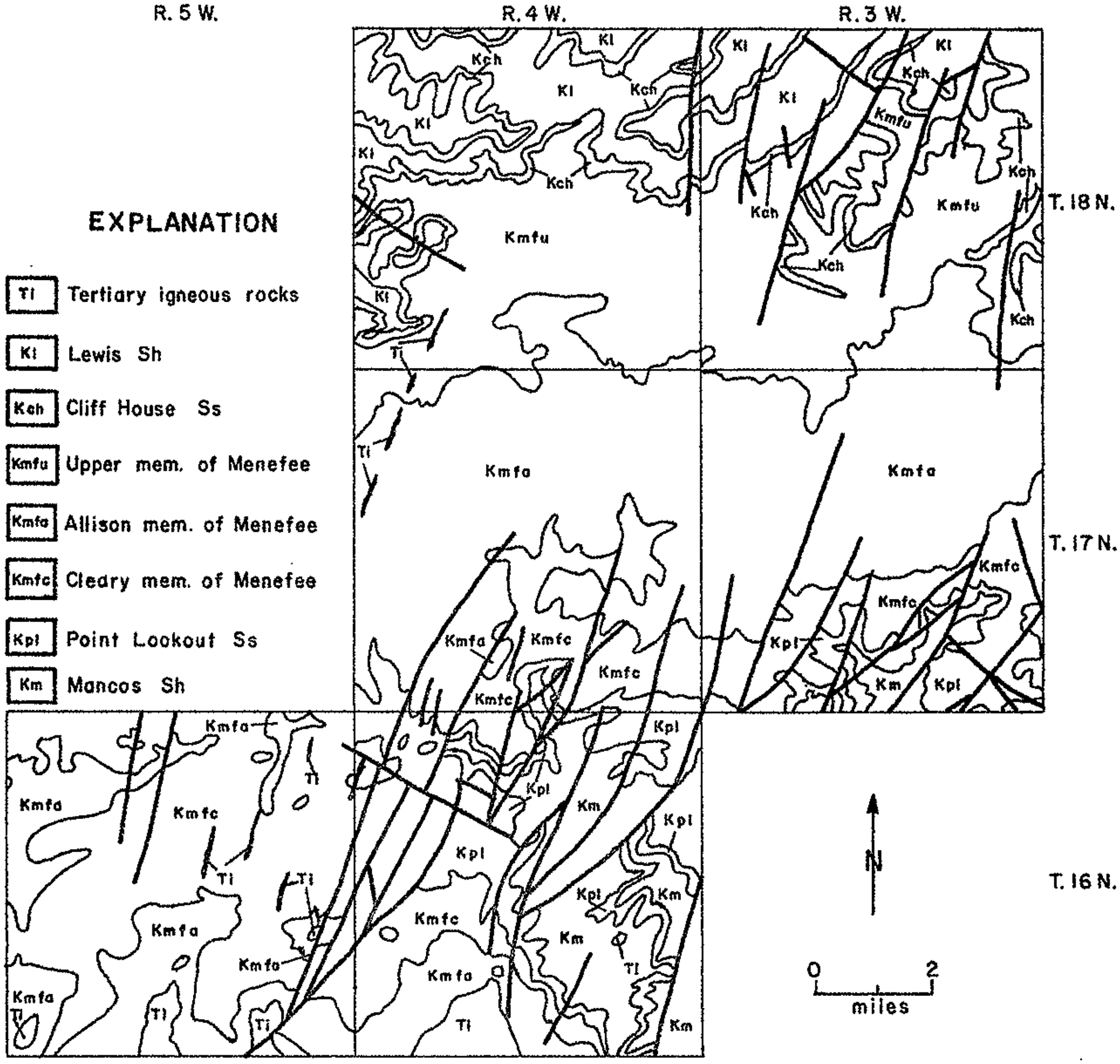



Figure 12. PAGE SIZE GEOLOGIC MAP OF THE TORREON WASH AREA

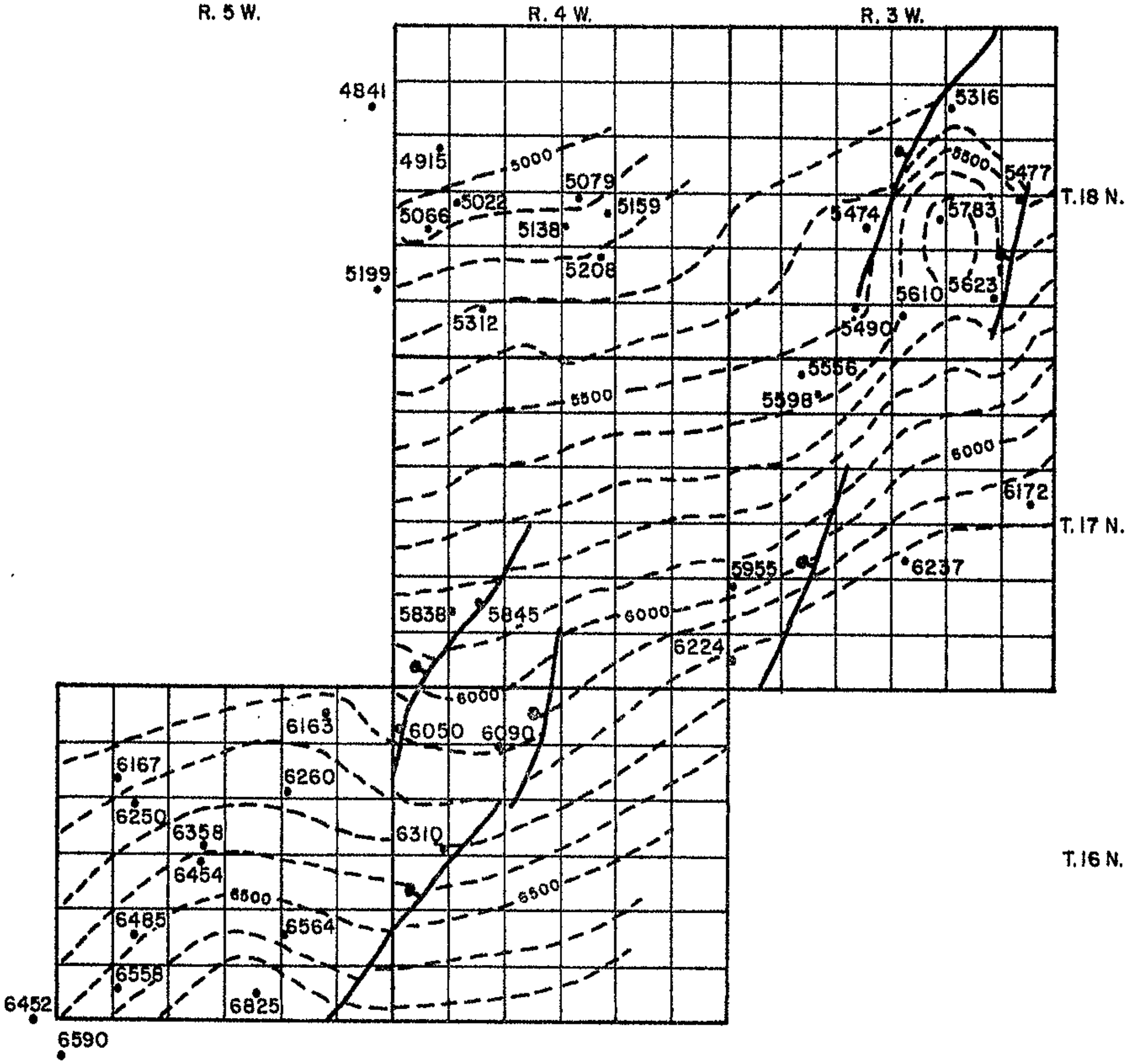



Figure 13. STRUCTURE CONTOUR MAP ON THE TOP OF THE POINT LOOKOUT SANDSTONE
(contour interval 100 ft.; datum sea level)

Folding in the area is relatively minor. The structure contour map on the top of the Point Lookout Sandstone shows a small domal structure in the southeastern part of T18N, R3W. This dome extends off a gentle north-plunging anticlinal flexure in T17N, R3W. Another gentle north-plunging anticlinal flexure occurs in T16N, R5W. Small amounts of folding also occur within 100 ft of some faults as a result of drag along the fault surface.

# DEPOSITIONAL ENVIRONMENT FOR MENEFEE COALS

## Introduction

The San Juan Basin region has been regarded as an area where depositional conditions were controlled by continued, steady subsidence and a variable supply of sediment to the shore (Sears, Hunt, and Hendricks, 1941). If sediment supply increased beyond the volume created by subsidence, then the shoreline deposits would build seaward, causing a regression of the sea. If sediment supply was less than the volume created by subsidence, then the seas would rework and override the shoreline deposits, causing transgression of the sea. Using this logic, ancient regressive shoreline deposits should be thinner and not as well-developed as ancient transgressive shoreline deposits because of their smaller supply of sediment and greater amount of reworking and erosion. The thickest ancient shoreline deposits should be where sediment supply and subsidence were in equilibrium and successive shoreline deposits were stacked upon each other. Correspondingly thick coal deposits should be found landward of the thick shoreline deposits (Figure 14).

## Point Lookout Stratigraphy and Cleary Member Coals

The Point Lookout Sandstone forms the basal unit on which the Cleary Member of the Menefee Formation was deposited. This sandstone is clearly a regressive,

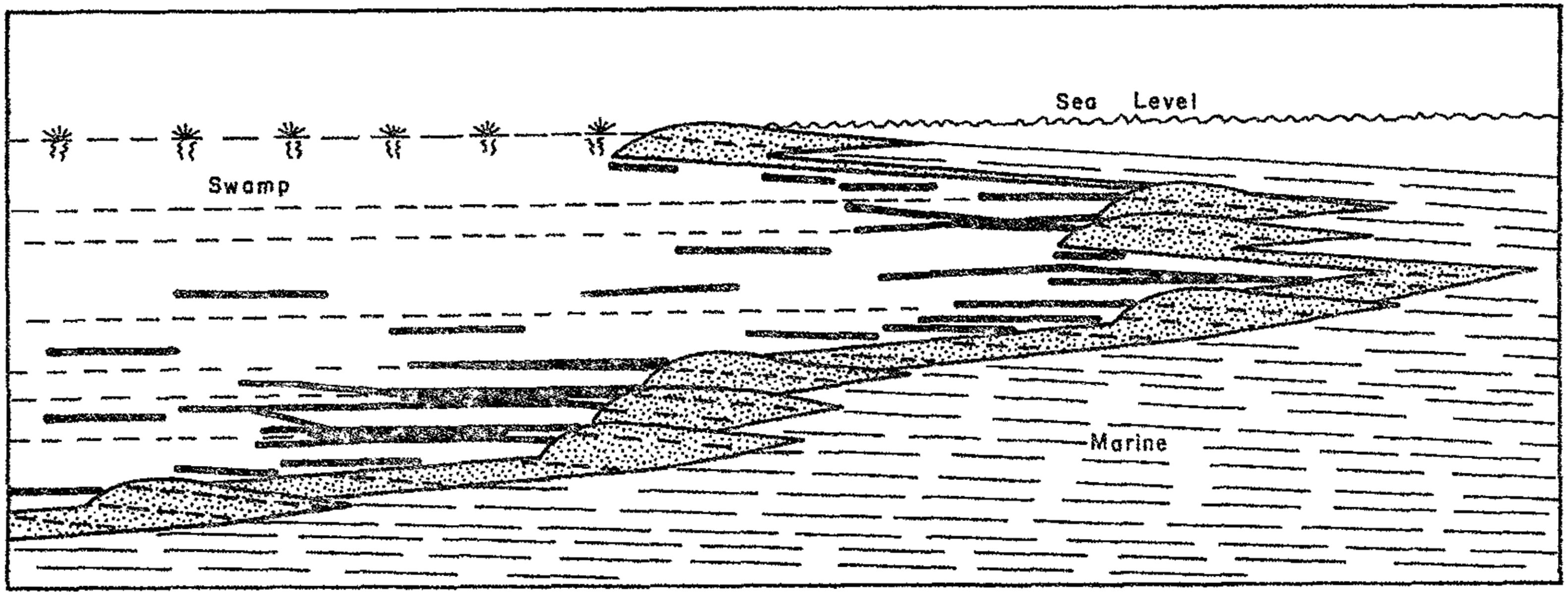



Figure 14. Diagrammatic section illustrating irregularity of sand and associated sediments for regressive and transgressive Cretaceous shoreline movements. (modified from Hollenshead and Pritchard, 1961)

shoreline-related deposit with its transitional sand-shale basal contact and a general upward increase in grain size. The Point Lookout forms a continuous, although progressively younger body of sand, starting from near Torreon in the south and extending northward over 120 mi to across the Colorado state line (Hollenshead and Pritchard, 1961). Hollenshead and Pritchard (1961) have further shown that rather than a single sheet, the Point Lookout consists of distinct northwest-southeast-trending benches which step up stratigraphically northeastward across the San Juan Basin. Along the length of the bench the thickness of the Point Lookout remains fairly constant at roughly 80 ft to 100 ft; however, at each step up it may thicken to as much as 250 ft. Northeast from each thickening,the lower part of the sandstone rapidly tongues out into marine shale while the upper part continues along at a new bench level.

Shomaker and others (1971) and Fassett and Hinds (1971) claim that Upper Cretaceous coal deposits in the San Juan Basin are oriented parallel to the ancient shorelines and are thickest landward of shoreline still stands,where a slow,steady buildup of sediment and organic debris occurred.

Understanding the nature of the stratigraphic changes in the Point Lookout in the Torreon Wash area should help understand the distribution of the Cleary or lower coals. Within the Torreon Wash area,two step-wise rises of the Point Lookout can be documented. The isopach of Point Lookout thicknesses (Figure 4, p. 11) shows a well-defined thickening of the

Point Lookout in the southern half of T18N, R3 and 4W, and a second, less well defined one running through the southern half of T17N, R4W. Correlation of electrical logs along a northeasterly-trending line from T16N, R5W, to T19N, R3W, further substantiates these two bench level changes (plate in pocket). Interestingly, in sec. 34 T17N, R4W, along the upper contact of a thick Point Lookout section where the southern edge of a stepwise rise occurs, a placer-like deposit or black sandstone deposit is exposed (Figure 15). This black sandstone deposit trends approximately N50°W, parallel to the ancient shoreline (Gill and Cobban, 1969). Houston and Murphy (1977) suggest that "black sandstone" concentrations are evidence of temporary shoreline stillstands during regression. Thus it would appear that the increased thickness of sand and the presence of black sandstone deposits in the Point Lookout do represent temporary stillstands of the shoreline before further regression.

The Point Lookout stratigraphic stepwise rises record shoreline orientation and stillstand conditions, the criteria previously cited for locating major coal deposits. Comparison of an isopach map of total coal thickness in the Cleary Member within 250 ft above the top of the Point Lookout, (Figure 6) with the isopach map for the Point Lookout (Figure 4, p. 11) shows the major accumulations of coal are found landward (south) and parallel to the benches of the Point Lookout, as would be expected. One northwest-trending accumulation of coal occurs in the southern part of T18N, R4W, and extends into

FIGURE 15 - The "black" sandstone deposit is visible as a dark ledge in the middle of the hill at the top of the vuggy-weathering white Point Lookout Sandstone. The covered slope above the "black" sandstone is coal-bearing lower Menefee Formation.

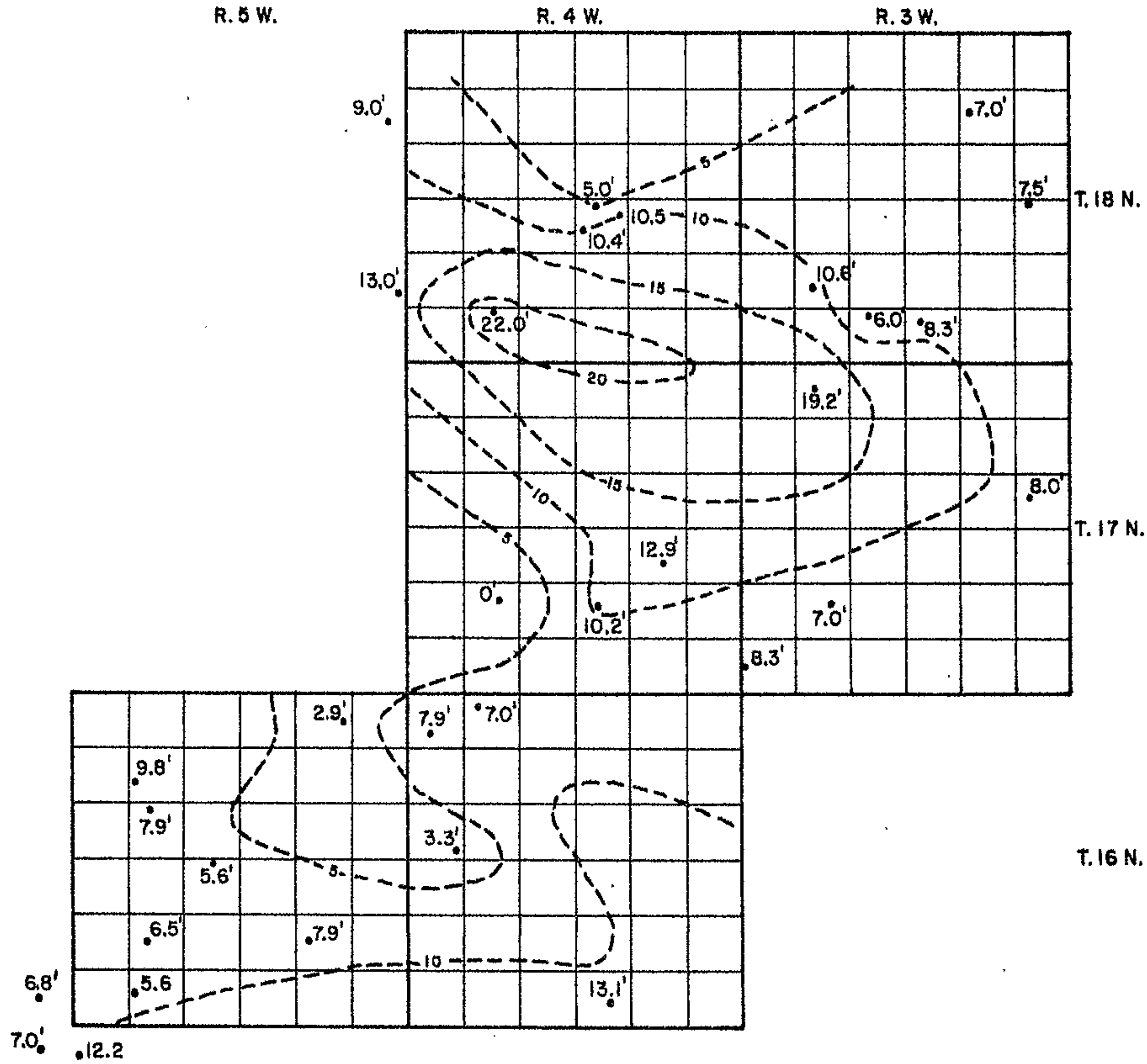



Figure 16. ISOPACHOUS MAP OF TOTAL COAL IN THE CLEARY MEMBER OF THE MENEFEE FORMATION
(for beds at least 1 ft. thick; contour interval 5 ft.)

the northwest corner of T17N, R3W. A second concentration of coal occurs in T16W, R4 and 5W.

Cliff House Stratigraphy and Upper Member Menefee Coals

As demonstrated with the Cleary coals, the upper member coals of the Menefee Formation are also associated with thick sand buildups related to shoreline stillstands. The upper member coals in the Torreon Wash area are related to the very thick La Ventana sand buildup to the northeast. Mannhard (1976) has shown this sand body resulted from a delicate balance between sediment supply and subsidence. This depositional condition caused numerous constructional and destructional delta front sands to be stacked vertically as a thick pile (Figure 17). Shomaker and Whyte (1977) discovered that considerable tonnages of coal occur in upper member Menefee tongues enclosed within the La Ventana in the subsurface across the San Juan Basin. Surface exposures of these coal-bearing tongues occur in the northeastern part of the study area. The upper member coals in the Torreon Wash area are up to 13 ft thick, but usually average 2 ft thick or less. These coals generally thin and become less numerous to the south and west across the northern township tier,eventually giving way to brown humic shales. Conversely,these coals thicken and become more numerous to the north and east. Dane (1936) reports beds commonly reaching 5 ft thick and several instances of prospects in beds 6-,7-, and 9-ft thick in T18N, R2W, and T19N, R1 and 2W.

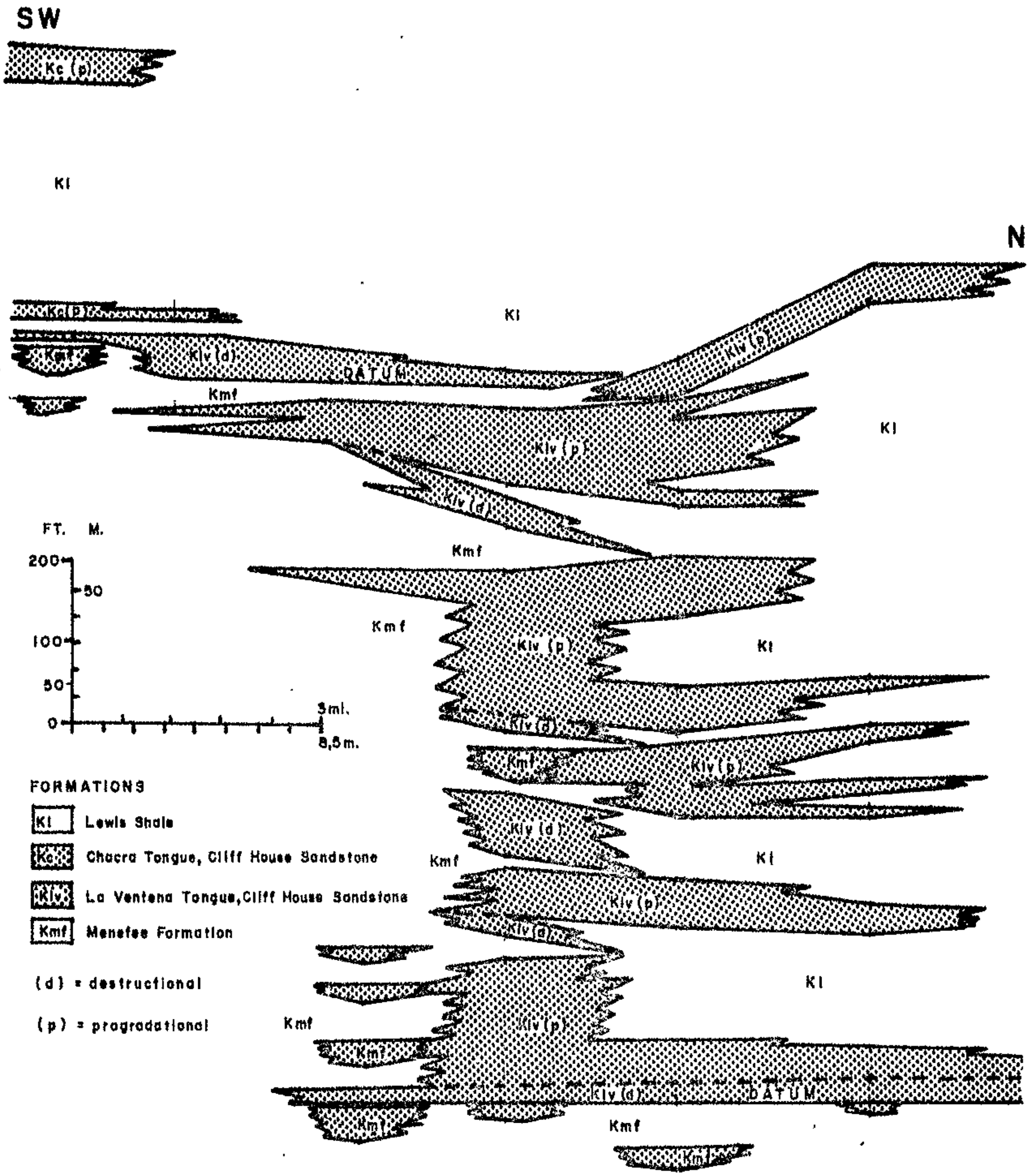



Figure 17. GENERAL STRATIGRAPHIC CROSS SECTION OF THE LA VENTANA TONGUE AND ADJACENT UNITS (modified from Mannhard, 1976)

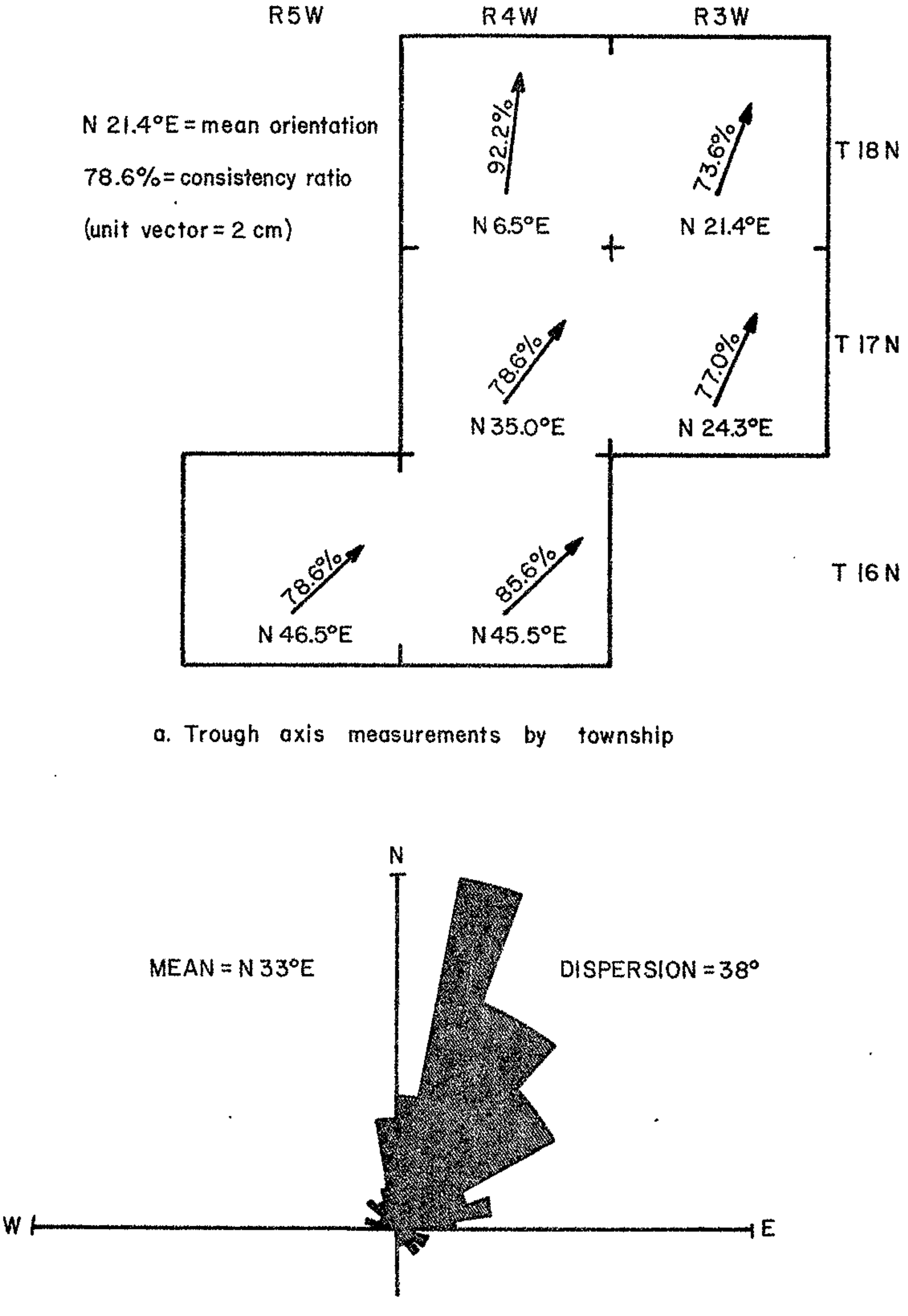
Only thin coals occur below or interstratified with the Cliff House Sandstone on Chacra Mesa in T18N, R4W. However, it has been recognized by Dane (1936) and Shomaker and others (1971) that the Cliff House represents a sand buildup similar to the La Ventana deltaic buildup,but shifted slightly to the southwest. The Cliff House Sandstone, which grades rapidly northeastward into marine shale, probably also graded southwestward to continental deposits which have since been removed by erosion. Were these nonmarine upper member rocks still present to the southwest of the Cliff House buildup,they undoubtedly would contain economic deposits of coal similar to those behind the La Ventana (Beaumont and Shomaker, 1974).

## General Environment of the Menefee

Several lines of evidence point to the fact that the Menefee Formation was deposited in a deltaic environment rather than in a lagoonal environment. The sandstone units enclosing the Menefee all appear to be deltaic or delta-related. The thick tongues of the transgressive Cliff House Sandstone which overlie and intertongue with the Menefee show definite deltaic features (Beaumont and others, 1977; Mannhard, 1976). The Point Lookout Sandstone which is overlain by the Menefee also appears to have deltaic affinities. The Point Lookout consists of a surprisingly thick (as much as 250 ft) regressive marine sandstone deposit. The immature, silty, clayey, very fine to fine sands which make up the Point Lookout are typical of the material delivered by fluvio-deltaic distributaries to a delta front. The sands of the Point Lookout often contain thin, interlaminated, carbonaceous debris and clay clasts, unlike typical, clean, wave-winnowed beach sands. The marine invertebrate fossils found in the Point Lookout are commonly accumulations of mixed faunal assemblages which appear to be storm deposits rather than a record of living communities (Shetiwy, 1978). Finally, the direct superposition of fresh-water coal swamp deposits on the Point Lookout and the lack of any recognized lagoonal deposits and an associated brackish-water faunal assemblage makes it difficult to fit the Point Lookout into a simple, barrier-beach depositional model.

The sediments of the Menefee Formation themselves show the characteristics of deltaic and fluvial plain deposits rather than those of lagoonal deposits (Beaumont and others, 1976; Siemers, 1978). As previously mentioned, no brackish-water invertebrates occur in the Menefee which is associated with the bounding marine sandstones. The close association of Menefee coals with fluvial channel sandstones offers more evidence that they were deposited in a fresh-water system. The coals also have common leaf impressions and bits of amber which suggests that they formed mainly from the accumulation of tree or woody vegetation in fresh-water swamps, and not from the accumulation of reeds in brackish marshes. A pollen study done on a coal sample taken from the lowest Menefee coal at a locality near Farmington, N.M., showed that 70% of the pollen came from trees,while the remaining 30% came from ferns (Tschudy, 1976). This pollen distribution is what would be expected in a tree-dominated,fresh-water swamp. The low sulfur content of the Menefee coals is another indication of their accumulation in a fresh-water system. The organic-rich sediments associated with the coals commonly contain iron-rich nodules. Mannhard (1976) reports these sideritic nodules are good indicators of reducing conditions typically caused by anaerobic,bacterial decay of vegetative debris in poorly drained,nonmarine,organic-rich sediments.

The normal succession of environments in a deltaic setting is from poorly drained,lower-delta-plain sediments to well-drained,fluvial sediments of the upper-delta-plain or fluvial plain. This transition is preserved in the Menefee when going from the Cleary Member to the Allison Member. The Allison Member is composed of channel sandstone bodies and organic-poor overbank mudstones and shales. The channel sand bodies are characterized by strong,unidirectional transport features as shown in the well-developed trough cross-stratification in these units (Figure 18). Statistical analysis of 279 trough axis measurements from the Menefee shows a closely grouped,northeast-trending transport direction with a consistency ratio of over 77%. The angular dispersion of the readings is fairly low at 38°,and probably reflects meandering of the Menefee channels. Mannhard (1976) calculated stream parameters for three Menefee channels based on their physical sedimentary characteristics and




a. Trough axis measurements by township



b. Rose diagram of 279 trough axis measurements (data group in 10° sectors)

Figure 18. MENEFEE TROUGH AXIS PALEOCURRENT DATA

determined that the streams which formed the channel deposits had irregular meanders along a low stream gradient (27m/km or less). These streams generally carried suspended loads and some mixed loads. The overbank mudstones and shales associated with the channel deposits are light gray, tan, and yellow and contain very little organic matter, reflecting well-drained,oxidizing depositional conditions of the upper delta plain.

The upper member of the Menefee reflects a reversal from upper-delta-plain/fluvial-plain deposits back to lower-delta-plain deposits. The organic-rich, coal-bearing sediments of the upper Menefee are definitely deltaic since they intertongue with the deltaic La Ventana sandstones.

From a systematic study of data from measured sections through the Menefee, Siemers (1978) was able to develop model Menefee depositional sequences. From his modelling he found that Menefee deposits do not represent nearshore marine or lagoonal deposits. The Menefee deposits instead reflect continental-fluvial-plain to delta-plain sedimentation.

## COAL GEOLOGY

### Description of Surface Exposures

T16N, R4W -- The Mancos Shale crops out in the central and eastern parts of this township. The Hosta and Point Lookout Sandstones cap the mesas in the eastern half of this township.

The Cleary Member of the Menefee Formation crops out in the low-lying area in sections 4-8, 17-20, and 30. Exposures of the coal beds in the Cleary are good throughout this area. These coals range in thickness from 1 ft to 4 ft, with an average of 2.5 ft. Parallel faults roughly spaced 1/3 mile apart splay from the south, disrupting this area. Coal in sections 29, 28, and 31-34 of this township occurs on the steep slopes of Mesa Chivato. These slopes are formed by the Cleary and Allision Members of the Menefee Formation and a thick basaltic flow at the top. Volcanic debris from the flow capping the mesa covers much of these slopes, leaving poor to fair exposures of the Cleary coal beds. Continuity of these beds is fair, with an average thickness of 2 ft.

T16N, R5W -- This township has good exposures of the Cleary Member throughout. In sections 1-12 the coal beds are well exposed. These beds show an average thickness of 2.8 ft. Sections 13-20 are underlain by coal with only a few outcrops exposing the coal beds for short distances. The upper portion of the Cleary Member is exposed in sections 21-25. Exposures of the barren Allison Member of the Menefee Formation outcrop along the highest slopes in sections 26-36.

T17N, R3W -- A north-facing dip slope of the Point Lookout Sandstone crosses the southern part of this township. Coals of the Cleary Member crop out in a roughly east-west belt to the north of this. Two coal zones are traceable across the township approximately 0 and 70 ft above the Point Lookout Sandstone. The lower of these zones contains good coal beds that are persistent but show a high degree of lenticularity. The lower coals average 2.5 ft in thickness. The higher zone has beds averaging 2 ft in thickness. The northern two thirds of this township are covered by the Allison Member; no coals occur there.

T17N, R4W -- No coals exist in the Allison Member which crops out in most of this township. This member consists of thick-bedded, light-colored sandstones and interbedded siltstones and shales forming north-dipping cuestas and mesas. The massive basal sand sequence creates a rugged terrain in the southern part of the township.

The southeastern quarter of this township has good to excellent coal exposures of the Cleary Member. In sections 22-27 and 34-36 the coal beds are continuous, with a variation in thickness from 1.5 ft to 3.5 ft. Three separate beds outcrop in these sections. A small amount of burned coal occurs in sec. 27 and 34. In sec. 34 the Tochias coal mine operated on two 2-ft beds from 1933 to 1935.

The northern half of this township has no coal exposures except in sections 3 and 4. In these two sections the upper unnamed member of the Menefee Formation begins to outcrop. The coals are continuous with an average thickness of 1.7 ft.

T18N, R3W -- The La Ventana sandstone, Cliff House Sandstone, and the Lewis Shale crop out in the northern half of this township. Tracing and correlating these units is difficult because of the lenticularity of the sandstones and the presence of faults.

Good exposures of six coal beds of the upper unnamed member of the Menefee Formation occur in the southern half of this township. The beds are continuous throughout the southern half of the township and range in thickness from 1.3 ft to 3.6 ft. Some burned coal occurs in sections 19 and 30.

T18N, R4W -- Exposures of the La Ventana sandstone, Lewis Shale, and Cliff House Sandstone cover the northern half of this township. They form a series of gently north-dipping mesas.

The upper unnamed member of the Menefee Formation occurs in the southern half of this township. Coal occurs in four horizons within this unit in T18N, R4W. Persistent burned coal horizons mask much of the outcrops in this area, making coal thicknesses unobtainable. Good exposures of coal are found in the southern part of this township. Here coal beds range in thickness from 1.2 ft to 1.9 ft **and** are quite continuous.

## Coal Analyses

The analyses given in this report are from core samples and drill cuttings. Moisture ranges from 4.64 to 13.66 percent with 11.74 percent being the average. The rank of the coal based on heating value is sub-bituminous C to sub-bituminous B. The range of heating value for these coals is 7,405 to 11,828 BTU per pound, with an average near 10,360 BTU per pound.

The ash content is present as discrete partings or material intimately mingled with the coal itself. The samples contain 3.2 to 33.8 percent ash, averaging 14.6 percent. Sulfur content ranges between 0.42 and 2.47 percent and averages about 0.8. Volatile matter ranges between 28.7 and 38.2 percent and averages 34.7; fixed carbon ranges between 30.6 and 48.2 percent with the average of 41.0 percent. Table 2 lists the analyses of samples from the drilling program for this study.

## Coal Prospects and Mines

One small prospect occurs in the study area **in** NW-l/4, NW-1/4 sec. 34, T17N, R4W. This prospect was operated by Mr, Rudolf Tochias from 1933 to 1935 under federal Coal prospecting permit #SF-065988. U.S.G.S. Conservation Division records show that Mr. Tochias sold 88 tons of coal from the prospect.

## COAL ANALYSES*

| | Proximate | | | | Ultimate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moisture | Ash | Volatile Matter | Fixed Carbon | Hydrogen | Carbon | Nitrogen | Oxygen | Sulfur | Ash | BTU/lb. |
| C1-4649+5455 | 11.31 | 8.09 | 38.25 | 42.35 | 4.53 | 61.99 | 1.45 | 11.98 | 0.65 | 8.09 | 11,030 |
| C1-5760+6061 | 11.46 | 16.00 | 34.61 | 37.93 | 3.76 | 55.56 | 1.16 | 9.59 | 2.47 | 16.00 | 9,858 |
| C1-6769 | 10.42 | 24.42 | 32.23 | 32.93 | 3.52 | 49.41 | 1.09 | 8.96 | 2.18 | 24.42 | 8,596 |
| C1-154158 | 11.12 | 6.21 | 36.81 | 45.86 | 4.44 | 65.17 | 1.36 | 11.20 | 0.50 | 6.21 | 11,357 |
| C1-158164 | 13.66 | 3.17 | 36.63 | 46.54 | 4.32 | 66.75 | 1.41 | 10.25 | 0.44 | 3.17 | 11,542 |
| C1-164168 | 12.27 | 4.90 | 36.52 | 46.31 | 3.75 | 65.68 | 1.39 | 11.58 | 0.43 | 4.90 | 11,423 |
| C2-117118+119121 | 11.35 | 16.49 | 35.34 | 36.82 | 4.04 | 57.22 | 1.35 | 8.81 | 0.74 | 16.49 | 9,783 |
| C3-221-224 | 6.72 | 8.68 | 36.38 | 48.22 | 4.66 | 67.43 | 1.33 | 10.49 | 0.69 | 8.68 | 11,828 |
| C4-171-175 | 9.55 | 9.84 | 35.03 | 45.58 | 4.44 | 64.63 | 1.36 | 9.75 | 0.43 | 9.84 | 11,270 |
| C5-1418 | 7.52 | 31.33 | 29.38 | 31.77 | 3.71 | 44.58 | 1.04 | 20.15 | 0.42 | 31.33 | 7,405 |
| C5-9799 | 6.90 | 33.80 | 28.71 | 30.59 | 4.09 | 46.63 | 1.06 | 14.51 | 0.47 | 33.80 | 8,244 |
| C5-123127 | 7.89 | 11.46 | 35.17 | 45.48 | 5.26 | 63.81 | 1.13 | 17.70 | 0.64 | 11.46 | 11,412 |
| R33-8085 | 4.64 | 15.91 | 36.55 | 42.90 | 4.91 | 62.44 | 1.32 | 14.75 | 0.78 | 15.91 | 10,927 |

<u>Explanation of sample number:</u>

C1 = core hole #1
R33 = rotary hole #33
4951 = sample from 49' to 51'
(for location of drill holes see appendix 2)

* As received

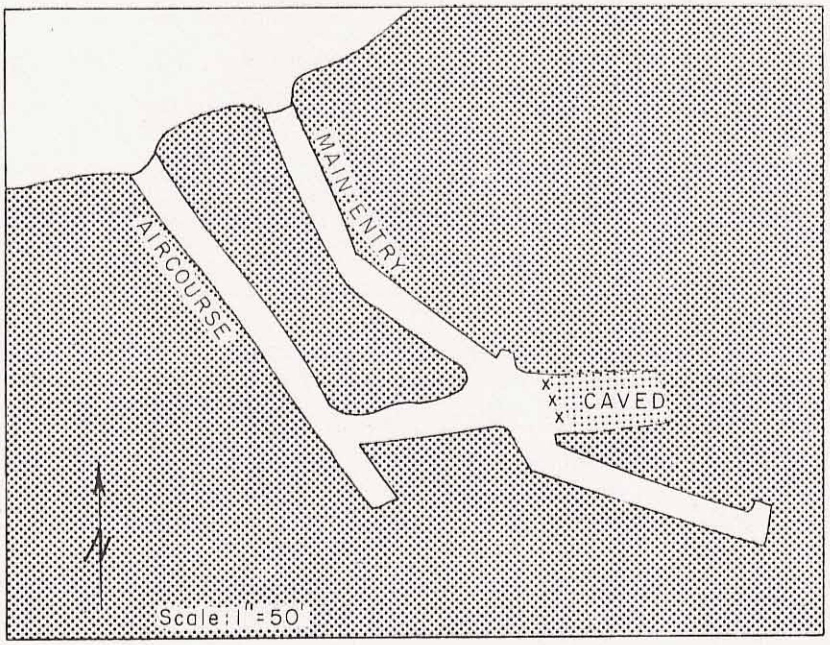
The underground workings consist of two parallel tunnels with a crosscut joining the two (Figure 19). Both tunnels are badly caved and no attempt was made to enter them. The surface works are in poor repair and therefore were not explored. An inspection report of the U.S.G.S. Mining Division made in 1935 states that the prospect workings were dry and flat.

T16N, R5W,and the western third of T16N, R4W,of the study area were recently nominated by Arizona Public Service Co. in response to a BLM request for company nominations of tracts of interest for leasing. This request was made to assess the suitability and impact of leasing federal coal lands in preparation for the establishment of a federal coal leasing policy.

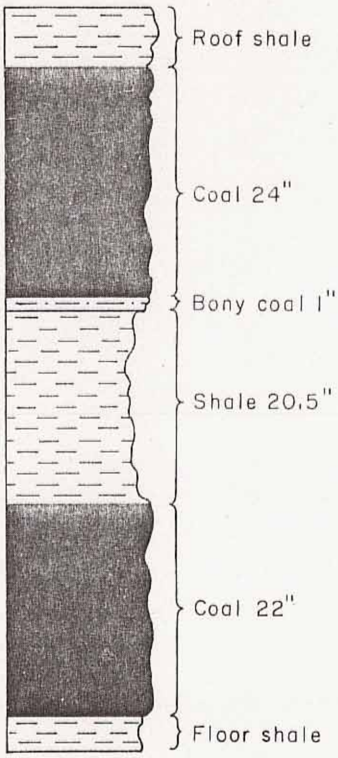
In January, 1978,a permit to surface mine coal two miles east of the study area in the N-1/2 sec. 16, T17N, R2W,was granted by the New Mexico Coal Surface Mining Commission to Mr. Albert J. Firchau of Seattle, Washington. The proposed Arroyo #1 mine will extract coal from the Cleary Member of the Menefee Formation,or first coal interval overlying the Point Lookout Sandstone. The mine plan calls for an annual production of 200,000 tons for six years.

West of the study area, in T16N, R6W, the Santa Fe Railroad conducted an exploration drilling program in 1972-73 to test reserves on their holdings. The coal interval drilled was the lower Menefee Formation. No plans for the development of this coal have been announced.

Surface Works of Tochias Prospect in 1978




Coal Mine Map-1935




Coal Section Mined

FIGURE 19 - Photograph and mine map of the Tochias prospect along with an illustration of the coal section mined.

## Coal Resources

The coal resources calculated for the Torreon area are based on field measurement of coal outcrops and drill hole information. All resources are calculated for coal beds 14 in (1.2 ft) or greater in thickness. An acre-foot of coal was assumed to weigh 1770 tons. Guidelines modified from those, set forth in U.S.G.S. Bulletin 1450-B are used; no measured resources are identified. Due to the extreme lenticularity of the coal beds, the data-point spacing is insufficient for precise quantitative determination of measured resources. The resources calculated fall into two classes, indicated and inferred.

Indicated resources are based on the following criteria:

> The points of observation are 1/2 mi (0.8 km) to 1-1/2 mi (2.4 km) apart or closer. Indicated resources are projected to extend as a 1/2 mi (0.8 km) wide belt from the outcrop or in a 1/4 mi radius around a drill hole.

Inferred resources are based on the following criteria:

> The points of observation are 1-1/2 mi (2.4 km) to 6 mi (9.6 km) apart. Inferred resources are projected to extend as a 2-1/4 mi (3.6 km) wide belt that lies more than 1/2 mi (0.8 km) from the outcrop or 1/4 mi from a drill hole.

The resources are further divided into two depth categories: shallow, those from 0 ft to 250 ft; and deep, those from 250 ft to 3000 ft (no coal deeper than 3000 ft occurs in study area). Using these criteria, the study area contains 117,027,692 tons of indicated resources and 389,566,363 tons of inferred resources within 250 ft of the surface. The shallow resources are listed by section and township in Table 5 on the following pages. The 250-3000 foot class contains 200,955,000 tons of indicated resources and 712,477,000 tons of inferred resources.

Table 3 - Shallow Indicated Resources

T.16 N., R.4 W.

| Sec. | Tons | Sec. | Tons |
|---|---|---|---|
| 1 | 0 | 19 | 1,470,836 |
| 2 | 0 | 20 | 230,602 |
| 3 | 1,797,683 | 21 | 19,505 |
| 4 | 1,219,043 | 22 | 0 |
| 5 | 1,997,171 | 23 | 0 |
| 6 | 1,819,304 | 24 | 0 |
| 7 | 249,498 | 25 | 0 |
| 8 | 0 | 26 | 0 |
| 9 | 0 | 27 | 76,393 |
| 10 | 0 | 28 | 780,305 |
| 11 | 0 | 29 | 910,219 |
| 12 | 0 | 30 | 1,180,135 |
| 13 | 0 | 31 | 0 |
| 14 | 0 | 32 | 0 |
| 15 | 0 | 33 | 0 |
| 16 | 0 | 34 | 3,845,675 |
| 17 | 1,061,211 | 35 | 0 |
| 18 | 605,988 | 36 | 0 |

Total 17,236,568 tons

Table 3 - Shallow Indicated Resources

T.16 N., R.5 W.

| Sec. | Tons | Sec. | Tons |
|---|---|---|---|
| 1 | 1,565,265 | 19 | 1,397,836 |
| 2 | 1,815,244 | 20 | 1,300,313 |
| 3 | 1,243,422 | 21 | 2,113,009 |
| 4 | 1,917,972 | 22 | 1,343,430 |
| 5 | 0 | 23 | 598,970 |
| 6 | 0 | 24 | 143,009 |
| 7 | 0 | 25 | 292,570 |
| 8 | 915,696 | 26 | 449,421 |
| 9 | 1,292,192 | 27 | 1,412,465 |
| 10 | 219,428 | 28 | 0 |
| 11 | 5,284,038 | 29 | 0 |
| 12 | 889,078 | 30 | 0 |
| 13 | 1,170,282 | 31 | 0 |
| 14 | 1,976,653 | 32 | 1,183,285 |
| 15 | 1,914,839 | 33 | 0 |
| 16 | 1,599,488 | 34 | 0 |
| 17 | 1,759,575 | 35 | 0 |
| 18 | 617,649 | 36 | 0 |

Total 34,415,129 tons

Table 3 - Shallow Indicated Resources

T.17 N., R.3 W.

| Sec. | Tons | Sec. | Tons |
|---|---|---|---|
| 1 | 0 | 19 | 0 |
| 2 | 0 | 20 | 24,381 |
| 3 | 0 | 21 | 195,047 |
| 4 | 0 | 22 | 1,344,225 |
| 5 | 0 | 23 | 1,111,768 |
| 6 | 0 | 24 | 2,015,435 |
| 7 | 0 | 25 | 0 |
| 8 | 0 | 26 | 113,776 |
| 9 | 0 | 27 | 2,045,572 |
| 10 | 0 | 28 | 832,343 |
| 11 | 0 | 29 | 1,547,263 |
| 12 | 0 | 30 | 162,486 |
| 13 | 715,172 | 31 | 3,445,689 |
| 14 | 71,517 | 32 | 1,472,386 |
| 15 | 0 | 33 | 637,168 |
| 16 | 0 | 34 | 165,789 |
| 17 | 214,552 | 35 | 195,047 |
| 18 | 97,523 | 36 | 48,762 |

Total 17,804,905 tons

Table 3 - Shallow Indicated Resources

T.17 N., R.4 W.

| Sec. | Tons | Sec. | Tons |
|---|---|---|---|
| 1 | 0 | 19 | 0 |
| 2 | 0 | 20 | 0 |
| 3 | 0 | 21 | 0 |
| 4 | 0 | 22 | 0 |
| 5 | 0 | 23 | 1,887,079 |
| 6 | 0 | 24 | 1,048,337 |
| 7 | 0 | 25 | 731,578 |
| 8 | 0 | 26 | 580,265 |
| 9 | 0 | 27 | 2,629,694 |
| 10 | 0 | 28 | 0 |
| 11 | 0 | 29 | 0 |
| 12 | 0 | 30 | 0 |
| 13 | 0 | 31 | 0 |
| 14 | 0 | 32 | 0 |
| 15 | 0 | 33 | 0 |
| 16 | 0 | 34 | 0 |
| 17 | 0 | 35 | 1,799,028 |
| 18 | 0 | 36 | 4,021,286 |

Total 12,812,698 tons

Table 3 - Shallow Indicated Resources

T.18 N., R.3 W.

| Sec. | Tons | Sec. | Tons |
|---|---|---|---|
| 1 | 0 | 19 | 4,557,154 |
| 2 | 534,246 | 20 | 6,712,769 |
| 3 | 0 | 21 | 5,639,908 |
| 4 | 1,782,936 | 22 | 47,121 |
| 5 | 0 | 23 | 432,354 |
| 6 | 0 | 24 | 58,495 |
| 7 | 0 | 25 | 250,310 |
| 8 | 0 | 26 | 0 |
| 9 | 0 | 27 | 357,586 |
| 10 | 0 | 28 | 1,078,220 |
| 11 | 1,177,209 | 29 | 1,062,995 |
| 12 | 19,498 | 30 | 105,645 |
| 13 | 0 | 31 | 29,247 |
| 14 | 1,441,789 | 32 | 19,505 |
| 15 | 1,084,136 | 33 | 38,996 |
| 16 | 0 | 34 | 0 |
| 17 | 0 | 35 | 0 |
| 18 | 2,145,537 | 36 | 175,542 |

Total 28,751,198 tons

Table 3 - Shallow Indicated Resources

T.18 N., R.4 W.

| Sec. | Tons | Sec. | Tons |
|---|---|---|---|
| 1 | 0 | 19 | 0 |
| 2 | 0 | 20 | 19,505 |
| 3 | 0 | 21 | 434,856 |
| 4 | 0 | 22 | 591,143 |
| 5 | 0 | 23 | 65,016 |
| 6 | 0 | 24 | 0 |
| 7 | 260,063 | 25 | 0 |
| 8 | 0 | 26 | 117,028 |
| 9 | 0 | 27 | 928,226 |
| 10 | 0 | 28 | 929,101 |
| 11 | 0 | 29 | 377,606 |
| 12 | 0 | 30 | 0 |
| 13 | 0 | 31 | 0 |
| 14 | 0 | 32 | 755,211 |
| 15 | 24,381 | 33 | 0 |
| 16 | 0 | 34 | 0 |
| 17 | 232,090 | 35 | 414,475 |
| 18 | 574,050 | 36 | 284,443 |

Total 6,007,194 tons

## Coal and Surface Ownership

The ownership pattern of the surface and coal rights in the study area shows the federal government is the predominant owner in both cases. 71.5% of the surface rights and 86.3% of the coal rights are federally owned. The remaining surface and coal rights are divided between state, private, and Indian ownership. Tables 4 and 5 show the exact breakdown for surface and coal ownership respectively for each township, as well as for the study area as a whole. No known coal leases exist within the Torreon Wash area. (See ownership maps in Appendix I).

Table 4

Percent Ownership of Surface by Township

| Township | T16N R4W | T16N R5W | T17W R3W | T17W R4W | T18W R3W | T18W R4W |
|---|---|---|---|---|---|---|
| Federal | 86.5% | 87.5% | 84 % | 66.0% | 66.0% | 40.5% |
| State | 5.6% | 0 | 10.8% | 8.3% | 2.8% | 5.6% |
| Private | 7 % | 12.5% | 4.2% | 10.4% | 13.9% | 0 |
| Indian | 0.7% | 0 | 1.4% | 15.3% | 17.3% | 56.1% |

TOTAL STUDY AREA: 71.5% -- Federal
5.4% -- State
8.0% -- Private
15.1% -- Indian

Table 5

Percent Ownership of Coal by Township

| Township | T16N R4W | T16W R5W | T17W R3W | T17W R4W | T18W R3W | T18W R4W |
|---|---|---|---|---|---|---|
| Federal | 72% | 77% | 89.2% | 89.5% | 97.2% | 93% |
| State | 11% | 6% | 10.8% | 4.9% | 2.8% | 4.2% |
| Private | 16% | 17% | 0 | 5.6% | 0 | 0 |
| Indian | 0.7% | 0 | 0 | 0 | 0 | 2.8% |

TOTAL STUDY AREA: 86.3% -- Federal
6.6% -- State
6.4% -- Private
0.6% -- Indian

It should be noted that the Bureau of Land Management, Department of the Interior, is in the process of exchanging approximately 6,080 acres or 4.4% of the surface rights of the study area. This exchange program is to adjust Navajo Indian land matters, particularly unauthorized occupancy in areas outside and in the vicinity of the Navajo Indian Reservation. Land involved in the exchange falls in T17N, R4W, and T18N, R3 and 4W. The exchange will involve only the surface rights to the land; mineral rights will be retained by the present owner. It is expected that the exchange will be completed by early 1979. A legal description of the land involved in the exchange follows:

T18N, R3W
sec. 4, lots 3, 4, and S½NW¼;
sec. 5, SW¼;
sec. 7, E½;
sec. 8, NE¼, NW¼, N½, SW¼,
N½SW¼, SW¼, SW¼, SW¼, SW¼,
E½SE", SW", SW¼, and SW¼;
sec. 16, NE¼ and SW¼;
sec. 18, lots 3, 4, E½SW¼, and SE¼;
sec. 20, SW¼;
sec. 21, NW¼;
sec. 28, W½;
sec. 29, SE¼.

T17N, R4W
sec. 2, SW¼ and SE¼;
sec. 3, SW¼;
sec. 5, lots 3, 4, and S½NW¼;
sec. 7, SE¼;
sec. 11, NW¼;
sec. 18, SE¼;
sec. 19, NE¼;
sec. 20, W½.

T18N, R4W
sec. 7, lots 1, 2, E½NW¼, and SE¼;
sec. 15, NE¼;
sec. 19, SE¼;
sec. 20, NE¼;
sec. 24, SE¼;
sec. 27, N½;
sec. 29, N½;
sec. 35, SE¼.

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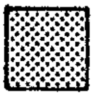
APPENDIX I

Coal and Surface Ownership Maps

# OWNERSHIP INDEX

## SURFACE OWNERSHIP

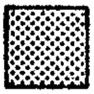
 PRIVATE

 STATE

 INDIAN

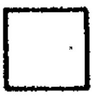
 FEDERAL

## COAL OWNERSHIP

 PRIVATE

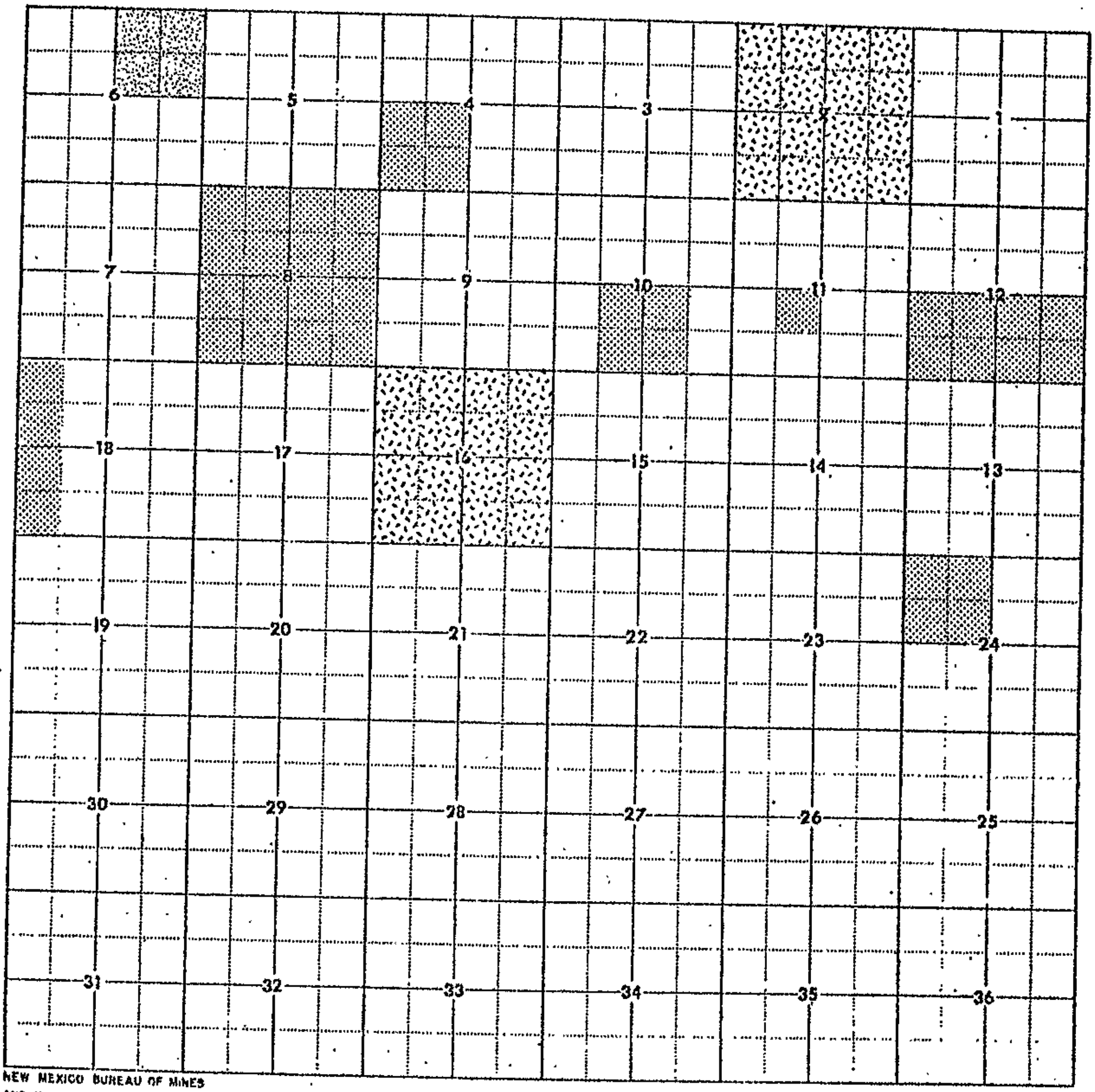
 STATE

 INDIAN

 FEDERAL

## SURFACE OWNERSHIP

LOCATION ________ TOWNSHIP T16N RANGE R4W COUNTY ________ STATE ________

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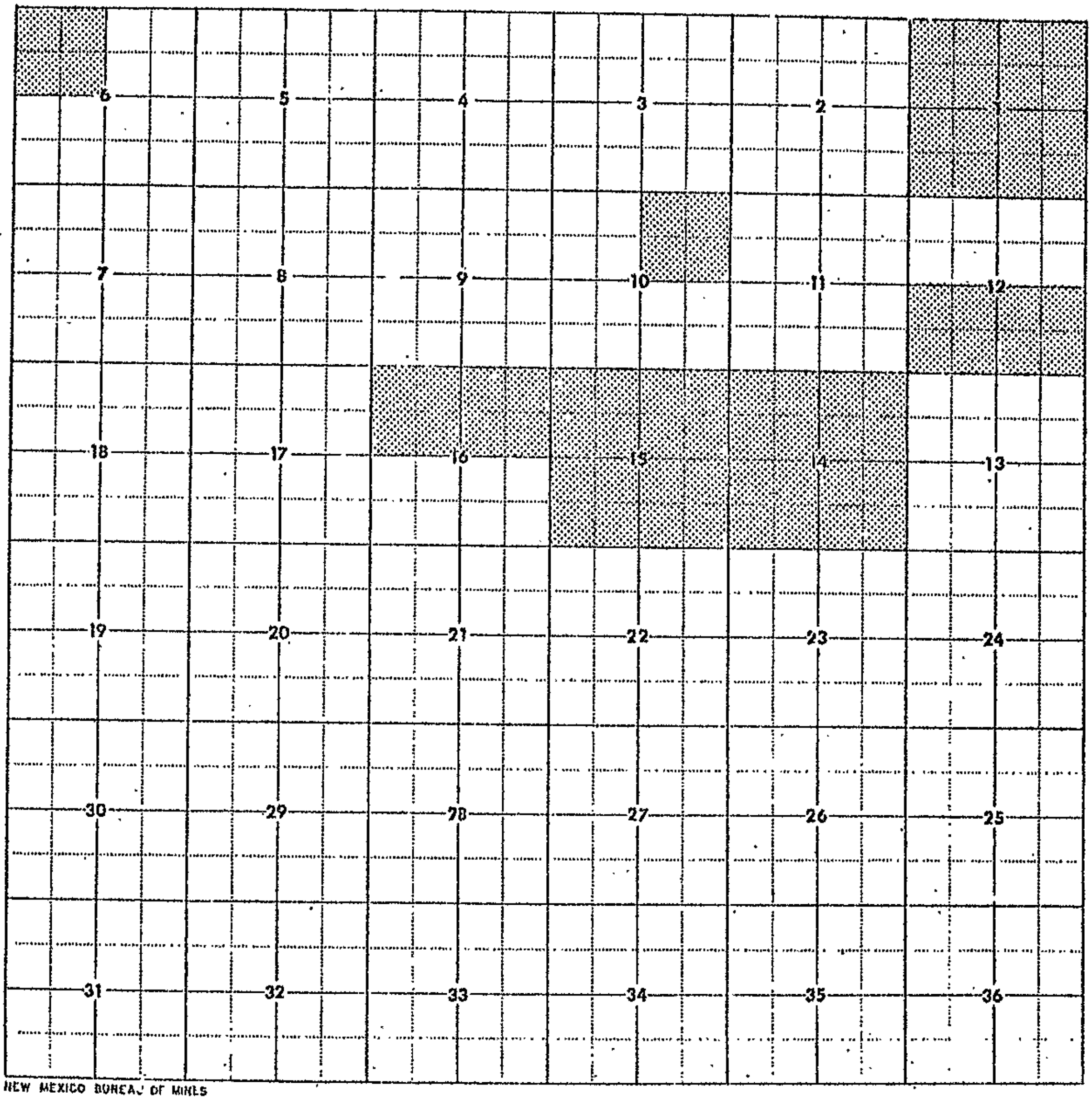
AND MINERAL RESOURCES

SURFACE OWNERSHIP

LOCATION............ TOWNSHIP T16N RANGE R5W COUNTY............ STATE............

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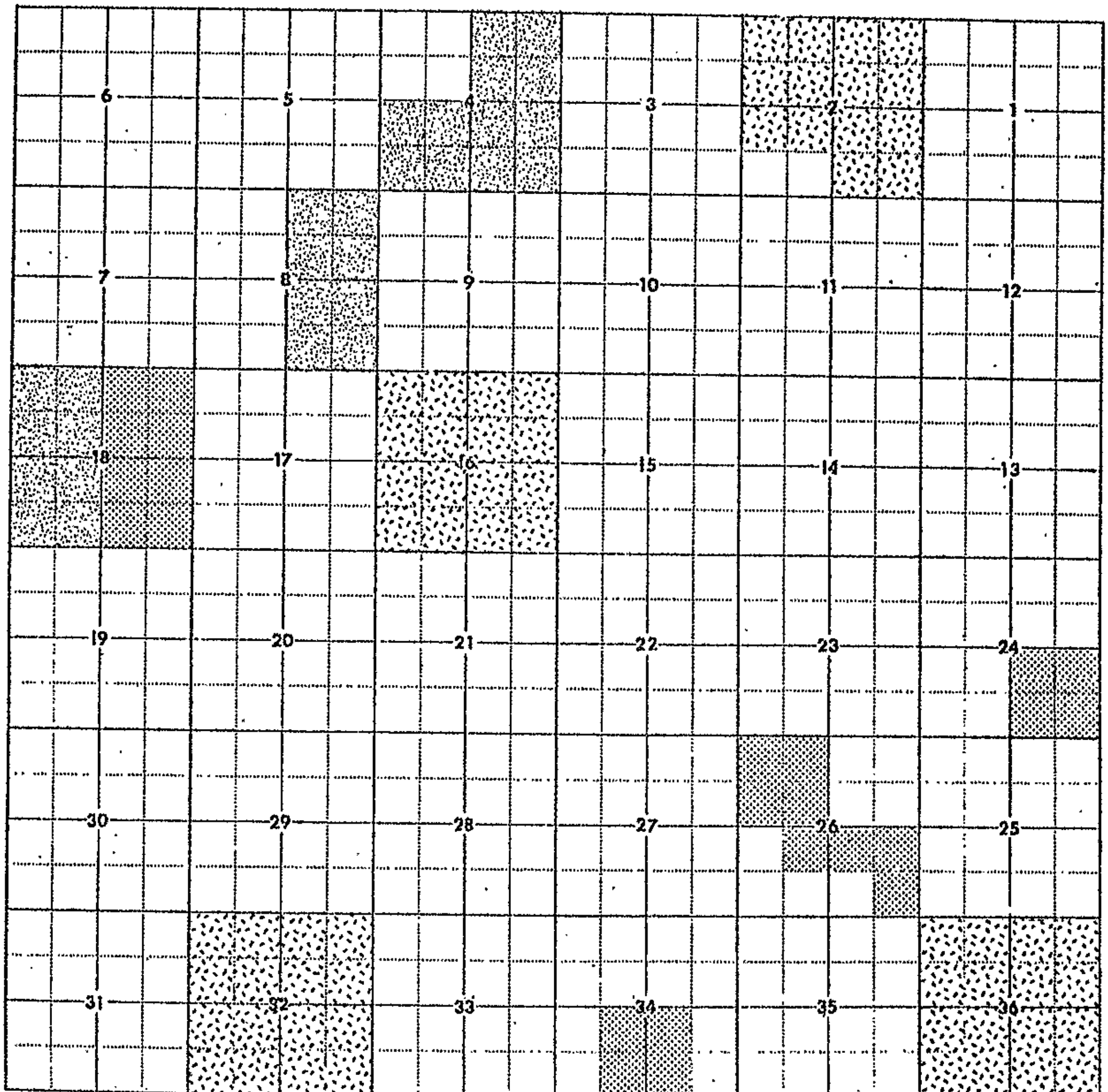
AND MINERAL RESOURCES

## SURFACE OWNERSHIP

LOCATION______ TOWNSHIP T17N RANGE R3W COUNTY______ STATE______

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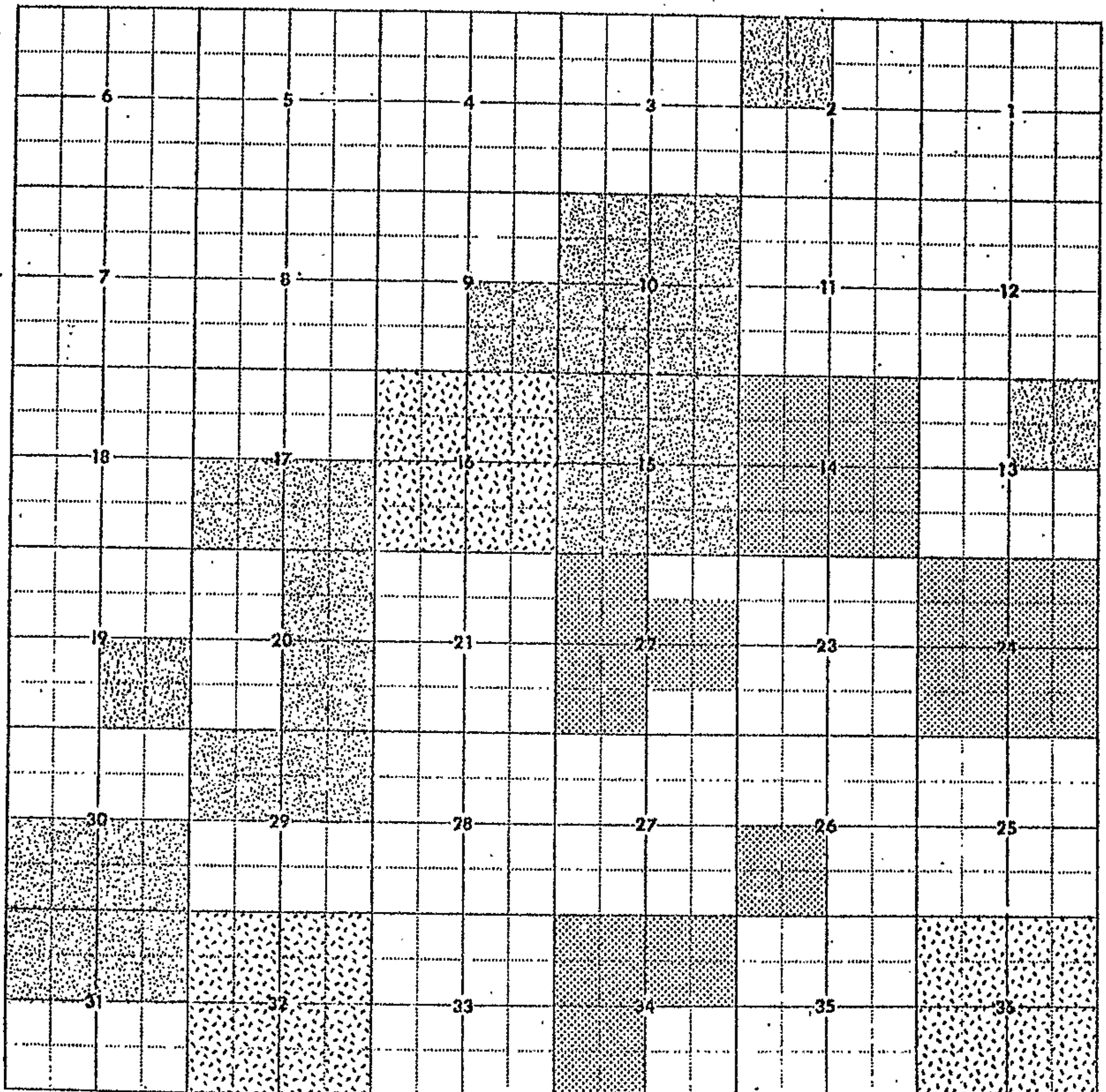
AND MINERAL RESOURCES

SURFACE OWNERSHIP

LOCATION ______ TOWNSHIP T17N RANGE R4W COUNTY ______ STATE ______

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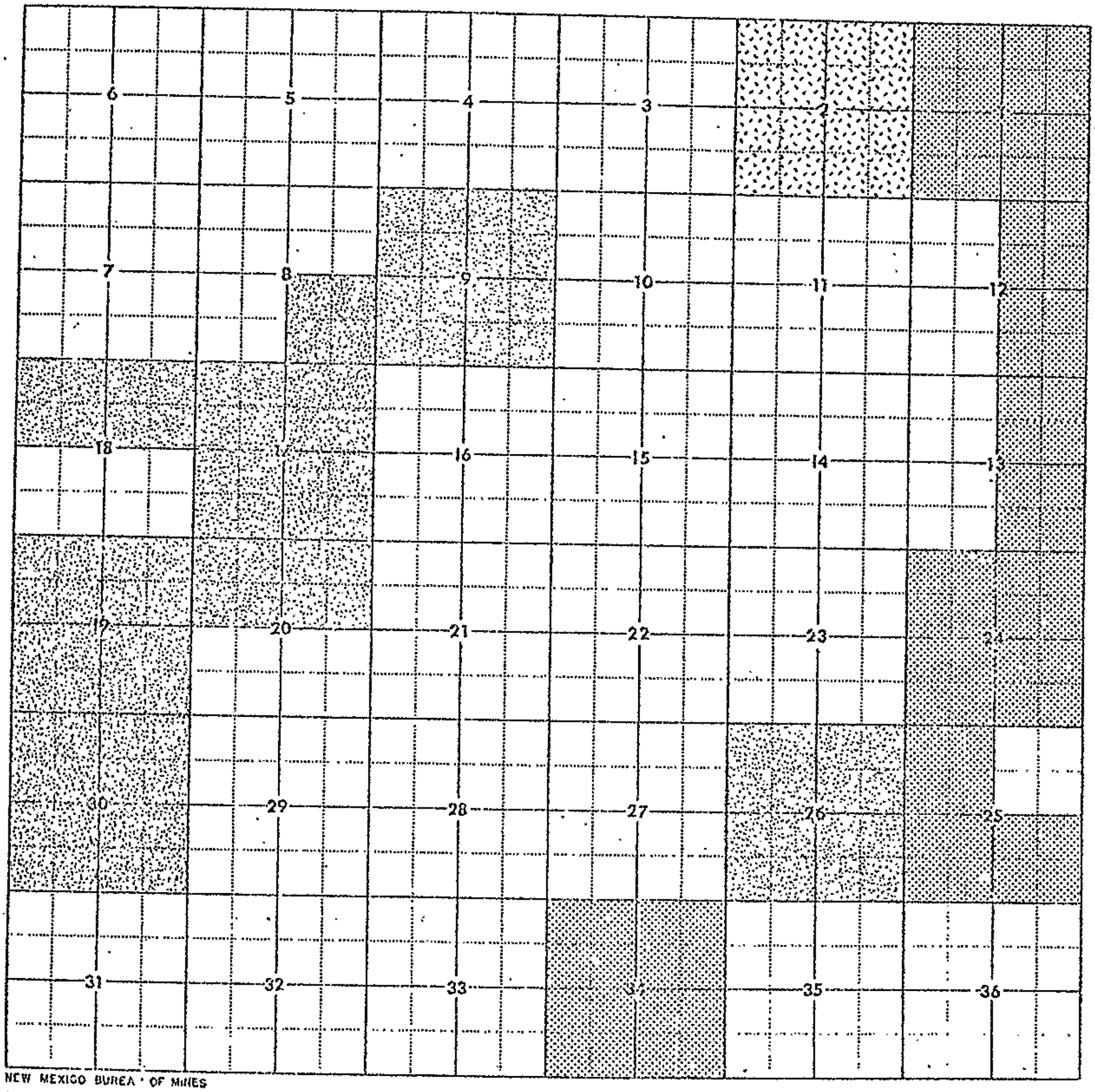
SURFACE OWNERSHIP

LOCATION ______ TOWNSHIP T18N RANGE R3W COUNTY ______ STATE ______

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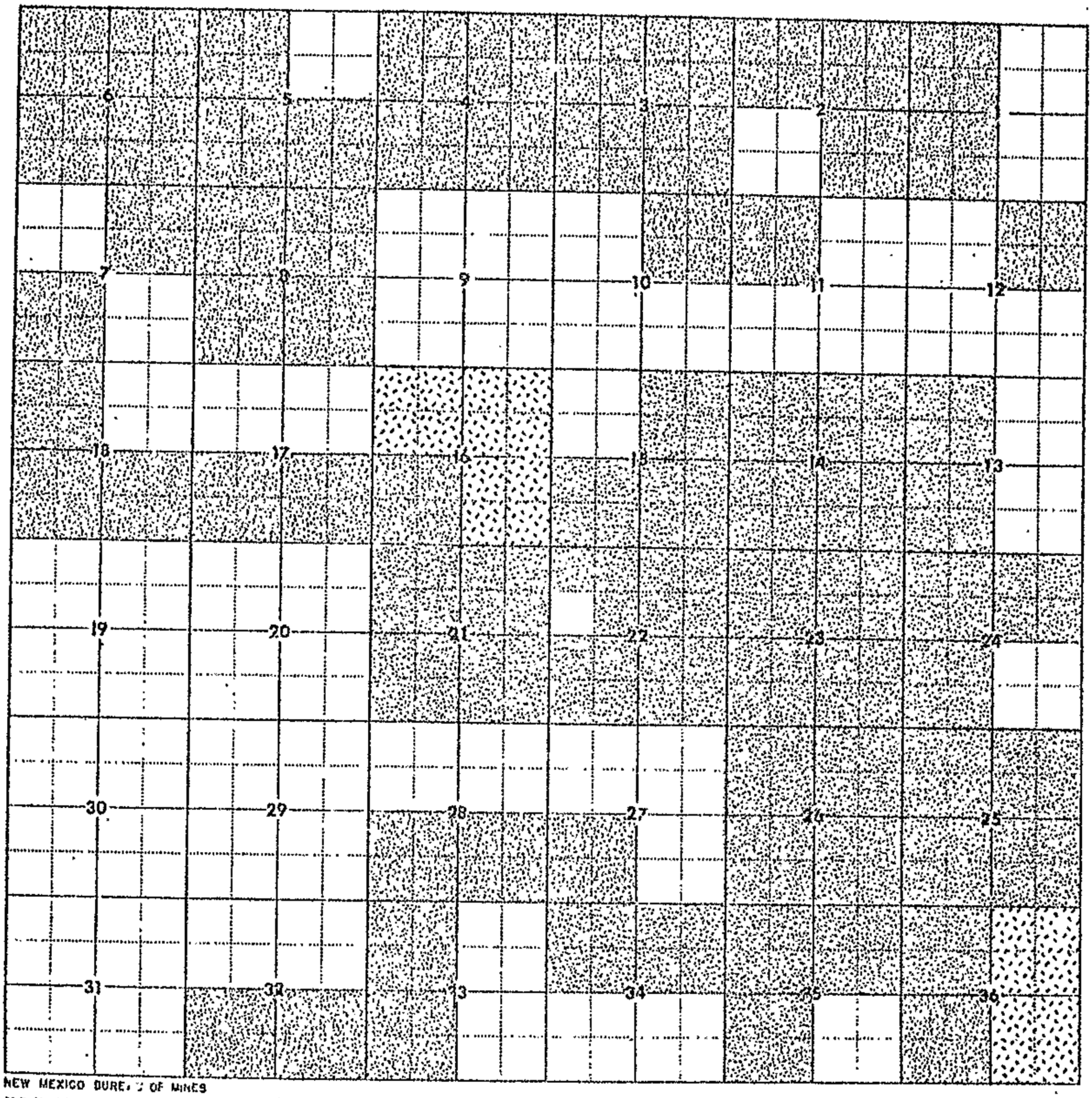
AND MINERAL RESOURCES

SURFACE OWNERSHIP

LOCATION________ TOWNSHIP T18N RANGE R4W COUNTY________ STATE________

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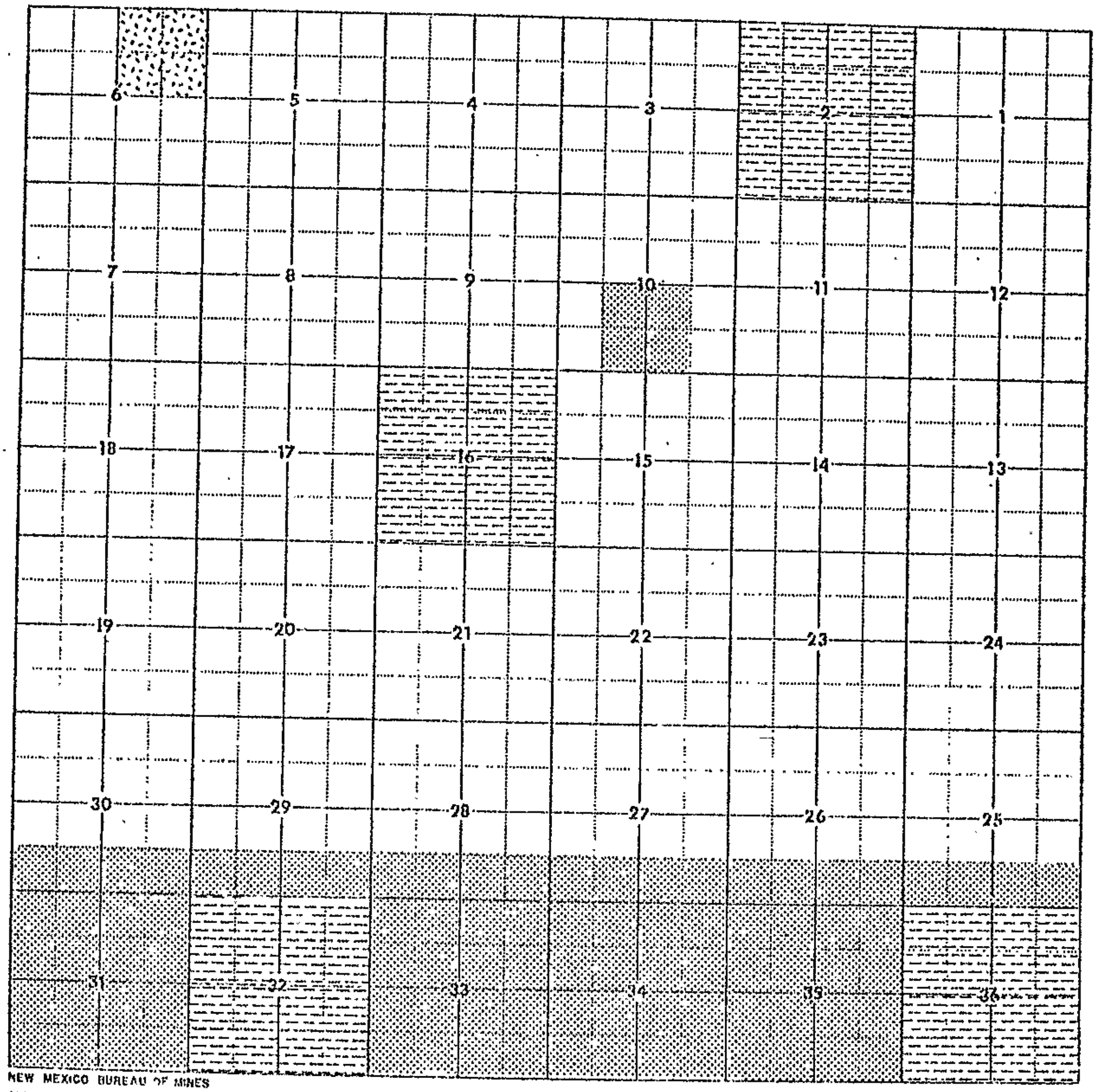
AND MINERAL RESOURCES

COAL OWNERSHIP

LOCATION ________ TOWNSHIP 16N RANGE 4W COUNTY ________ STATE ________

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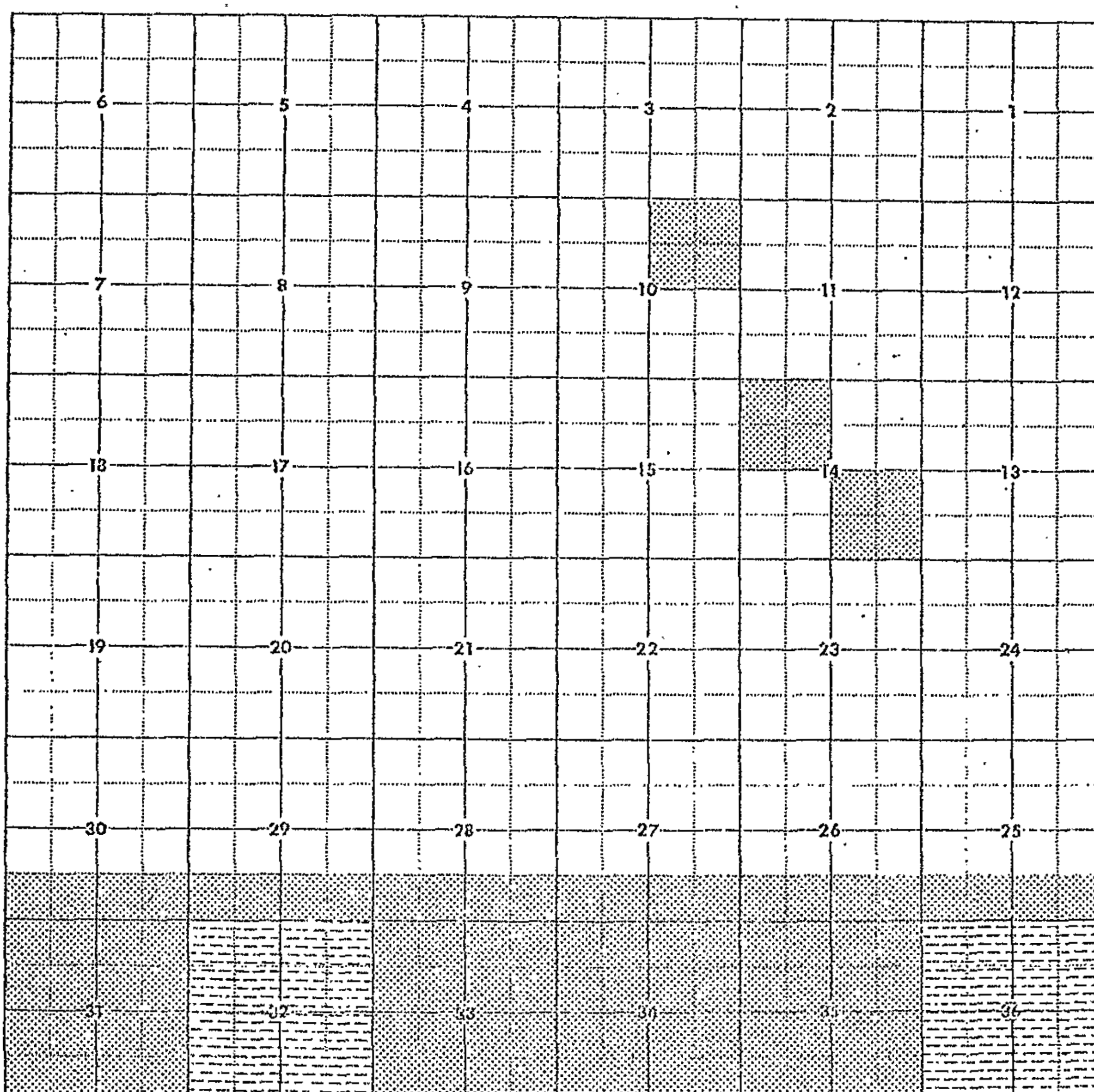
COAL OWNERSHIP

LOCATION ________ TOWNSHIP 16W RANGE 5W COUNTY ________ STATE ________

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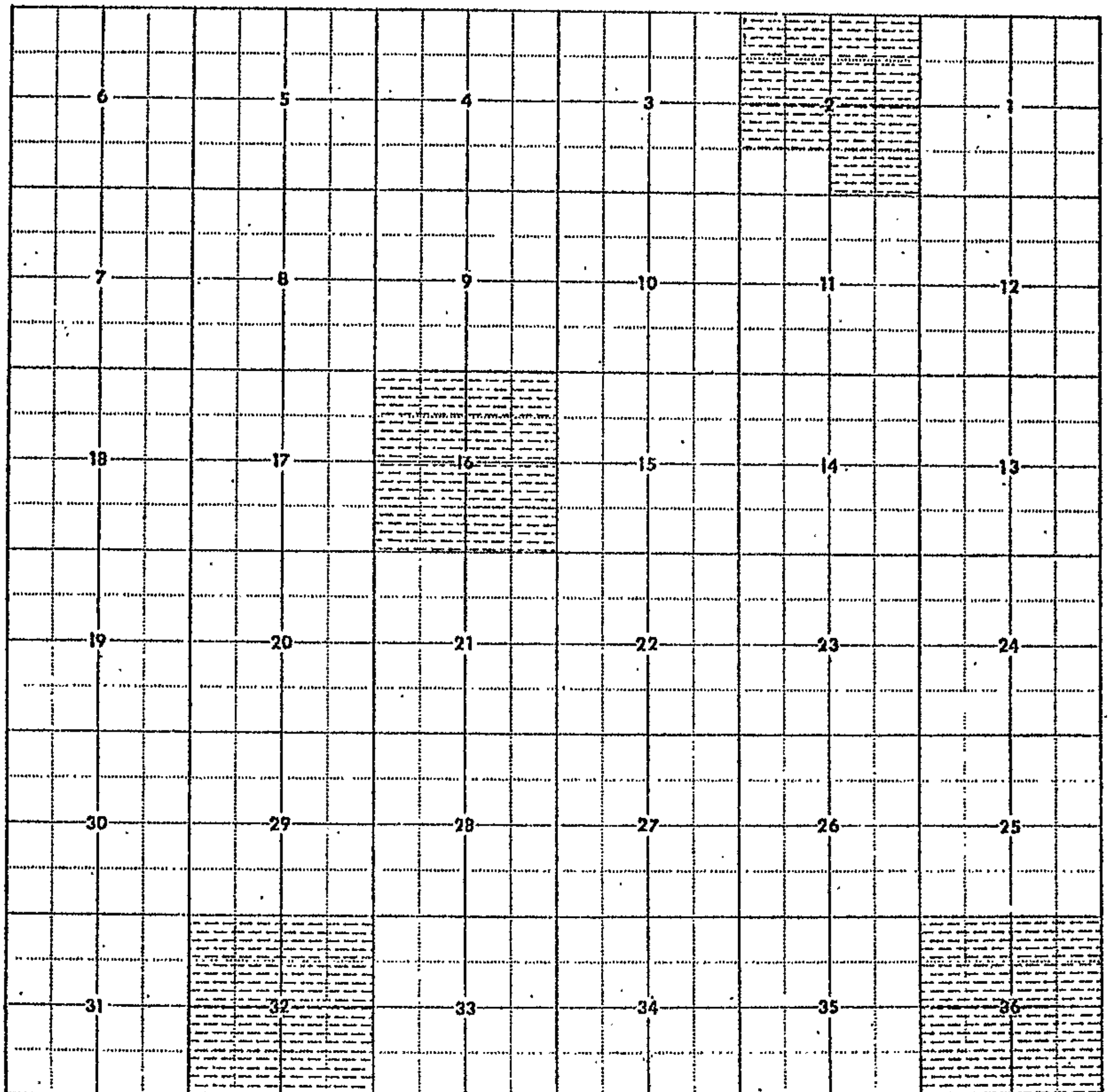
## COAL OWNERSHIP

LOCATION________ TOWNSHIP 17N RANGE 3W COUNTY________ STATE________

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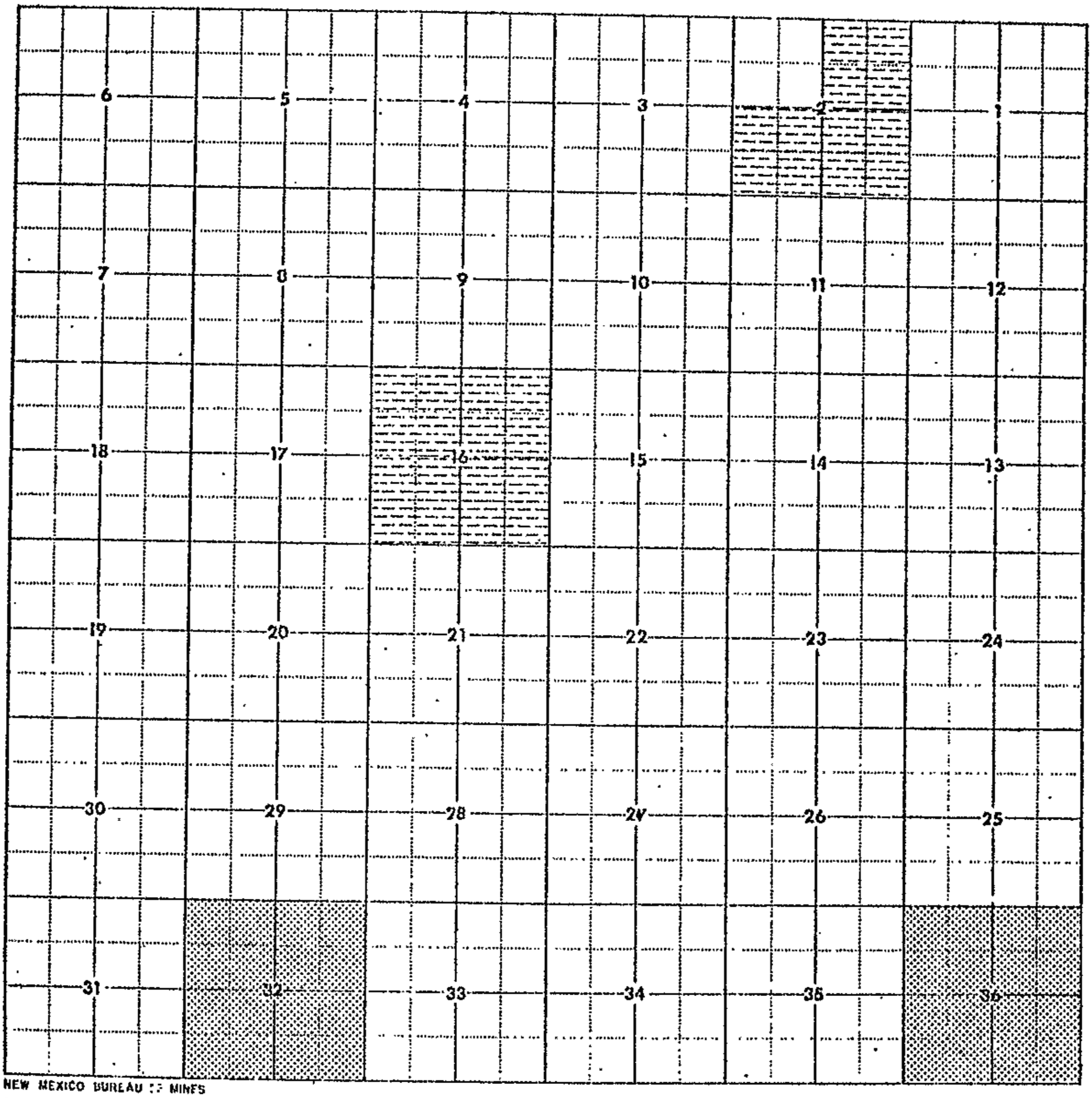
COAL OWNERSHIP

LOCATION ________ TOWNSHIP 17N RANGE 4W COUNTY ________ STATE ________

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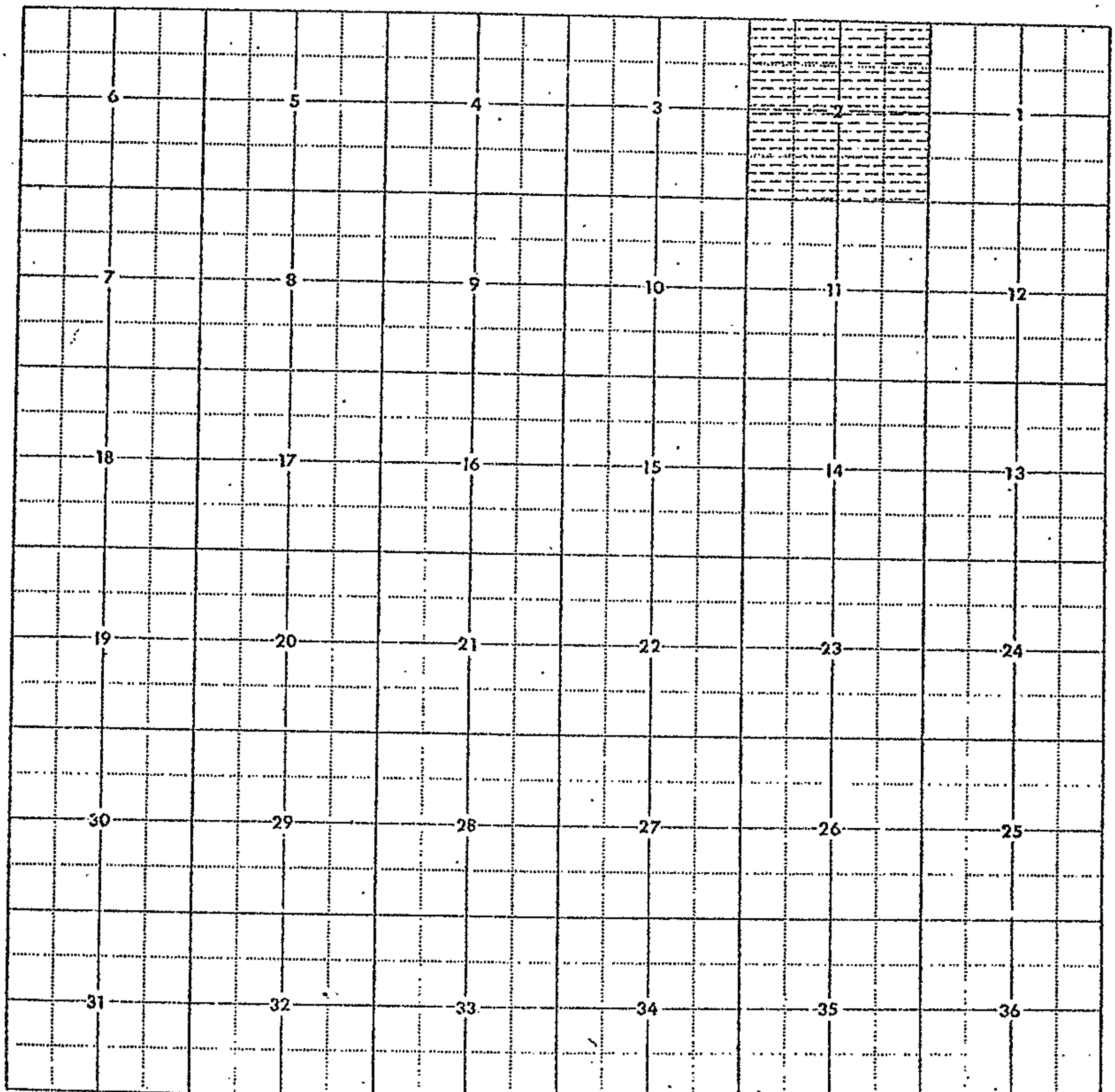
COAL OWNERSHIP

LOCATION ________ TOWNSHIP 18N RANGE 3W COUNTY ________ STATE ________

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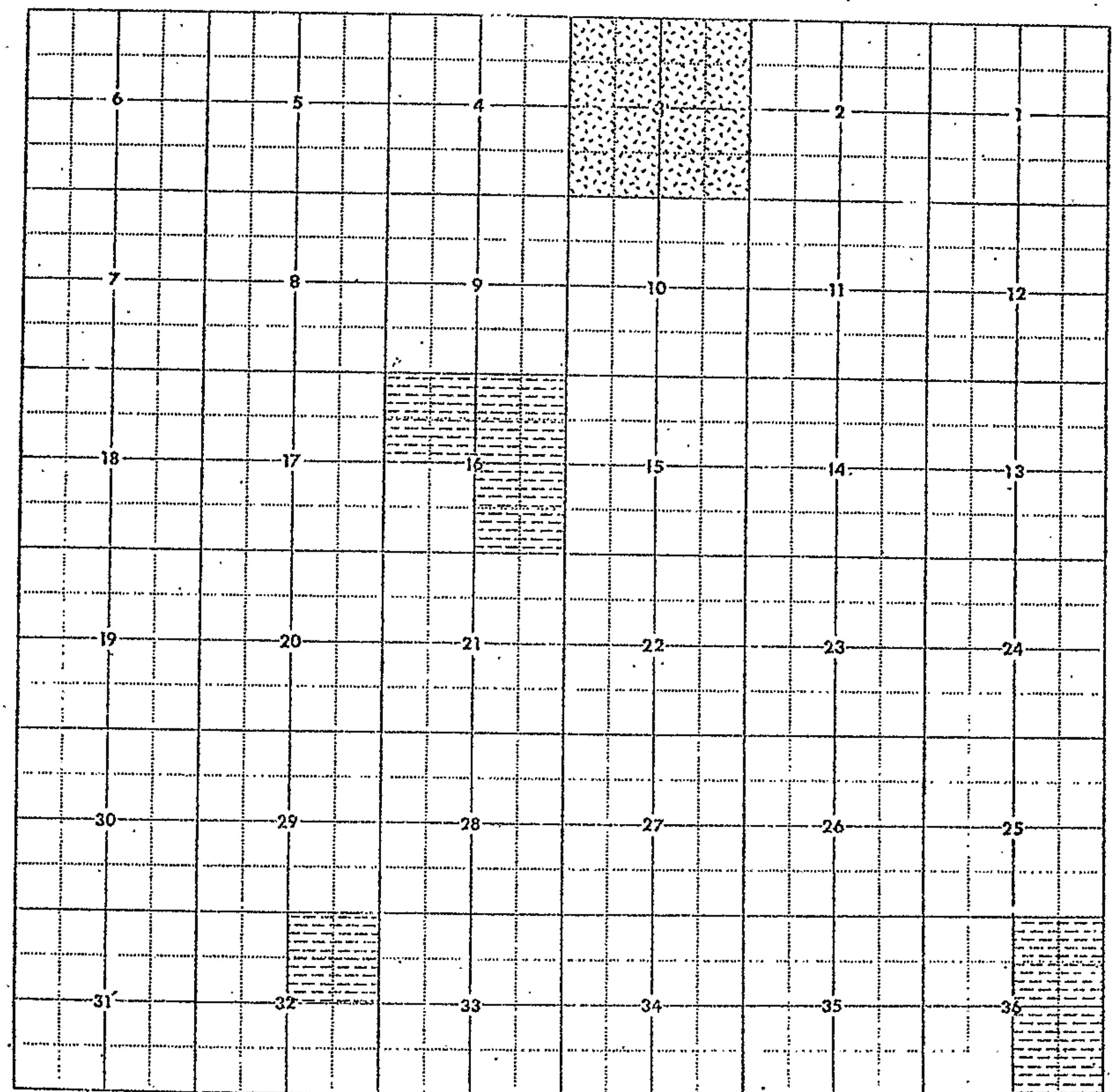
AND MINERAL RESOURCES

COAL OWNERSHIP

LOCATION ______ TOWNSHIP 18N RANGE 4W COUNTY ______ STATE ______

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# APPENDIX II

## Coal Drill Hole Summary Sheets

Torreon Project

Location of Drill Holes

| Drill Site No. | Section | Township | Range | GL ELEV. |
|---|---|---|---|---|
| C5 | SE¼NW¼NW¼ SEC. 5 | 16 N. | 4 W. | 6110 |
| R23 | NW¼SW¼SW¼ SEC. 6 | 16 N. | 4 W. | 6230 |
| R21 | SE¼SE¼SE¼ SEC. 18 | 16 N. | 4 W. | 6415 |
| R24 | SW¼SE¼NE¼ SEC. 2 | 16 N. | 5 W. | 6305 |
| C6 | NE¼NE¼NW¼ SEC. 17 | 16 N. | 5 W. | 6390 |
| R12 | NW¼NW¼NE¼ SEC. 21 | 16 N. | 5 W. | 6510 |
| R13 | SW¼NW¼NW¼ SEC. 26 | 16 N. | 5 W. | 6630 |
| R11 | SE¼NE¼NW¼ SEC. 29 | 16 N. | 5 W. | 6530 |
| R43 | NE¼SW¼NW¼ SEC. 4 | 17 N. | 3 W. | 6465 |
| R41 | NW¼SE¼SW¼ SEC. 13 | 17 N. | 3 W. | 6480 |
| R42 | SW¼SE¼NW¼ SEC. 17 | 17 N. | 3 W. | 6235 |
| C3 | NW¼SE¼NE¼ SEC. 29 | 17 N. | 3 W. | 6390 |
| R33 | SW¼SW¼NW¼ SEC. 31 | 17 N. | 3 W. | 6325 |
| R32 | NE¼NW¼SE¼ SEC. 23 | 17 N. | 4 W. | 6170 |
| C4 | NW¼SE¼NW¼ SEC. 27 | 17 N. | 4 W. | 6240 |
| R31 | SW¼SW¼SW¼ SEC. 29 | 17 N. | 4 W. | 6280 |
| R63 | NW¼NE¼SW¼ SEC. 4 | 18 N. | 3 W. | 6560 |
| R62 | SE¼NW¼NE¼ SEC. 11 | 18 N. | 3 W. | 6730 |
| C1 | NW¼NW¼SW¼ SEC. 20 | 18 N. | 3 W. | 6530 |
| R61 | NW¼SW¼SE¼ SEC. 21 | 18 N. | 3 W. | 6650 |
| R52 | SE¼NW¼SW¼ SEC. 11 | 18 N. | 4 W. | 6400 |
| C2 | NW¼SE¼NE¼ SEC. 18 | 18 N. | 4 W. | 6620 |
| R53 | SE¼NE¼NE¼ SEC. 28 | 18 N. | 4 W. | 6440 |
| R51 | NE¼NW¼NE¼ SEC. 32 | 18 N. | 4 W. | 6460 |

WELL NAME C-1 TORREON LOCATION NW,SW S 20 T 18N R 3W

COMPANY NMBM&MR ELEVATION: KB 6350 GL (above SL)

COUNTY Sandoval LOGS RUN core hole LOG INT'VAL

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 9/28+29/78

FORMATION TOPS:

DEPTH(S) TO COAL AND THICKNESS:

*46.7'(3.0' coal)

54.3'(1.0' coal)

*57.7'(3.2' coal)

*67.2'(2.1' coal)

*154.8'(13.7' coal)

* TOTAL COAL THICKNESS 22.0'

WELL NAME C-2 TORREON LOCATION SE,NE S 18 T 18N R 4W

COMPANY NMBM&MR ELEVATION: KB 6620 GL (above SL)

COUNTY Sandoval LOGS RUN core hole LOG INT'VAL

SPUDDED IN Lewis Shale DATE DRILLED OR ~~LOGGED~~ 10/14+15/78

FORMATION TOPS:

Cliff House Ss. 70'

Menefee Fmtn. 103'

DEPTH(S) TO COAL AND THICKNESS:

117.1'(1.6' coal)

119.8'(1.2' coal)

TOTAL COAL THICKNESS 2.8'

WELL NAME C-3 TORREON LOCATION SW,NE S 29 T 17N R 3W

COMPANY NMBM&MR ELEVATION: ____ KB 6390 GL (above SL)

COUNTY Sandoval LOGS RUN core hole LOG INT'VAL ____

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 8/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

36.0'(0.9' coal)

63.0'(1.0' coal)

*107.8'(1.2' coal)

*112.6'(1.5' coal)

*135.0'(1.3' coal)

*221.3'(3.0' coal)

* TOTAL COAL THICKNESS 7.0'

WELL NAME C-4 TORREON LOCATION SE,NW S 27 T 17N R 4W

COMPANY NMBM&MR ELEVATION: KB 6240 GL (above SL)

COUNTY Sandoval LOGS RUN core hole LOG INT'VAL

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 8/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

*103.3'(1.2' coal)

*112.1'(1.9' coal)

*151.6'(2.0' coal)

156.7'(1.0' coal)

*171.5'(4.0' coal)

* TOTAL COAL THICKNESS 9.1'

WELL NAME C-5 TORREON LOCATION NW,NW S 5 T 16N R 4W

COMPANY NMBM&MR ELEVATION: KB 6110 GL (above SL)

COUNTY Sandoval LOGS RUN core hole LOG INT'VAL

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 5/78

FORMATION TOPS:

Point Lookout Ss. 147.2'

DEPTH(S) TO COAL AND THICKNESS:

* 14.6'(3.7' coal)

23.0'(0.8' coal)

* 95.8'(0.9' coal)

* 97.0'(2.0' coal)

101.4'(0.8' coal)

*125.7'(1.3' coal)

* TOTAL COAL THICKNESS 7.9'

WELL NAME C-6 TORREON LOCATION NE,NW S 17 T 16N R 5W

COMPANY NMBM&MR ELEVATION: KB 6390 GL (above SL)

COUNTY McKinley LOGS RUN core hole LOG INT'VAL

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 7/78

FORMATION TOPS:

Point Lookout Ss. 139.5'

DEPTH(S) TO COAL AND THICKNESS:

57.1'(0.7' coal)

* 59.3'(1.2' coal)

68.6'(0.7' coal)

*119.6'(2.9' coal)

129.2'(1.1' coal)

*137.3'(2.2' coal)

* TOTAL COAL THICKNESS 6.3'

WELL NAME R-11 TORREON LOCATION SE,NW S 29 T16N R5W

COMPANY NMBM&MR ELEVATION: ____ KB 6535 GL (above SL)

COUNTY McKinley LOGS RUN HRD, G, EL LOG INT'VAL 8'-174'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 5/24/78

FORMATION TOPS:

Point Lookout Ss. 50.0'

DEPTH(S) TO COAL AND THICKNESS:

23.5'(3.5' coal)

28.0'(3.0' coal)

TOTAL COAL THICKNESS 6.5'

WELL NAME R-12 TORREON LOCATION NW,NE S 21 T 16N R 5W

COMPANY NMBM&MR ELEVATION: KB 6520 GL (above SL)

COUNTY McKinley LOGS RUN HRD, G, EL LOG INT'VAL 0'-187'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 5/29/78

FORMATION TOPS:

Point Lookout Ss. 66.0'

DEPTH(S) TO COAL AND THICKNESS:

47.5'(1.2' coal)

49.5'(2.5' coal)

62.0'(1.9' coal)

TOTAL COAL THICKNESS 5.6'

WELL NAME R-13 TORREON LOCATION SW,NW S 26 T16N R5W

COMPANY NMBM&MR ELEVATION: KB 6630 GL (above SL)

COUNTY McKinley LOGS RUN HRD, G, EL LOG INT'VAL 0'-227'

SPUDDED IN Menefee DATE DRILLED OR LOGGED 5/17/78

FORMATION TOPS:

Point Lookout Ss. 66.5'

DEPTH(S) TO COAL AND THICKNESS:

*34.0'(2.0' coal)

*36.7'(1.9' coal)

39.5'(0.9' coal)

*51.1'(2.1' coal)

59.0'(1.0' coal)

* TOTAL COAL THICKNESS 6.0'

WELL NAME R-21 TORREON LOCATION SE,SE S 18 T16N R4W

COMPANY NMBM&MR ELEVATION: KB 6410 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N LOG INT'VAL 4'-250'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 6/16-18/78

FORMATION TOPS:

Point Lookout Ss. 100.0'

DEPTH(S) TO COAL AND THICKNESS:

*50.5'(2.1' coal)

66.0'(1.1' coal)

* TOTAL COAL THICKNESS 2.1'

WELL NAME R-23 TORREON LOCATION SW,SW S 6 T16N R4W

COMPANY NMBM&MR ELEVATION: KB 6230 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N, EL LOG INT'VAL 0'-235'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 6/20/78

FORMATION TOPS:

Point Lookout Ss. 180.0'

DEPTH(S) TO COAL AND THICKNESS:

* 34.1'(2.2' coal)

* 67.0'(2.2' coal)

143.8'(0.8' coal)

*165.5'(3.5' coal)

* TOTAL COAL THICKNESS 7.9'

WELL NAME R-24 TORREON LOCATION SE.NE S 2 T 16N R 5W

COMPANY NMBM&MR ELEVATION: KB 6340 GL (above SL)

COUNTY McKinley LOGS RUN HRD, G, N, EL LOG INT'VAL 0'-216'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 6/22/78

FORMATION TOPS:

Point Lookout Ss. 177.0'

DEPTH(S) TO COAL AND THICKNESS:

75.0'(1.0' coal)

*164.1'(1.9' coal)

*TOTAL COAL THICKNESS 1.9'

WELL NAME R-31 TORREON LOCATION SW,SW S 29 T17N R4W

COMPANY NMBM&MR ELEVATION: KB 6280 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, EL LOG INT'VAL 7'-201'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 4/19/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

none

TOTAL COAL THICKNESS 0.0'

WELL NAME R-32 TORREON LOCATION NW,SE S 23 T 17N R 4W

COMPANY NMBM&MR ELEVATION: KB 6170 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N LOG INT'VAL 0'-234'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 4/19/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

141.0'(2.5' coal)

193.0'(2.2' coal)

211.9'(3.2' coal)

223.9'(5.0' coal)

TOTAL COAL THICKNESS 12.9'

WELL NAME R-33 TORREON LOCATION SW,NW S 31 T17N R3W

COMPANY NMBM&MR ELEVATION: KB 6280 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G LOG INT'VAL 4'-150'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 4/19/78

FORMATION TOPS:

Point Lookout Ss. 104.5'

DEPTH(S) TO COAL AND THICKNESS:

*82.4'(1.5' coal)

86.9'(0.8' coal)

*89.7'(6.0' coal)

TOTAL COAL THICKNESS 7.5'

WELL NAME R-41 TORREON LOCATION SE,SW S 13 T17N R3W

COMPANY NMBM&MR ELEVATION: KB 6480 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N, EL LOG INT'VAL 10'-210'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 7/19/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

131.5'(2.2' coal)

188.0'(2.2' coal)

TOTAL COAL THICKNESS 4.4'

WELL NAME R-42 TORREON LOCATION SW,NW S 17 T 17N R 3W

COMPANY NMBM&MR ELEVATION: KB 6235 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N, EL LOG INT'VAL 8'-162'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 7/7/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

107.2'(1.2' coal)

TOTAL COAL THICKNESS 1.2'

WELL NAME R-43 TORREON LOCATION SW,NW S 4 T 17N R 3W

COMPANY NMBM&MR ELEVATION: KB 6465 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N, EL LOG INT'VAL 4'-164

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 7/20/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

none

TOTAL COAL THICKNESS 0.0'

WELL NAME R-51 TORREON LOCATION NW,NE S 32 T 18N R 4W

COMPANY NMBM&MR ELEVATION: KB 6460 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G LOG INT'VAL 0'-248'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 9/27/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

* 26.8'(1.3' coal)

63.0'(1.0' coal)

98.8'(1.0' coal)

*131.2'(1.3' coal)

*135.6'(1.5' coal)

* TOTAL COAL THICKNESS 4.1'

WELL NAME R-52 TORREON LOCATION NW,SW S 11 T 18N R 4W

COMPANY NMBM&MR ELEVATION: KB 6400 GL (above SL)

COUNTY Sandoval LOGS RUN drilling log LOG INT'VAL 0'-250'

SPUDDED IN La Ventana Tongue DATE DRILLED OR ~~LOGGED~~ 11/16+17/78

FORMATION TOPS:

La Ventana Tongue 0.0'

Menefee Fmtn. 38.0'

DEPTH(S) TO COAL AND THICKNESS:

51.5'(1.0' coal)

*57.5'(3.0' coal)

65.0'(1.0' coal)

*67.0'(2.0' coal)

*199.0'(2.0' coal)

* TOTAL COAL THICKNESS 7.0'

WELL NAME R-53 TORREON LOCATION NE,NE S 28 T18N R4W

COMPANY NMBM&MR ELEVATION: KB 6440 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G LOG INT'VAL 9'-239'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 10/16+17/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

38.2'(2.5' coal)

56.4'(2.2' coal)

70.6'(1.4' coal)

TOTAL COAL THICKNESS 6.1'

WELL NAME R-61 TORREON LOCATION SW,SE S 21 T 18N R 3W

COMPANY NMBM&MR ELEVATION: KB 6650 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G LOG INT'VAL 9'-238'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 10/13/78

FORMATION TOPS:

all in Menefee Fmtn. or

tongues of La Ventana ss.

DEPTH(S) TO COAL AND THICKNESS:

| | |
|---|---|
| * 76.4'(2.0' coal) | *130.0'(1.4' coal) |
| * 81.1'(1.3' coal) | *147.6'(3.4' coal) |
| * 93.5'(2.5' coal) | *154.5'(2.0' coal) |
| * 97.7'(1.3' coal) | *158.2'(2.5' coal) |
| *107.8'(2.0' coal) | *171.2'(1.2' coal) |
| 116.6'(1.0' coal) | *175.3'(2.2' coal) |

* TOTAL COAL THICKNESS 21.8'

WELL NAME R-62 TORREON LOCATION NW,NE S 11 T 18N R 3W

COMPANY NMBM&MR ELEVATION: KB 6730 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G LOG INT'VAL 0'-255

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 10/2+3/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

119.0'(2.9' coal)

130.6'(1.4' coal)

248.6'(1.4' coal)

TOTAL COAL THICKNESS 5.7'

WELL NAME R-63 TORREON LOCATION NE,SW S 4 T 18N R 3W

COMPANY NMBM&MR ELEVATION: KB 6560 GL (above SL)

COUNTY Sandoval LOGS RUN HRD, G, N LOG INT'VAL 9'-239'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 9/30 to 10/1/78

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

*30.7'(2.2' coal, somewhat burned)

*85.6'(2.2' coal)

*88.2'(1.7' coal)

97.0'(1.0' coal)

* TOTAL COAL THICKNESS 6.1'

WELL NAME IC-1 LOCATION NW,SE S 34 T16N R4W

COMPANY Pioneer Nuclear, Inc. ELEVATION: KB 7125 GL (above SL)

125'-

COUNTY Sandoval LOGS RUN GG, EL LOG INT'VAL 2510'

SPUDDED IN Menefee DATE DRILLED OR LOGGED 1975?

FORMATION TOPS:

Point Lookout Ss. 366'

Mancos Sh. 441'

DEPTH(S) TO COAL AND THICKNESS:

168.4'(4.6' coal)

187.0'(2.5' coal)

190.2'(2.0' coal)

326.0'(4.0' coal)

TOTAL COAL THICKNESS 13.1'

1980FSL

WELL NAME #1 Federal Tract 16 LOCATION 698FWL S 8 T 16N R 5W

COMPANY Hughes and Hughes ELEVATION: 6527 KB 6523 GL (above SL)

100'-

COUNTY McKinley LOGS RUN CFD, IEL LOG INT'VAL 1611'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 7/20/66

FORMATION TOPS:

Point Lookout Ss. 350'

Mancos Sh. 615'

DEPTH(S) TO COAL AND THICKNESS:

284'(2.5' coal)

333'(2.8' coal)

336'(2.0' coal)

346'(2.5' coal)

TOTAL COAL THICKNESS 9.8'

WELL NAME #2 Federal Tract 15 LOCATION 1660FSL 1980FEL S 16 T 16N R 5W

COMPANY Hughes and Hughes ELEVATION: 6440 KB 6346 GL (above SL)

COUNTY Mckinley LOGS RUN CFD, IEL LOG INT'VAL 36'-1335'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 7/14-16/66

FORMATION TOPS:

Point Lookout Ss. 78'

Mancos Sh. 212'

DEPTH(S) TO COAL AND THICKNESS:

none shows on logs

TOTAL COAL THICKNESS 0.0'

WELL NAME IC-11 LOCATION SW,NW S 32 T 16N R 5W

COMPANY Pioneer Nuclear, Inc. ELEVATION: KB 6660 GL (above SL)

COUNTY McKinley LOGS RUN GG, EL LOG INT'VAL 10'-2225'

SPUDDED IN Menefee DATE DRILLED OR LOGGED 1975?

FORMATION TOPS:

Point Lookout Ss. 102'

Mancos Sh. 312'

DEPTH(S) TO COAL AND THICKNESS:

64.2'(0.9' coal)

*82.2'(1.8' coal)

*90.0'(1.3' coal)

*98.8'(2.5' coal)

* TOTAL COAL THICKNESS 5.6'

WELL NAME Torreon Core Hole #2 LOCATION SE,NW S 5 T 17N R 3W

COMPANY Tenneco Oil Company ELEVATION: 6419 KB 6408 GL (above SL)

COUNTY Sandoval LOGS RUN D, IEL LOG INT'VAL 52'-986'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 5/18-23/67

FORMATION TOPS:

Point Lookout Ss. 854'

Mancos Sh. 956'

DEPTH(S) TO COAL AND THICKNESS: (from core)

648.0'(3.0' coal)

750.0'(1.5' coal)

809.8'(6.2' coal, shaley)

820.0'(3.0' coal)

828.0'(1.5' coal)

849.0'(4.0' coal)

TOTAL COAL THICKNESS 19.2'

WELL NAME Cabezon #1 LOCATION 1980FNL 1980FEL S 29 T 17N R 4W

COMPANY Refiners Petroleum ELEVATION: 6432 KB 6423 GL (above SL)

COUNTY Sandoval LOGS RUN CFD, IEL LOG INT'VAL 125'-4055'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 6/21 to 7/20/71

FORMATION TOPS:

Point Lookout Ss. 590'

Mancos Sh. 778'

DEPTH(S) TO COAL AND THICKNESS:

no coal shows on logs or well cuttings

TOTAL COAL THICKNESS 0.0'

WELL NAME San Luis Federal #1 LOCATION 1980FNL 660FWL S 11 T 18N R 3W

COMPANY Tesoro Petroleum Corp. ELEVATION: 6698 KB 6685 GL (above SL)

COUNTY Sandoval LOGS RUN CFD, IEL LOG INT'VAL 250'-4196'

SPUDDED IN Menefee DATE DRILLED OR ~~LOGGED~~ 12/26/72

FORMATION TOPS:

Point Lookout Ss. 1382'

Mancos Sh. 1504'

DEPTH(S) TO COAL AND THICKNESS:

273.5'(3.0' coal) 556.5'(3.0' coal)

306.0'(1.2' coal) 1280.0'(4.0' coal)

310.0'(2.0' coal) 1379.0'(3.0' coal)

318.0'(4.0' coal)

356.0'(1.8' coal)

551.5'(3.0' coal)

TOTAL COAL THICKNESS 27.0'

WELL NAME Sandoval Federal #1 LOCATION 330FSL 990FWL S 24 T 18N R 3W

COMPANY Sun Oil Company ELEVATION: 6579 KB 6562 GL (above SL)

COUNTY Sandoval LOGS RUN IEL LOG INT'VAL 376'-3178'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 6/9/71

FORMATION TOPS:

Point Lookout Ss. 1102'

Mancos Sh. 1204'

DEPTH(S) TO COAL AND THICKNESS:

601.5'(2.5' coal)

637.0'(2.5' coal)

874.5'(2.0' coal)

976.0'(3.0' coal)

1010.0'(2.5' coal)

1049.0'(2.0' coal)

TOTAL COAL THICKNESS 14.5'

WELL NAME Torreon Core Hole #4    LOCATION 1630FSL 1555FWL S 29 T 18N R 3W

COMPANY Tenneco Oil Company    ELEVATION: 6470 KB 6459 GL (above SL)

COUNTY Sandoval    LOGS RUN CFD, IEL    LOG INT'VAL 52'-1142'

SPUDDED IN Menefee    DATE ~~DRILLED~~ OR LOGGED 5/26/67

FORMATION TOPS:

Point Lookout Ss. 1132'

DEPTH(S) TO COAL AND THICKNESS:

165.0'(2.0' coal)    1119.5'(2.5' coal)

216.0'(1.9' coal)

224.5'(1.5' coal)

998.5'(2.1' coal)

1026.0'(2.5' coal)

1028.8'(3.5' coal)

TOTAL COAL THICKNESS 16.0'

WELL NAME Ann #14 LOCATION 660FNL 1980FWL S 33 T 18N R 3W

COMPANY Kreatschman and Stowe ELEVATION: 6468 KB 6459 GL (above SL)

COUNTY Sandoval LOGS RUN CFD, IEL LOG INT'VAL 113'-3383'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 8/3/67

FORMATION TOPS:

Point Lookout Ss. 978.5'

Mancos Sh. 1060.0'

DEPTH(S) TO COAL AND THICKNESS:

922.0'(3.0' coal)

935.5'(3.0' coal)

TOTAL COAL THICKNESS 6.0'

WELL NAME Torreon Core Hole #7 LOCATION 910FNL 1190FWL S 34 T 18N R 3W

COMPANY Tenneco Oil Company ELEVATION: 6479 KB 6466 GL (above SL)

COUNTY Sandoval LOGS RUN CFD LOG INT'VAL 48'-1154'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 8/7/67

FORMATION TOPS:

Point Lookout Ss. 856'

Mancos Sh. 956'

DEPTH(S) TO COAL AND THICKNESS: (core from 200'-672')

*673'(1.5' coal)

*740'(4.0' coal)

*790'(1.8' coal)

837'(1.0' coal)

*TOTAL COAL THICKNESS 7.3'

WELL NAME John Toledo #2 LOCATION 790FSL 1780FWL S 7 T 18N R 4W

COMPANY Theron J. Graves ELEVATION: 6632 KB 6620 GL (above SL)

COUNTY Sandoval LOGS RUN CFD, G LOG INT'VAL 150 122

SPUDDED IN Cliff House Ss. DATE DRILLED OR ~~LOGGED~~ 10/5-9/73

FORMATION TOPS:

DEPTH(S) TO COAL AND THICKNESS:

*216.0'(2.0' coal) *596.6'(1.4' coal)

*410.0'(1.8' coal) 599.0'(1.0' coal)

*420.8'(1.9' coal)

*523.9'(2.7' coal)

*590.0'(2.0' coal)

*594.7'(1.3' coal)

* TOTAL COAL THICKNESS 13.1'

WELL NAME Torreon #1 LOCATION 1980FSL 660FWL S 22 T 18N R 4W

COMPANY Reynolds Mining Corp. ELEVATION: 6381 KB 6372 GL (above SL)

COUNTY Sandoval LOGS RUN G, N, LL LOG INT'VAL 16'-7518'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 2/1/56

FORMATION TOPS:

Point Lookout Ss. 1243'

Mancos Sh. 1332'

DEPTH(S) TO COAL AND THICKNESS:

468.0'(2.6' coal)

1121.0'(2.8' coal)

1162.5'(2.0' coal)

1227.0'(3.5' coal)

1235.5'(2.1' coal)

TOTAL COAL THICKNESS 13.0'

WELL NAME Navajo #2 LOCATION SE,NE S 22 T 18N R 4W

COMPANY Albuquerque Assoc. Oil Co. ELEVATION: ____ KB 6340 GL (above SL)

COUNTY Sandoval LOGS RUN EL LOG INT'VAL 116'-3782'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 2/25/53

FORMATION TOPS:

Point Lookout Ss. 1181'

Mancos Sh. 1371'

DEPTH(S) TO COAL AND THICKNESS:

238'(2.0' coal)

469'(4.0' coal)

985'(2.5' coal)

1048'(5.0' coal)

1113'(3.0' coal)

TOTAL COAL THICKNESS 16.5'

WELL NAME Navajo #22-4 LOCATION 660FNL 1980FWL S 22 T 18N R 4W

COMPANY O. A. Larrizola ELEVATION: KB 6427 GL (above SL)

34'-

COUNTY Sandoval LOGS RUN EL LOG INT'VAL 1142'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 12/14/58

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

280.5'(4.5' coal)

457.0'(3.5' coal)

918.0'(3.0' coal)

1041.8'(2.0' coal)

TOTAL COAL THICKNESS 13.0'

WELL NAME Larrazola 27-1 Federal LOCATION 660FNL 660FEL S 27 T 18N R 4W

COMPANY Stewart Bros. & Parker Drilling ELEVATION: ____ KB 6325 GL (above SL)

COUNTY Sandoval LOGS RUN EL LOG INT'VAL 32'- 1200'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 5/11/59

FORMATION TOPS:

all in Menefee Fmtn.

DEPTH(S) TO COAL AND THICKNESS:

492'(3.0' coal)

761'(3.0' coal)

TOTAL COAL THICKNESS 6.0'

WELL NAME F. F. Kelly State #1 LOCATION 660FNL 1980FEL S 32 T 18N R 4W

COMPANY Plymouth Oil Company ELEVATION: 6490 KB 6482 GL (above SL)

COUNTY Sandoval LOGS RUN EL LOG INT'VAL 200'-1300'

SPUDDED IN Menefee DATE ~~DRILLED~~ OR LOGGED 4/13/53, 5/21/53

FORMATION TOPS:

Point Lookout Ss. 1178'

Mancos Sh. 1298'

DEPTH(S) TO COAL AND THICKNESS:

| | |
|---|---|
| 261.5'(3.5' coal) | 1126.5'(1.5' coal) |
| 269.0'(1.7' coal) | 1146.2'(1.4' coal) |
| 897.8'(2.0' coal) | 1155.3'(4.2' coal) |
| 1062.5'(3.5' coal) | 1172.0'(2.0' coal) |
| 1106.0'(3.2' coal) | 1176.0'(2.0' coal) |
| 1118.8'(3.2' coal) | |

TOTAL COAL THICKNESS 28.2'

WELL NAME Glasebrook #1 LOCATION 990FSL 990FEL S 25 T 18N R 5W

COMPANY Bernard King ELEVATION: ____KB ____GL (above SL)

105'

COUNTY McKinley LOGS RUN EL LOG INT'VAL 3301

SPUDDED IN Cliff House Ss. DATE ~~DRILLED~~ OR LOGGED 5/12/57

FORMATION TOPS:

Point Lookout Ss. 1501'

Mancos Sh. 1630'

DEPTH(S) TO COAL AND THICKNESS:

931.5'(3.5' coal)

1073.0'(4.0' coal)

1401.5'(3.5' coal)

1473.5'(3.0' coal)

1491.0'(3.0' coal)

1497.0'(3.5' coal)

TOTAL COAL THICKNESS 20.5'

APPENDIX III

Water Well Program Report

by

William J. Stone

and

Steven D. Craigg

# Water Well Program[1]

## Background and Purpose

Since 1974 the Bureau has been cooperating with the Water Resources Division of the U.S. Geological Survey and the New Mexico State Engineer in a study of the hydrogeology and water resources of northwestern New Mexico. The study was prompted by the growing energy-development activity in the New Mexico portion of the San Juan Basin. Main objectives include 1) identifying the potential aquifers, 2) delineating their geologic and hydrologic characteristics, and 3) modeling the hydrologic system associated with post-Triassic deposits in the Basin so that the hydrologic impact of various energy development activities may be evaluated. The Survey is responsible for compiling the hydrologic data and modeling the Basin. The Bureau is responsible for characterizing the geologic framework of the Basin and determining the extent to which this framework controls the occurrence, movement, and quality of water in the Basin.

In order to gain some appreciation of local conditions in an otherwise regional study, the Bureau has supported four masters theses on the water-resource situation in

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[1] Prepared November 1978, for inclusion in report to U.S.G.S. on Torreon coal project -- William J. Stone, Hydrogeologist, Bureau, and Steven D. Craigg, Graduate Research Assistant, Geoscience Dept., New Mexico Tech.

selected 15-minute-quadrangle-sized areas in the Basin. One of these focuses on the Chico Arroyo-Torreon Wash area, and thus overlaps with the Bureau's coal project area. This locality is significant not only because of its potential for coal development, but also because it lies within the southeastern ground-water discharge area for the Basin. As no funds have been available in the regional water study for drilling, it was indeed fortunate that some of the coal bore holes could be completed as ground-water observation wells. These wells permit testing, sampling, and monitoring not only the potential aquifers in the area, but also the major rock types associated with the Menefee coal.

Wells Established

Original plans called for completing 7 of the coal holes as water wells: 3 in the Point Lookout Sandstone, 2 in the coals of the Menefee Formation (1 upper and 1 lower), 1 in a channel sandstone of the Menefee, and 1 in a Menefee mudstone. It was hoped that the Point Lookout wells would help establish the gradient of ground water in the area. The remaining wells were planned to provide hydrologic information for future mining or rèclamation activity associated with the Menefee Formation.

Geologic and water-level conditions necessitated altering these plans; 5 holes were completed as water wells instead of 7. The 5 holes completed permit study of the aquifers originally identified except channel sandstones in the Menefee Formation. The general approach to their construction is shown in Figure 1,

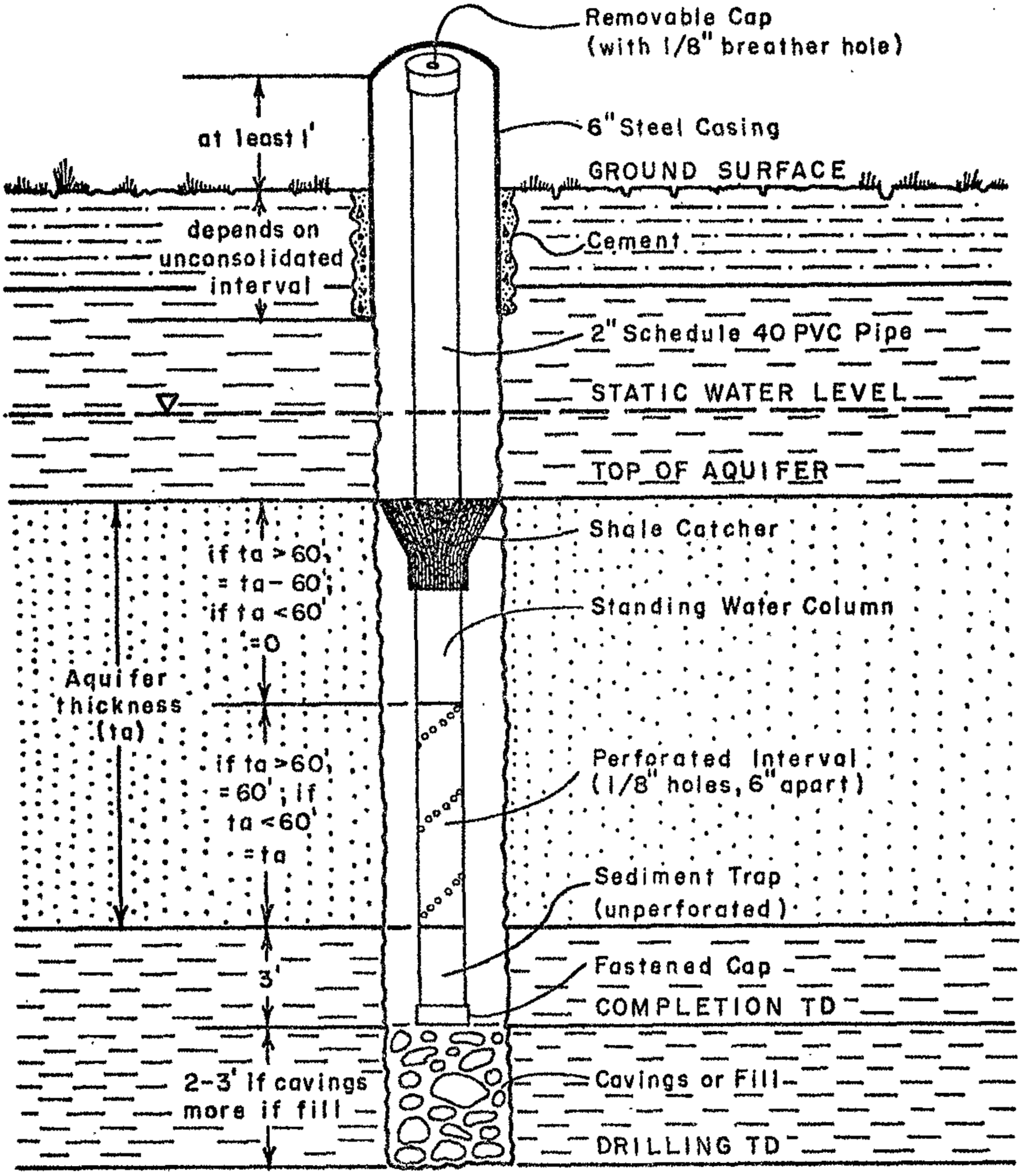



Figure 1. Idealized construction of wells used in Torreon water study (not to scale). At places, aquifer extends to bottom of hole. Locally water is confined so that static level is above top of aquifer only in well bore.

whereas details regarding their location and construction are summarized in Table 1.

## Preliminary Results

During the summer and early fall of 1978, major effort was directed toward establishing the water observation wells. Nonetheless, pumping tests were conducted and samples were analyzed for 3 of the holes. Results of pumping tests conducted to date are given in Table 2. Results of chemical analyses made thus far are presented in Table 3. The compositions of the water analyzed are compared by means of a trilinear plot in Figure 2. Preliminary data show that the quality of water from the Point Lookout is quite good with total dissolved solids contents less than 700 ppm. Water from the lower Menefee coal, however, is quite poor (falling in the moderately saline category) with a dissolved solids content of 9,210 ppm. The sample from R21 would be classified as sodium-bicarbonate water, that from R23 is sodium-bicarbonate-sulfate water, and R32 yielded sodium-bicarbonate-sulfate-chloride water (Fig. 2).

## Work in Progress

Steve Craigg is continuing the study of the hydrogeology and water resources of the Chico Arroyo-Torreon Wash area as his M.S. thesis project. In addition to hydrologic work, the study includes analysis of the stratigraphic framework of the area, the petrographic characteristics (texture, porosity,

Table 1. Summary of location and construction details for coal holes converted to water observation wells, Torreon Project; Kpl = Point Lookout Sandstone, Kmf = Menefee Formation, D = driller's observation, F = field measurement, L = log value.

| Well No. | R21 | R23 | R24 | R32 | C1 |
|---|---|---|---|---|---|
| Location | SE,SE,SE<br>Sec. 18<br>16N, 4W | NW,SW,SW<br>Sec. 6<br>16N, 4W | SW,SE,NE<br>Sec. 2<br>16N, 5W | NE,NW,SE<br>Sec. 23<br>17N, 4W | NW,NW,SW<br>Sec. 20<br>18N, 3W |
| Ground Elev.(ft) | 6,395 | 6,235 | 6,305 | 6,175 | 6,540 |
| Depth (ft)[1] | 244 | 248 | 220F | 235 | 172D |
| Water Level[1] (ft; date) | 102.20F<br>(7-27-78) | 93.25<br>(8-31-78) | 123F<br>(10-13-78) | 41.50F<br>(9-29-78) | 156D<br>(9-78) |
| Aquifer | Kpl | Kpl | Kpl | Kmf<br>(lower coal) | Kmf<br>(upper coal) |
| Top of Aquifer (ft)[1] | 100L | 180L | 177L | 228L | 155D |
| Aquifer Thickness (ft) | 144L | 68L | 49L | 5L | 15D |
| Perforated Interval (ft)[1] | 84-241 | 128-245 | 177-217 | 228-233 | 155-169 |
| Perforated Length (ft) | 157 | 117 | 40 | 5 | 14 |

[1] Values given are depths below ground surface.

Table 2. Summary of pumping tests conducted to date; Kpl = Point Lookout Sandstone, Kmf = Menefee Formation.

| Well No. | R21 | R23 | R32 |
|---|---|---|---|
| Location | SE,SE,SE<br>Sec. 18<br>16N, 4W | NW,SW,SW<br>Sec. 6<br>16N, 4W | NE,NW,SE<br>Sec. 23<br>17N, 4W |
| Depth (ft) | 244 | 248 | 235 |
| Water Level<br>(ft; date) | 102.20<br>(7-27-78) | 93.25<br>(8-31-78) | 41.50<br>(9-29-78) |
| Aquifer | Kpl | Kpl | Kmf<br>(lower coal) |
| Pumping Test Data | | | |
| Type of Test<br>(Date) | Bailer<br>(7-27-78) | Swabbing<br>(8-31-78) | Swabbing<br>(9-29-78) |
| Rate (gpm) | 0.27 | 1.1 | 1.4 |
| Drawdown (ft) | 17.6 | 4.1 | 76.0 |
| Elapsed Time (min) | 85 | 74 | 15 |
| Recovery (ft) | 10.9 | 1.1 | 4.0 |
| Elapsed Time (min) | 87 | 180 | 381 |
| Transmissivity ($ft^2$/day)[1] | .40 | .01 - .035 | .0001 |

[1] Determined by slug method (Lohman, 1972, p. 28).

Table 3. Results of chemical analyses of waters made to date; ppm = parts per million, TDS = total dissolved solids, μmhos = micromhos, Kpl = Point Lookout Sandstone, Kmf = Menefee Formation, F = field observation, L = laboratory measurement.

| Well No. | R21 | R23 | R32 |
|---|---|---|---|
| Aquifer | Kpl | Kpl | Kmf (lower coal) |
| Cations (ppm)L | | | |
| Ca (none)[1] | 7.8 | 40.1 | 24.8 |
| Mg (125) | 1.5 | 12.5 | 18.4 |
| Na (115) | 150 | 40.1 | 3,225 |
| K (none) | 3.25 | 3.7 | 4.4 |
| Anions (ppm)L | | | |
| $HCO_3$ (none) | 315 | 328 | 1,750 |
| $CO_3$ (none) | 0 | 0 | 0 |
| $SO_4$ (250) | 90 | 260 | 3,842 |
| Cl (250) | 3.8 | 6.8 | 1,220 |
| TDS (ppm; 500)L | 415 | 667 | 9,210 |
| Temperature (°C)F | 16 | 16 | 16 |
| Specific Conductance (μmhos) | 580 F<br>527 L | 980 F<br>895 L | 7,000 F<br>9,790 L |
| pH | 8.8 F<br>8.2 L | 7.5 F<br>8.2 L | 7.2 F<br>8.0 L |

[1] Values in parentheses are recommended limits for domestic use (California Water Pollution Control Board).

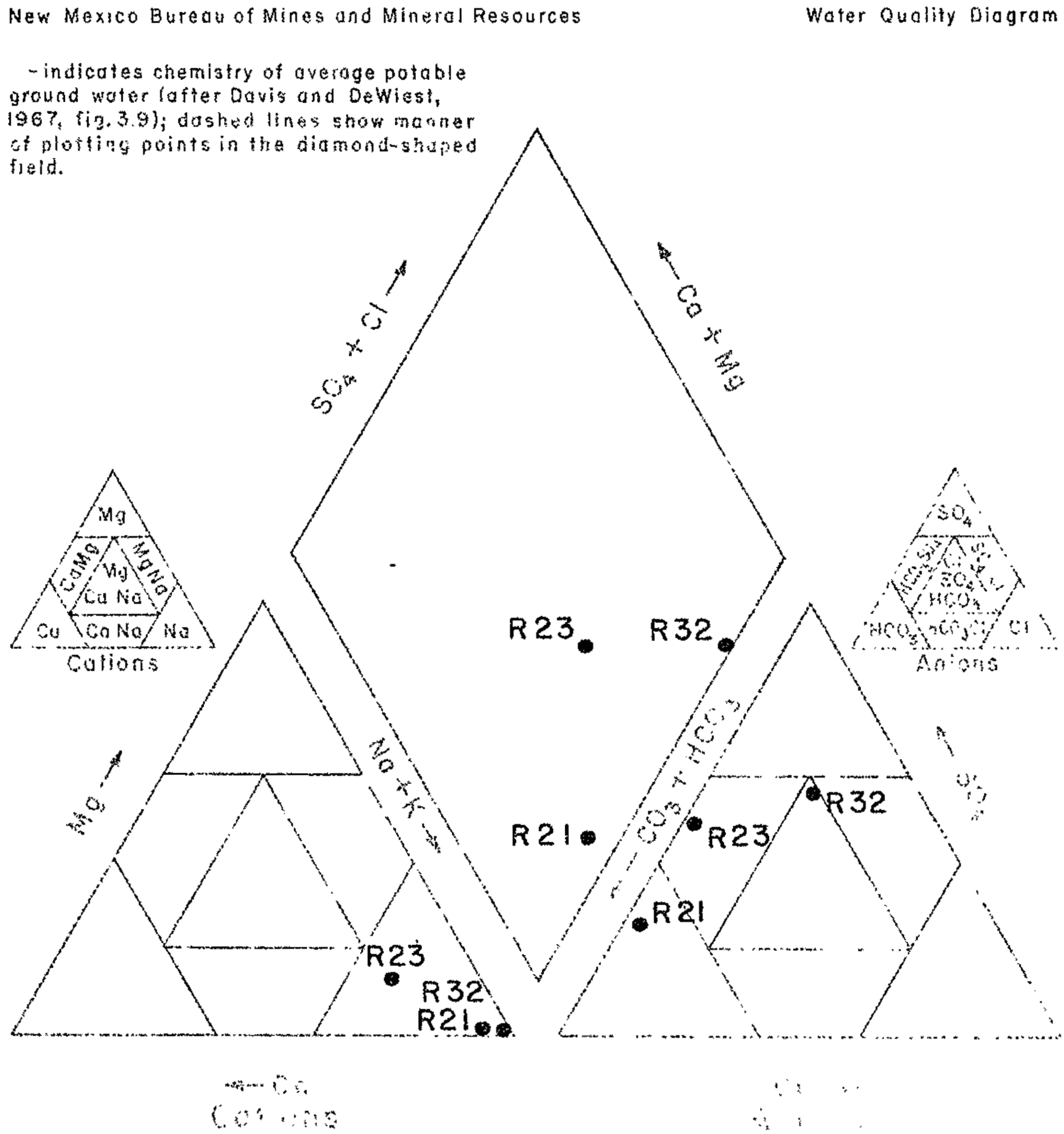



Figure 2. Trilinear plot of concentrations of major dissolved solids encountered in waters from Torreon wells analyzed to date; points identified by well numbers (see Tables 1, 3, and 4). Small triangles at sides give key to classification of waters.

composition) of the potential aquifers and associated units, and the role these factors play in controlling water-resource availability in the area. Final results of the thesis study are scheduled to be published by the Bureau as Hydrogeologic Sheet 4.

The wells will also provide a means of monitoring the major aquifers after the thesis study is completed. The existence of such wells should prove especially useful should coal mining be initiated in the area. Specific use depends on the location and nature of the development. Pending such development, the wells will be visited annually for water-level measurement, water sampling and general inspection.

## References Cited

Davis, S.N. and DeWiest, R.J.M., 1966, Hydrogeology: New York, John Wiley and Sons Inc., 463 p.

Lohman, S.W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p.


Base from USGS

Geology by David E. Tabet, Stephen J. Frost and Michael R. Whyte 1977–78

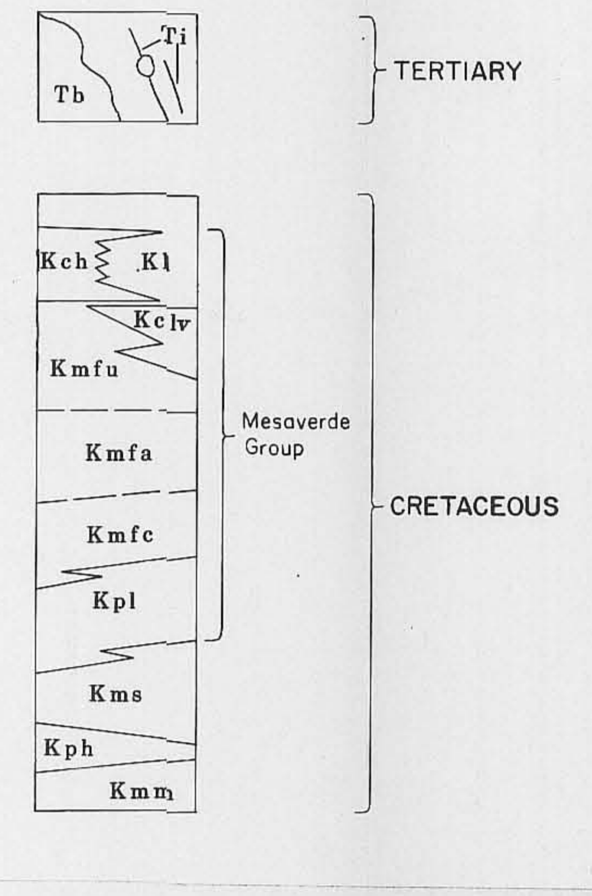
# BEDROCK GEOLOGY OF TORREON WASH AREA, NEW MEXICO

Scale 1:24,000 Contour interval 20 ft

mi

km

## CORRELATION OF UNITS




## DESCRIPTION OF MAP UNITS

**Tb | Ti** Tertiary Volcanics — *Tb, basalt flows capping Mesa Chivato; Ti, basalt dikes and plugs related to Mt. Taylor volcanic center*

**Kl** Lewis Shale — *Light- to dark-gray silty shale interbedded with Cliff House Sandstone*

**Kch | Kclv** Cliff House Sandstone — *Gray or tan fine-grained, even-bedded to crossbedded sandstone. Main body of Cliff House, Kch, dies out rapidly to northeast as lower La Ventana Tongue, Kclv, appears; La Ventana consists of several tongues*

**Kmfu | Kmfa | Kmfc** Menefee Formation — *Kmfu, upper coal-bearing member, intertongues with La Ventana Tongue of Cliff House; Kmfa, Allison Member, predominantly fine to medium crossbedded sandstone and tan to light-gray shale; Kmfc, Cleary Member, gray to dark-brown carbonaceous shale, tan sandstone, and coal*

**Kpl | Kph** Point Lookout Sandstone — *Tan to brown, fine-grained, even-bedded to crossbedded sandstone; interbedded with shale near base. The Hosta Tongue, Kph, is separated from the main body of the Point Lookout Sandstone, Kpl, by the Satan Tongue of the Mancos Shale*

**Kms | Kmm** Mancos Shale — *Light- to dark-gray, silty shale with a few thin sandstone or limestone beds or limestone concretions. The Satan Tongue, Kms, is separated from the Mulatto Tongue, Kmm, by the Hosta Tongue of the Point Lookout Sandstone*

*Strike and dip of beds*

15°

*Axis of trough crossbedding*

*Coal bed, dashed where approximate, dotted where inferred (measurement in ft)*

1.5'

*Coal mine or prospect*

*Burned coal bed*

*Fault, dashed where approximate or concealed (ball on downthrown side)*

*Contact, dashed where approximate*


Base from USGS

Geology by David E. Tabet, Stephen J. Frost and Michael R. Whyte 1977–78

# BEDROCK GEOLOGY OF TORREON WASH AREA, NEW MEXICO

Scale 1:24,000 Contour interval 20 ft

For explanation see sheet 1


# BEDROCK GEOLOGY OF TORREON WASH AREA, NEW MEXICO

Scale 1:24,000

Contour interval 20 ft

1 0 1 mi

1 0 1 km

For explanation see sheet 1

PLATE IV. ELECTRIC LOG CROSS-SECTION OF UPPER CRETACEOUS STRATA, TORREON WASH AREA, N.M.