GEOLOGY AND COAL RESOURCES
PINEHAVEN QUADRANGLE

By

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ABSTRACT

The Pinehaven 7.5 minute quadrangle is located approximately 8 mi south of Gallup. Four stratigraphic units are found in the area; the Gallup Sandstone, the Crevasse Canyon Formation, the upper Bidahochi Formation, and Quaternary Alluvium. The majority of the coals present belong to the Crevasse Canyon Formation, with a few coals present in the Gallup Sandstone. The thickest, near-surface coals are found in two horizons within the Crevasse Canyon Formation.

Coals are present in a lower horizon which occurs directly above the Gallup Sandstone and are high volatile bituminous B or C in rank. The coals of the upper horizon, located in the upper portion of the Crevasse Canyon Formation, are of lower grade, having a rank of subbituminous A. Outcrop data is sparse; however, sixteen drill holes provide coverage for reserve calculation for most of the quadrangle. Reserves for the measured and indicated categories are calculated to be 34.65 million tons and 146.25 million tons respectively. These coals are low in sulfur, but may have as much as 40% ash. About 41% of the coal is owned by the Navajo tribe and 20% is owned by the Zuni tribe. The federal government owns 26% of the coal. The remaining 13% of the coal rights are held by private individuals and the State of New Mexico.

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INTRODUCTION

LOCATION--The Pinehaven quadrangle lies 8 to 17 miles south of Gallup, New Mexico, between State Highway 32 on the west and the Nutria Monocline and the Zuni Mountains on the east (fig. 1). The area is almost equally distributed over four townships, Townships 12 and 13 N., and Range 17 and 18 W. in southwestern McKinley County.

The only paved road within the study area connects the small Navajo community of Bread Springs with State Highway 32. This road passes through the northwestern quarter of the quadrangle. Numerous dirt roads, some well maintained, provide access to nearly all parts of the quadrangle.

GEOGRAPHY--Ubiquitous but widely spaced dwellings, the majority inhabited by Indians, are present in the quadrangle. The community of Pinehaven is located in the northeastern part of the area along the road to McGaffey. The southeastern quarter of the quadrangle lies within the Zuni Reservation while the northeastern quarter includes the western fringes of the Cibola National Forest.

Three drainage systems and their tributaries carry water from the area and eventually empty into the Little Colorado River. Tributaries of Bread Springs Wash drain the far northern edge of the area. Whitewater Arroyo crosses the area from northeast to southwest and drains most of the central portion of the quadrangle. The southeastern portion of the area is drained by tributaries of the Rio Nutria.

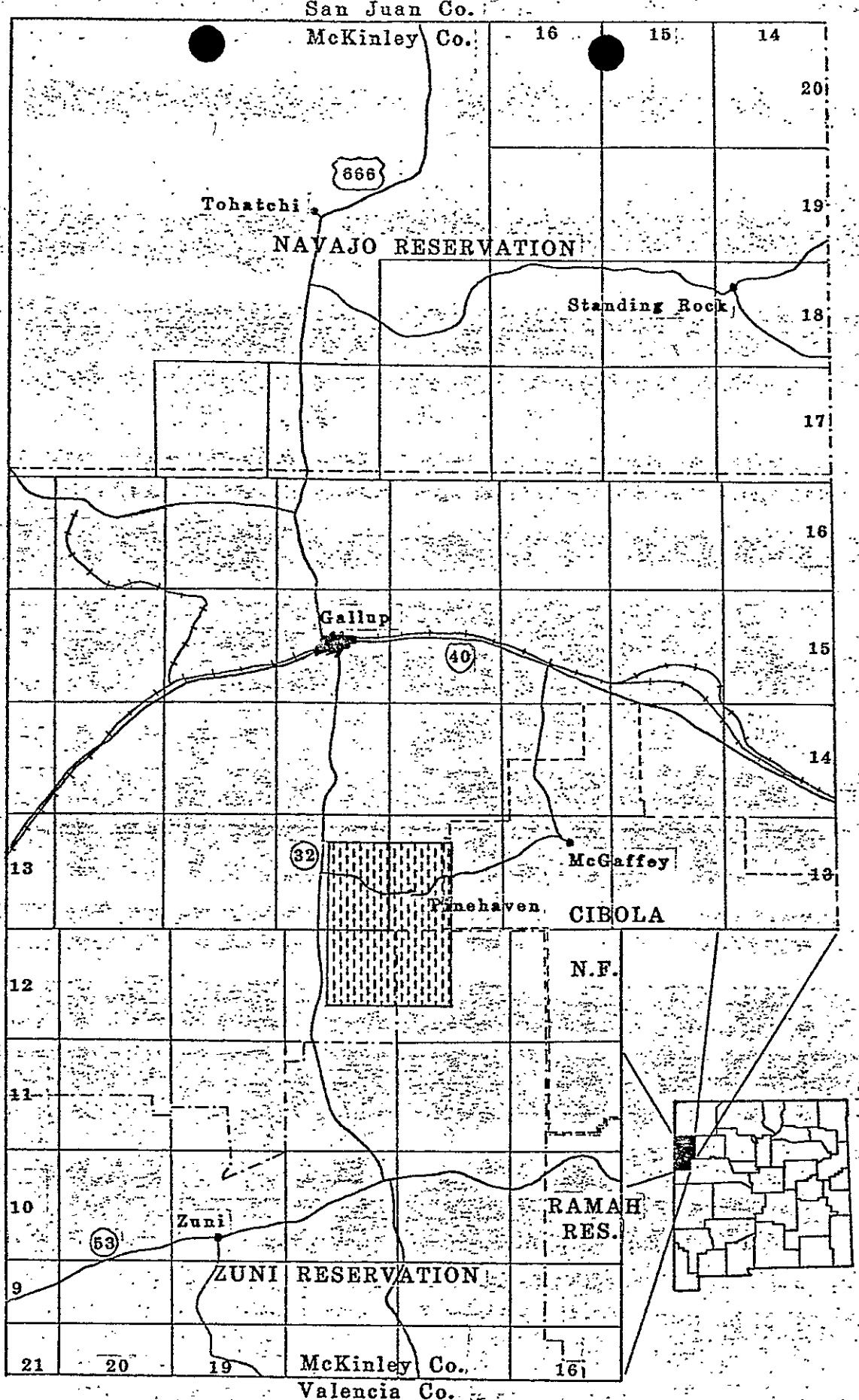


Figure 1--Location of Pinehaven quadrangle.

The streams have deeply dissected a gently westward sloping plateau that has an average elevation of about 7,300 ft above sea level. The old plateau surface now stands as much as 350 ft above the valley bottoms, producing a rugged terrain. The maximum elevation of 7,740 ft above sea level occurs in the northeast corner of the quadrangle while the lowest elevation, 6,820 ft, occurs in the southeastern part.

VEGETATION--The rocky mesa tops and canyon sides generally support a pinon-juniper forest with some scattered stands of ponderosa pine and scrub oak, with shrubs, grasses, and cacti providing the understory. The valley bottoms, with their deep soil, are characterized by grass-shrub vegetation alone. The vegetational boundary between grass-shrub and woodland areas often marks the contact between alluvial valley fill and exposures of bedrock on the canyon sides.

PREVIOUS WORK--The geology of the Pinehaven area had attracted the attention of investigators long before New Mexico became a state. Gilbert (1875) made an early reconnaissance study of the geology and is attributed with naming the Nutria Monocline. Dutton (1885) also reported on the general geology and structure of the Gallup-Zuni basin and noted the presence of coal in the region. Later reconnaissance studies of the structure and geology of this area were made by Darton (1910; 1922; and 1928) and Gregory (1917).

Schrader (1906) and Shaler (1907) made the first reconnaissance studies directed specifically toward coal deposits in the region. They produced preliminary maps and gave a few

measurements on the thickness and quality of coal in nearby Gallup and Zuni. Sears (1925) produced the first detailed report on the structure, stratigraphy and coal geology of the Gallup-Zuni area, and included in his report some earlier unpublished work by D.E. Winchester on coals on the Zuni Reservation. Sears subdivided the Mesaverde Formation in the Gallup area into the Gallup Sandstone Member, the Dilco Coal Member, and the Allison Barren Member, in ascending order. A reconnaissance of strippable coals in the Zuni area was done as a part of the San Juan Basin study (Shoemaker, et al, 1971). Reconnaissance and photogeologic mapping of the Gallup area by Hackman and Olson (1977) has updated the New Mexico geologic map of Dane and Bachman (1965).

Pike (1947) measured sections from this area for his landmark paper describing the regional intertonguing relationships between the marine and non-marine rocks of Upper Cretaceous age. He showed that the Mesaverde section thickens southward from Gallup at the expense of the underlying Mancos Shale in a more systematic approach than earlier investigators.

Allen and Balk (1954) revised Sears' terminology for the Gallup area Mesaverde rocks by raising the Gallup Sandstone to formational rank, and proposing a new formation the Crevasse Canyon Formation to include the overlying coal-bearing and barren members, including the Dalton Sandstone Member. In so doing, the Mesaverde was elevated from formation to group status. This terminology was formalized by Beaumont, Dane, and Sears (1956) and in addition, the Allison Barren Member was assigned to the Menefee Formation.

Papers by Beaumont (1957), Dane, Bachman, and Reeside (1957) and Molenaar (1973, 1974) discuss the stratigraphy, lithology, facies, and correlation of the Gallup Sandstone and associated formations. A good summary of Upper Cretaceous stratigraphy of the Four Corners area is provided in O'Sullivan, Repenning, Beaumont, and Page (1972).

SCOPE OF PRESENT STUDY--The work for this report is the result of a cooperative project with the Conservation Division of the U.S. Geological Survey and the Minerals Department of the Navajo Tribe. Most of the funding was provided under U.S. Geological Survey Grant 14-08-0001-G-570. This report presents the data from five months of detailed field mapping at 1:24000 scale and the subsequent drilling of several shallow drill holes. Analyses of core samples provide information on the chemical properties of fresh coals in the area. Coal resources were calculated following the parameters outlined in U.S. Geological Survey Bulletin 1450-B (1976). In addition to geologic information, a summary of land and mineral ownership are provided along with the history of coal mining and prospecting of the Pinehaven area.

ACKNOWLEDGMENTS--The many residents of the Pinehaven area are thanked for giving permission to enter their lands for geologic mapping. Thanks are also extended to the Zuni Indians, particularly Shirley Belson and Governor Robert Lewis, for granting permission to work on the Upper Nutria part of the reservation.

Messrs William Armstrong and Aktar Zaman of the Navajo Tribe Minerals Department arranged to work cooperatively on tribal lands

and kindly provided geologic and land ownership information and assisted with drilling entry problems. Messrs. Andrew Livingston of Bokum Resources, Inc., Rajendra Reddy of Carbon Coal Company and Peter Mattson of Utah International, Inc., graciously supplied drilling data from company files. Mr. Ijaz Khan of the Navajo Tribe Water and Sanitation Department provided drilling data from tribal water wells in the area. Ms. Idita Claymore and her staff at the Southwest Title Plant of the Bureau of Indian Affairs kindly provided access to their files so that patterns of mineral and surface ownership could be determined.

Help with the mapping was provided by Luis Martinez, of the State Bureau of Geology, and Gary Massingill, formerly with the New Mexico Bureau of Mines and Mineral Resources. Frank Campbell aided in compilation of the final report. Finally, the assistance of the U.S.G.S. Conservation Division staff of New Mexico, specifically Wayne Lambert and Norman Wingard, was most helpful in completing this study.

GEOLOGIC STRUCTURE

The Pinehaven quadrangle is situated within a broad shallow depression extending off the southwestern part of the San Juan Basin. This depression, the Gallup sag (Hackman and Olson, 1977), is bounded by the Defiance Monocline on the west and the Nutria Monocline on the east. The Gallup sag is an asymetrical depression with its axis located very close to its eastern edge; the west limb is broad and gently sloping, while the east limb is

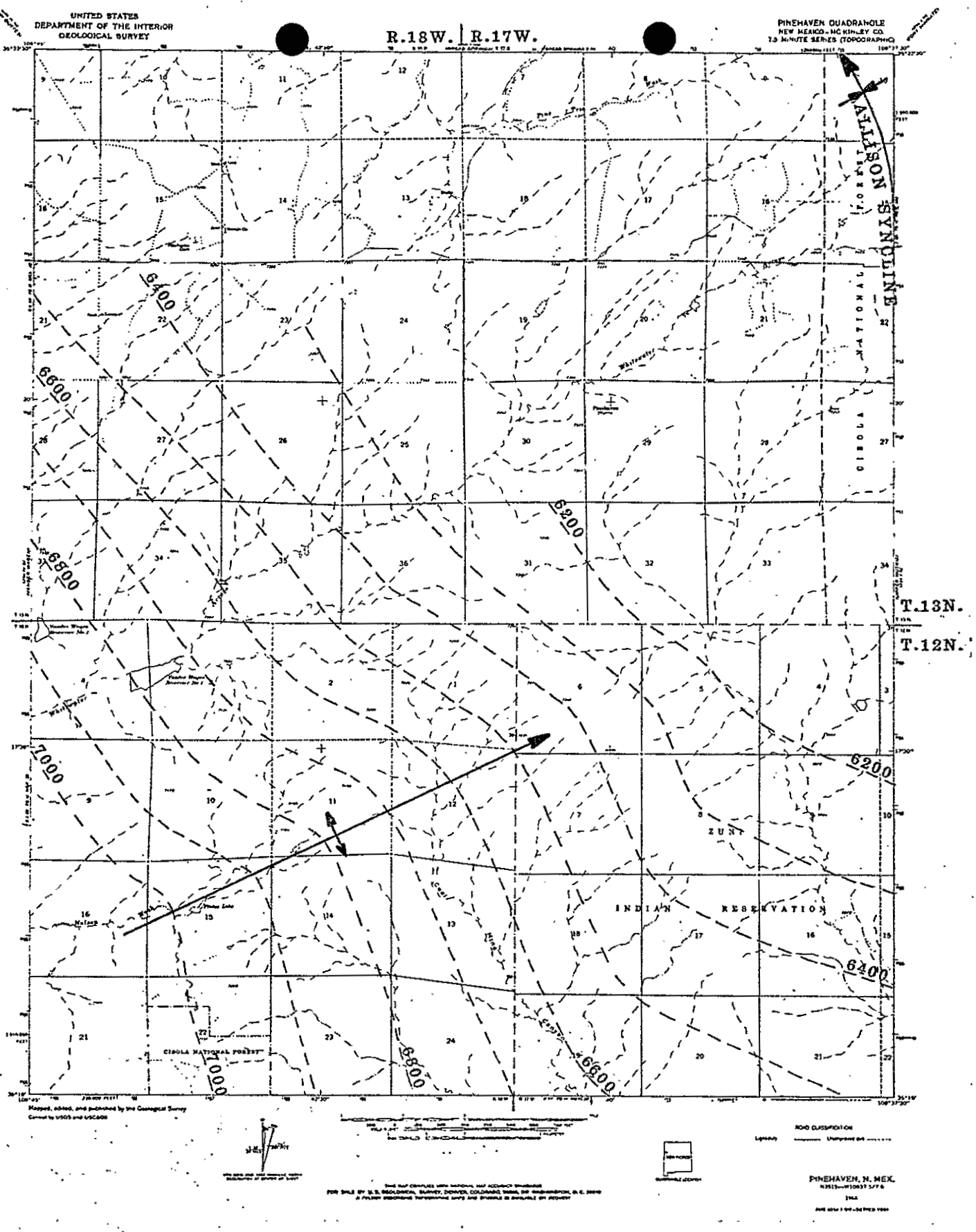


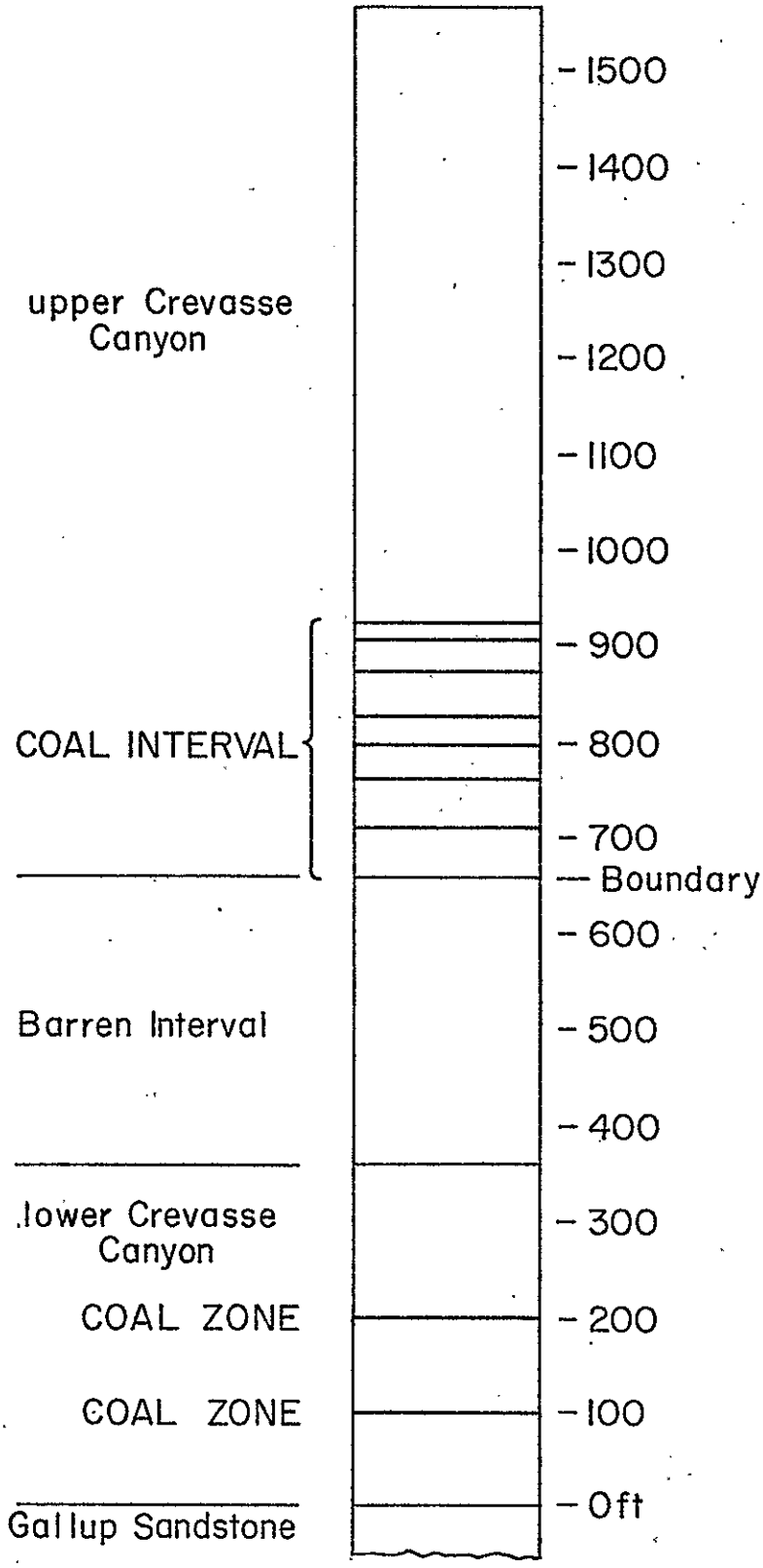
Figure 2--Structure contour on top of Gallup Sandstone. (contour interval 100 ft, datum is sea level)

narrow and steep. The axial structure of the Gallup sag is called the Allison syncline (Fig. 2). Complicating the overall asymetrical sag or synclinal structure are a number of gentle anticlines and synclines which tend to parallel the north-south structural trend.

The Pinehaven quadrangle lies along the broad western limb of the Allison syncline with the dips of the area ranging from 2 to 12 degrees to the northeast with and averaging 5 degrees. A gentle northeast plunging anticlinal flexure (Fig. 2) occurs in the southwestern quarter of the area and creates some northwesterly dips there. One normal fault, trending N. 15 E., is exposed in sec. 16, T. 12 N., R. 18 W. and has about 20 ft of displacement with the east side down relative to the west.

GENERAL STRATIGRAPHY

There are only a few stratigraphic units exposed in the study area. The youngest is Quaternary alluvium. The only Tertiary unit is the Bidahochi, which can attain a thickness of 180 ft. Two Cretaceous units, the Crevasse Canyon (possibly 1500 ft), and the Gallup Sandstone are exposed within the study area. The Gallup was penetrated in drilling. The general topographic relationships of these units, as well as structural features are shown on the geologic map of the Pinehaven 7.5 minute quadrangle (Plate I).



Scale 1:2,400

Figure 3

STRATIGRAPHIC COLUMN
PINEHAVEN QUADRANGLE

UPPER BIDAHOCHI FORMATION--Sediments of the upper member of the Bidahochi Formation (Reagan, 1924) cap the mesa tops of the Pinehaven quadrangle except in the easternmost part. Cooley and Akers (1961) assign a Middle Pliocene age to this member. As noted by McCann (1938), these sediments rest unconformably on a westward-sloping surface of beveled Upper Cretaceous rocks in the Pinehaven area and older rocks to the west. The elevation of the base of the Bidahochi drops from approximately 7,460 ft in the northeast to about 7,100 ft to the southwest. This drop in elevation of this contact is gradual throughout the quadrangle, except near the eastern margin of the area.

The unconsolidated upper Bidahochi member sediments are composed mainly of reddish-brown to whitish, argillaceous, medium to fine grained sandstone along with lesser amounts of brown, nodular, resistant sandstone, minor white, biotite-bearing volcanic ash beds and some porous limestone beds. The sandstone is generally lighter in color when the carbonate content is greater. Exposures of the poorly consolidated Bidahochi sediments are characteristically covered by colluvial material except for a few steep slopes or under some resistant beds along mesa tops. Resistant sandstone or white tuff beds often hold up the upper surface of the Bidahochi. Usually the uppermost Bidahochi shows some signs of reworking, as indicated by the presence of a lag gravel containing pebbles of chert, quartzite and Cretaceous

sandstone or a veneer of eolian sand. The author agrees with McCann's (1938) suggestion that the upper surface of the Bidahochi Formation may have been reworked by wind in Pleistocene and Holocene time throughout the Gallup-Zuni area. For this reason the Bidahochi is mapped as Quaternary and Tertiary in age. The thickness of the Bidahochi sediments ranges from a knife edge to as much as 180 ft with an average of about 60 ft. Headward-cutting tributaries of the major drainages are slowly stripping away the Tertiary sediments.

UPPER CRETACEOUS STRATIGRAPHY

INTRODUCTION--The major coal-bearing rocks of the Pinehaven quadrangle are the Gallup Sandstone and Crevasse Canyon Formation and these are the only Upper Cretaceous rocks that outcrop. Figure 3 is a generalized stratigraphic column, showing the Crevasse Canyon Formation and the position of the major coal horizons present in the Pinehaven quadrangle. Below the Gallup, in the subsurface, is another interval of non-marine, coal-bearing rocks, termed the lower part of the Gallup Sandstone (Pike, 1947, Molenaar, 1973). Exploration and water well drilling indicate that the coals in this interval are too thin in the Pinehaven area to be of economic significance. This lower Gallup interval thins to the north, pinching out into the Mancos Shale, and thickens to the south at the expense of the Mancos (Molenaar, 1973).

GALLUP SANDSTONE--The Gallup Sandstone was named by Sears (1925) for exposures in the vicinity of the town of Gallup, New Mexico.

The well-known section in the hogback, east of Gallup, consists of three prominent ledges of sandstone and two intervening softer shaly intervals. The whole formation ranges from 220 to 280 ft in thickness. The two lower sands and the intervening sandy shale unit are marine in origin, while the upper soft interval is nonmarine and contains one or more coal beds. The uppermost Gallup sandstone is a 30- to 60-ft-thick, pink, coarse-grained, arkosic, fluvial sandstone. This unit thins to the north and east of Gallup, but is a persistent horizon to the south through the Gallup-Zuni basin (Dane and others, 1957). Molenaar (1973) has proposed naming and mapping this upper sandstone as the Torrivio Sandstone Member of the Gallup.

Only the uppermost 20 ft of the Gallup Sandstone is exposed in the central part of sec. 16, T. 12 N., R. 18 W. These limited exposures are of tan, fine-grained, well sorted sandstone. Internally the sandstone is composed of 1 to 3-ft-thick tabular to wedge-shaped beds with high-angle cross lamination. The cross sets have a common northwesterly dip direction.

CREVASSE CANYON FORMATION--Allen and Balk (1954) named this formation for the continental and nearshore rocks in the interval between the Gallup Sandstone and the Point Lookout Sandstone, as exposed near Crevasse Canyon in San Juan County, New Mexico. In the type area, the Crevasse Canyon Formation consists of the Dilco Coal Member, the Dalton Sandstone, and the Gibson Coal Member, in ascending order. The Bartlett Barren Member (Sears, 1925) is also recognized as a part of the Crevasse Canyon Formation and represents the landward equivalents of the marine Dalton

Sandstone. Both the Dalton and Point Lookout sandstones pinch out north of Gallup, thus eliminating convenient persistent breaks in the continental section. This results in the Gibson being overlain and hence, indistinguishable from the Cleary Coal Member of the Menefee. These two units are mapped together as part of the Crevasse Canyon. The Bartlett Barren Member of the Gallup-Zuni sag is distinguished from the Dilco and Gibson members on the basis of its lack of thick coals and as such has very imprecise boundaries. Sears (1925) divided the Crevasse Canyon in the Gallup area as follows: the Dilco Coal Member - the lower 240 to 300 ft, the Bartlett Barren Member - the medial 330 to 440 ft, and the combined Cleary and Gibson Coal Members - the upper 150 to 175 ft. Recent investigators in the Gallup East Quadrangle (Green and Jackson, 1976) were unable to follow these same divisions and combined all units from the Dilco up through the Cleary as the Crevasse Canyon undivided. The large amount of cover and the lack of readily identifiable boundaries between the members of the Crevasse Canyon in the Pinehaven area caused the present writer to map the rocks overlying the Gallup as Crevasse Canyon undivided.

The Crevasse Canyon is thinnest in the southwest quarter of the study area and thickens to the north and east. Over 980 ft of Crevasse Canyon strata have been penetrated by a Bokum drill hole in sec. 5, T. 12 N., R. 17 W., and projections from structural data indicate there may be 1500 ft of these strata in the northeast corner of the area. This thickness is greater than the equivalent Crevasse Canyon section of Sears (1925) near Gallup. Although not mappable on the surface, coal-bearing and

noncoal-bearing portions of the Crevasse Canyon can be recognized on cross sections constructed from drill hole data. These divisions, discussed in more detail in the coal geology section, may or may not correspond to the Dilco, Bartlett Barren, and Gibson-Cleary Members of the Crevasse Canyon Formation.

Lithologically, the Crevasse Canyon Formation of the Pinehaven area consists of varying amounts of sandstone, siltstone, shale, and coal. The presence or absence of coal has been the criteria for dividing the Crevasse Canyon into members. Therefore, since the other lithologic constituents are similar throughout the formation it is reasonable to describe them for the formation as a whole, rather than for each member unit.

The sandstones of the Crevasse Canyon Formation are composed of fine to medium quartz grains, with minor feldspar and chert. The grains are generally subangular to subrounded and moderately to poorly cemented. The sandstones occur as yellow to tan lenticular bodies up to 25 ft thick. These bodies have sharp, often erosional, lower contacts along which clay rip-up clasts are present. Internally the sand bodies consist of low- to high-angle, cross-cutting, trough cross beds. Particles within these bodies may show a fining upward, but more commonly show an upward decrease in the scale of cross-bedding and often exhibit ripple bedding at the top.

Shales of the Crevasse Canyon are of two types; carbonaceous and noncarbonaceous. The carbonaceous shales are generally brown to grayish-black and may contain petrified wood or iron-rich concretions. These shales are closely associated with coals. The

noncarbonaceous shales are yellowish-green to yellowish-gray or tan and also contain petrified wood. Both are commonly silty with minor laminations and thus can be termed mudstones.

Yellow or tan siltstone is the other major lithotype in the Crevasse Canyon. It is often in gradational contact with the silty noncarbonaceous shales or the silty sandstones.

Petrified wood is the most common type of fossil and is found throughout the Crevasse Canyon section. Several types of wood exist based on hand specimen appearance. Leaf impressions and seed casts may be found locally. Only a few scattered vertebrate remains were found. Fragments of chelonid carapaces were found in the lower part of the Crevasse Canyon at two locations; one in sec. 12, T. 12 N., R. 18 W. and one in sec. 18, T. 12 N., R. 17 W. Possible "dinosaur" bone scraps were locally in sec. 15 T. 13 N., R. 17 W. No identification of these bone fragments or their exact age was possible.

COAL GEOLOGY

STRATIGRAPHY--The coal geology discussed here is only that of the Crevasse Canyon portion of the Upper Cretaceous section. Coal also occurs within the Gallup Sandstone and the "lower Gallup" interval (as used by Molenaar, 1973, 1974); however, because of the lack of data on these coals and their generally thin and uneconomic nature, they will not be discussed. The Crevasse Canyon strata of the study area are comprised of two coal-bearing

intervals and an intervening relatively barren interval. This conclusion is drawn from the compilation of coal occurrence data from outcrops and exploration holes onto several cross sections, Plate II (a, b, c).

The lower 350 ft of the Crevasse Canyon, probably equivalent to the Dilco Coal Member, is the most important coal-bearing horizon. Coals of this interval crop out primarily in secs. 9, 13, 16, 23, and 24 of T. 12 N., R. 18 W. Coals occur throughout this interval but the thickest and most persistent coal horizons are found approximately 100 and 200 ft above the top of the Gallup Sandstone. Coal beds in this lower coal-bearing interval average about 2.0 ft thick, but locally reach over 6.0 ft thick. In some places the aggregate thickness of several thinner coal seams within a 20 ft zone totals as much as 7.4 ft. As many as 13 coal beds thicker than one foot occur within the lower coal-bearing interval. The coal beds are highly lenticular, but appear to be traceable for a distance of several miles. In general, these lower coal beds thicken and become more numerous toward the eastern side of the quadrangle toward the axis of the Allison syncline.

Above the lower coal-bearing horizon is an essentially barren interval roughly 300 ft thick which may be correlative with the Bartlett Barren Member of the Crevasse Canyon. Some thin, lenticular coal beds of very limited lateral extent are found in this interval, however; lithologically this interval is dominated by sandstone channel deposits. The ubiquitous channel sandstones have commonly scoured through the few thin coals present in this zone is the major factor in the coals lack of persistence.

Overlying the medial barren interval is another coal bearing portion of the Crevasse Canyon. As much as 900 ft of strata comprise this interval and are probably equivalent to the Gibson-Cleary Members undivided and possibly even part of the Allison Member of the Menefee Formation. Coal occurs mainly in the lowest 250 ft of this interval. Good exposures of these lowermost coals occur in T. 12 N., R. 17 W. on the Zuni Indian Reservation (Plate 3). The coal beds in the basal part of the upper coal interval range from 1.0 to 4.6 ft thick, but generally average 1.5 ft thick. Coal beds are generally thinner and not laterally persistent above the basal part. The maximum measured thickness of coal in the upper part of the upper coal interval is 2.0 ft. Unlike the lower coal-bearing interval, coal beds in the upper coal-bearing interval do not show any distinct thickening or abundance trends.

COAL ANALYSES--Analyses of the coals sampled was done by Hazen Laboratories of Golden, Colorado. Table 1 gives a breakdown of the Btu, proximate and ultimate analyses of four coal seams penetrated by drilling, and compares them to average analyses of Mesaverde Group coals. The description of these cores can be found in Appendix I. The two coals present in drill hole 1318-26-1 have a thickness of 3.2 ft at a depth of 113.6 ft and 3.6 ft at a depth of 189.4 ft. Hole 1218-14-1 has a coal at a depth of 256.3 ft with a thickness of 2.6 ft. Hole 1218-9-1 has a 4.2 ft coal at a depth of 130.0 ft. The coals sampled have a depth sufficient enough to avoid the influence of surface oxidation. According to the method outlined in ASTM 388-77 these

TABLE 1
ANALYSIS OF PINEHAVEN COALS
(on as received basis)

Sample	V.M.	F.C.	H20	ASH	C	H	N	S	O
1318-26-1 (113.6-116.8')	31.25	28.78	13.60	26.37	44.66	3.72	.69	.57	10.39
1318-26-1 (189.4-193.0')	23.88	22.76	12.61	40.75	35.04	2.85	.84	.35	7.56
1218-14-1 (256.3-258.9')	35.62	47.37	8.41	8.60	66.09	4.59	1.29	.71	10.31
1218-9-1 (130-134.2')	40.46	45.92	3.00	10.62	66.56	4.99	1.36	.68	12.79
AVERAGE MESAVERDE	39.50	47.30	10.70	9.4	65.60	5.50	1.30	1.10	17.10

	FORMS OF SULFUR			
	TOTAL	PYRITIC	ORGANIC	SULFATE
1318-26-1 (113.6-116.8')	.57	.32	.25	0.0
1318-26-1 (189.4-193.0')	.35	.11	.24	0.0
1218-14-1 (256.3-258.9')	.71	.20	.51	0.0
AVERAGE MESAVERDE	.75	.35	.40	0.0

BTU VALUES AND RANK

	AS RECEIVED BTU	MOIST MINERAL MATTER FREE BTU	RANK
1318-26-1 (113.6-116.8)	7955	11132	SUBBITUMINOUS A
1318-26-1 (189.4-193.0)	6128	11114	SUBBITUMINOUS A
1218-14-1 (256.3-258.9')	11589	12816	H.V. C BITUMINOUS
1218-9-1	11255	13323	H.V. B BITUMINOUS

four coals vary in rank from subbituminous A to high volatile B bituminous. This compares favorably with the average rank (high volatile bituminous C) for Mesaverde coals. The average sulfur content of these four coals is .58%, less than the Mesaverde average of 1.1%. Drill hole 1218-9-1 is a sample collected from cuttings, and as a result the moisture content is low and the ash content is high.

The coals in hole 1318-26-1 are 730-800 ft above the Gallup and therefore from the upper coal zone, while the coals from holes 1218-14-1 and 1218-9-1 are 39-165 ft above the Gallup and from the lower coal zone. The coals from the two coal zones can be readily divided into two groups based on their analyses. The lower zone coals present in holes 1218-14-1 and 1218-9-1 have a slightly higher rank than the upper zone coals in hole 1318-26-1. The proximate and ultimate analyses of the coals drilled in holes 1218-14-1 and 1218-9-1 are superior to those of hole 1318-26-1 for all values except sulfur. The upper zone coals in hole 1318-26-1 have a lower total sulfur content than the lower zone coals. The few samples collected made establishing trends based on the organic/inorganic ratios of sulfur impractical. The two upper zone coals present in hole 1318-26-1 have higher ash and moisture contents than do either of the lower zone coals in holes 1218-14-1 or 1218-9-1, as would be expected for coals of subbituminous rank. The ash content of the coals present in holes 1318-26-1 is considerably higher than either of the other two coals sampled or the Mesaverde average. This ash content is even higher than what would be expected for subbituminous coals. A possible reason for

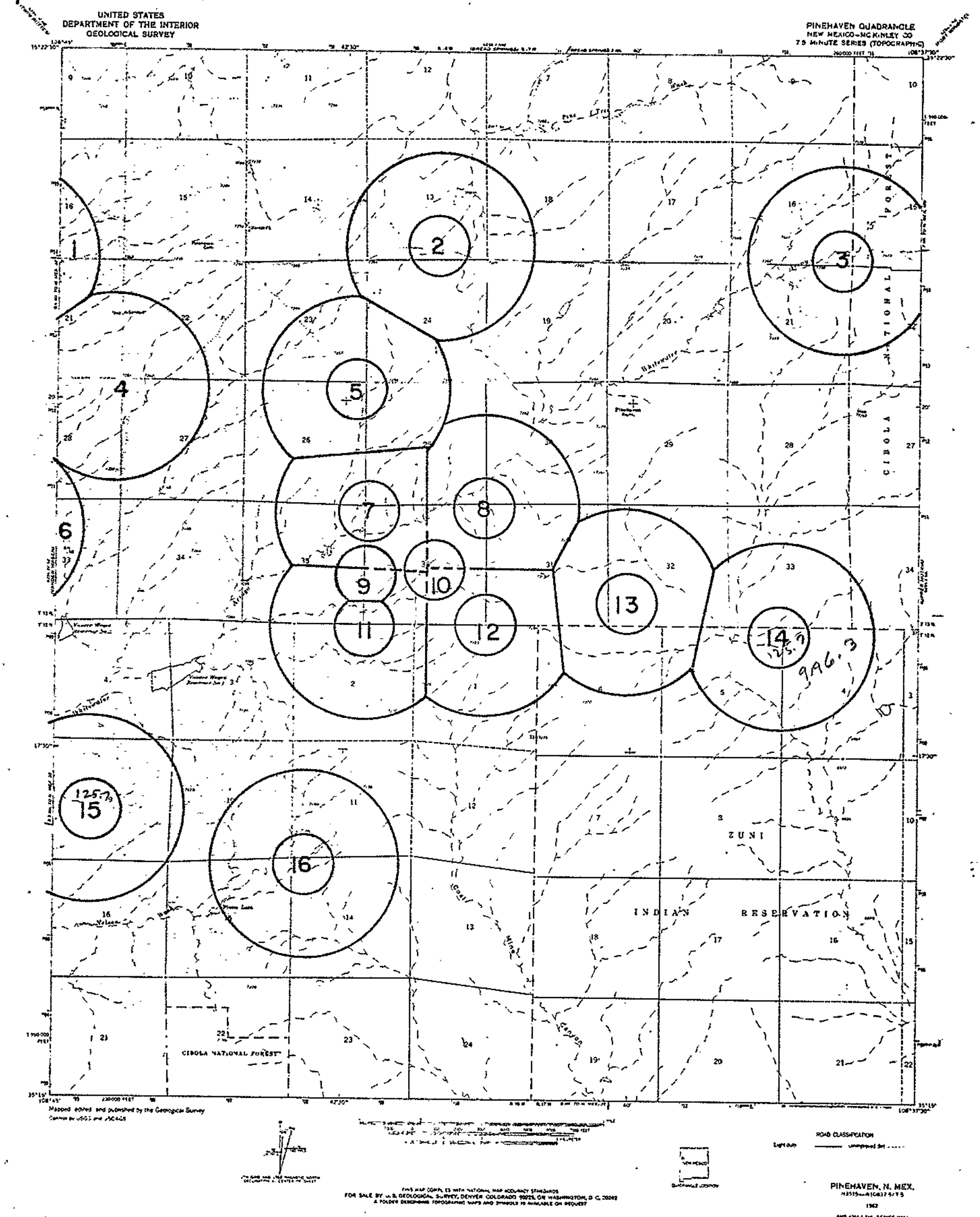

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TABLE 2

Identifcation of Drill Holes

1	Utah International	SW1/4, SW1/4 sec. 16, T. 13 N. R. 18 W.
2	NMBMMR 1318-13-2	SE1/4, SW1/4 sec. 13, T. 13 N. R. 18 W.
3	NMBMMR 1317-16-1	SE1/4, SE1/4 sec. 16, T. 13 N. R. 17 W.
4	NMBMMR 1318-28-1	NE1/4, NE1/4 sec. 28, T. 13 N. R. 18 W.
5	NMBMMR 1318-26-1	NE1/4, NE1/4 sec. 26, T. 13 N. R. 18 W.
6	Utah International	NW1/4, NW1/4 sec. 32, T. 13 N. R. 18 W.
7	Carbon Coal DH2	NW1/4, NW1/4 sec. 36, T. 13 N. R. 18 W.
8	Carbon Coal and Utah International	NE1/4, NE1/4 sec. 36, T. 13 N. R. 18 W.
9	Carbon Coal DH1	NW1/4, SW1/4 sec. 36, T. 13 N. R. 18 W.
10	Carbon Coal DH4	NW1/4, SE1/4 sec. 36, T. 13 N. R. 18 W.
11	Utah International	SW1/4, SW1/4 sec. 36, T. 13 N. R. 18 W.
12	Carbon Coal DH3	NW1/4, NE1/4 sec. 36, T. 13 N. R. 18 W.
13	Carbon Coal	SW1/4, SW1/4 sec. 32, T. 13 N. R. 17 W.
14	Bokum 14C	NE1/4, NE1/4 sec. 5, T. 12 N. R. 17 W.
15	NMBMMR 1218-9-1	NE1/4, SW1/4 sec. 9, T. 12 N. R. 18 W.
16	NMBMMR 1218-4-1	NW1/4, NW1/4 sec. 14, T. 12 N. R. 18 W.

Table 3 -- Coal Resources of Pinehaven quadrangle (figures in millions of tons).

a) Measured coal resources in beds 1.2 to 2.5 ft thick

Area	0-250 ft	250-1000 ft
T. 12 N., R. 17 W.	2.40	2.23
T. 12 N., R. 18 W.	2.33	0.26
T. 13 N., R. 17 W.	1.55	2.35
T. 13 N., R. 18 W.	3.13	5.05
Total*	9.42	9.89

b) Measured coal resources in beds greater than 2.5 ft thick

Area	0-250 ft	250-1000 ft
T. 12 N., R. 17 W.	2.46	2.20
T. 12 N., R. 18 W.	0.93	1.01
T. 13 N., R. 17 W.	0.20	2.44
T. 13 N., R. 18 W.	1.60	4.50
Total*	5.19	10.15

c) Indicated coal resources for the whole quadrangle

Category	0-250 ft	250-1000 ft
beds 1.2-2.5 ft	23.10	48.22
beds >2.5 ft	21.45	53.48
Total*	44.55	101.70

* Figures are rounded and may not equal total

this could be that the coals are near the edge of a coal swamp. A second possibility could be a non uniform subsidence resulting in a greater influx of clays and silt into the coal swamp.

COAL RESOURCES--Coal resources were calculated using the system of the U.S. Department of the Interior (U.S. Geological Survey Bulletin 1450-B). In-place coal was assumed to weigh 1770 tons per acre-foot, that of subbituminous coals. A weight of 1800 tons per acre-foot is normally used for bituminous coals, but determination of which coals are bituminous or subbituminous is not practical from well logs so the more conservative figure was used for all coals. Coal resources were calculated for the measured and indicated categories; the lenticularity of the coals suggests that the inferred category is highly speculative. Figure 4 is a location map of drill holes available for resource calculation, showing the measured (smaller) and indicated (larger) spheres of influence. Note that hole number 4 (NMBMMR1318-28-1) has no coal, even though the measured and indicated spheres are shown. The resources are tabulated, for both the measured and indicated categories, by township, depth and thickness (Table 3). Data from both drill holes and surface exposures were used in determining measured resources, while only drill hole data was used for indicated resource calculations. Appendix II contains the drill hole summary sheets used for reserve calculations, with minable coals indicated by an asterisk (*). The cuttings descriptions of holes drilled by the New Mexico Bureau of Mines are located in Appendix III.

TABLE 4

SURFACE AND COAL OWNERSHIP
(figures rounded to nearest percentile)

OWNER	SURFACE	COAL
Zuni Pueblo	20%	20%
Navajo Tribe	50%	41%
Navajo Allotted	10%	0%
Private	13%	8%
U.S. Gov't	2%	26%
State	5%	5%

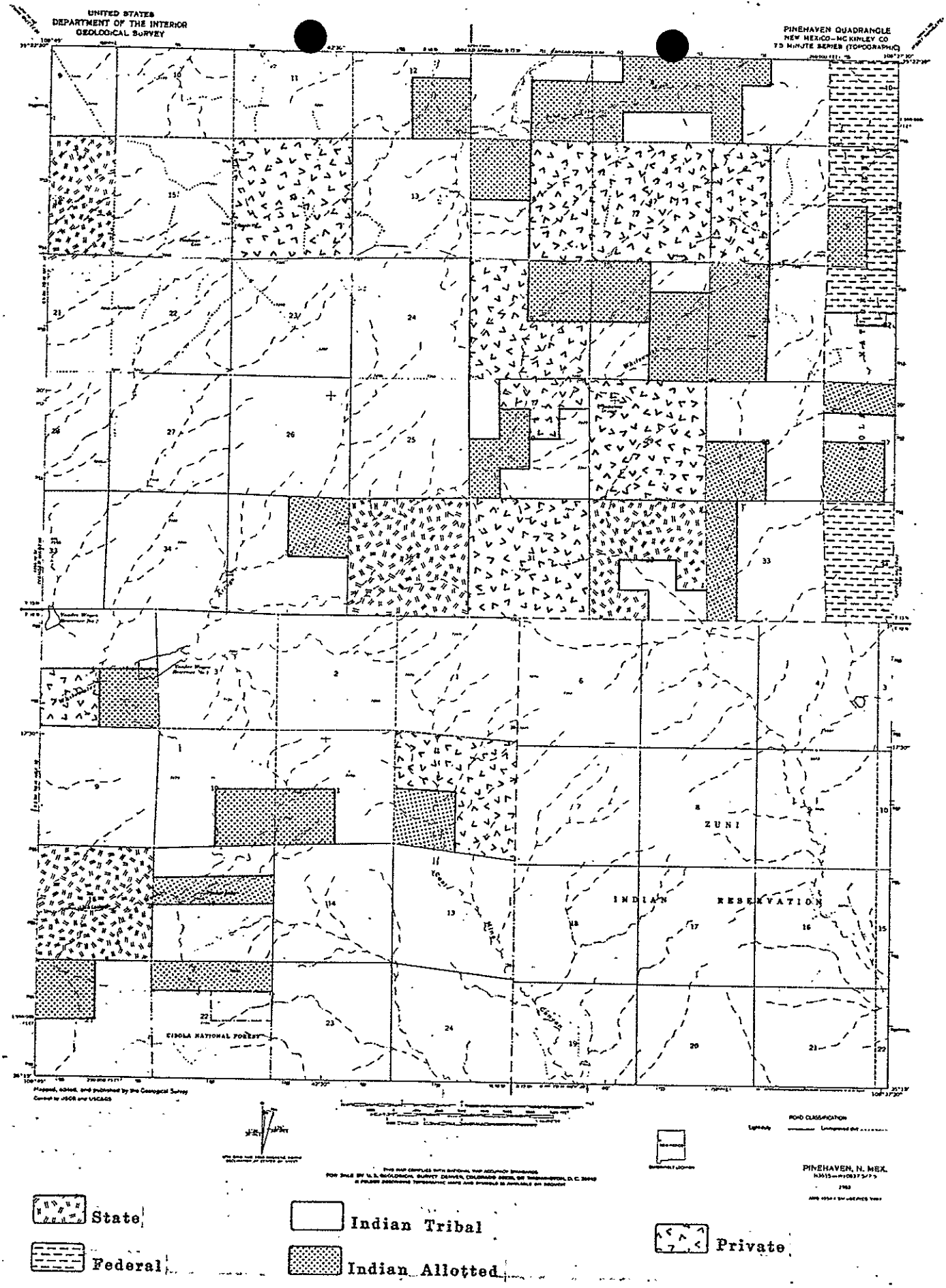

Figure 5--Surface ownership of the quadrangle.

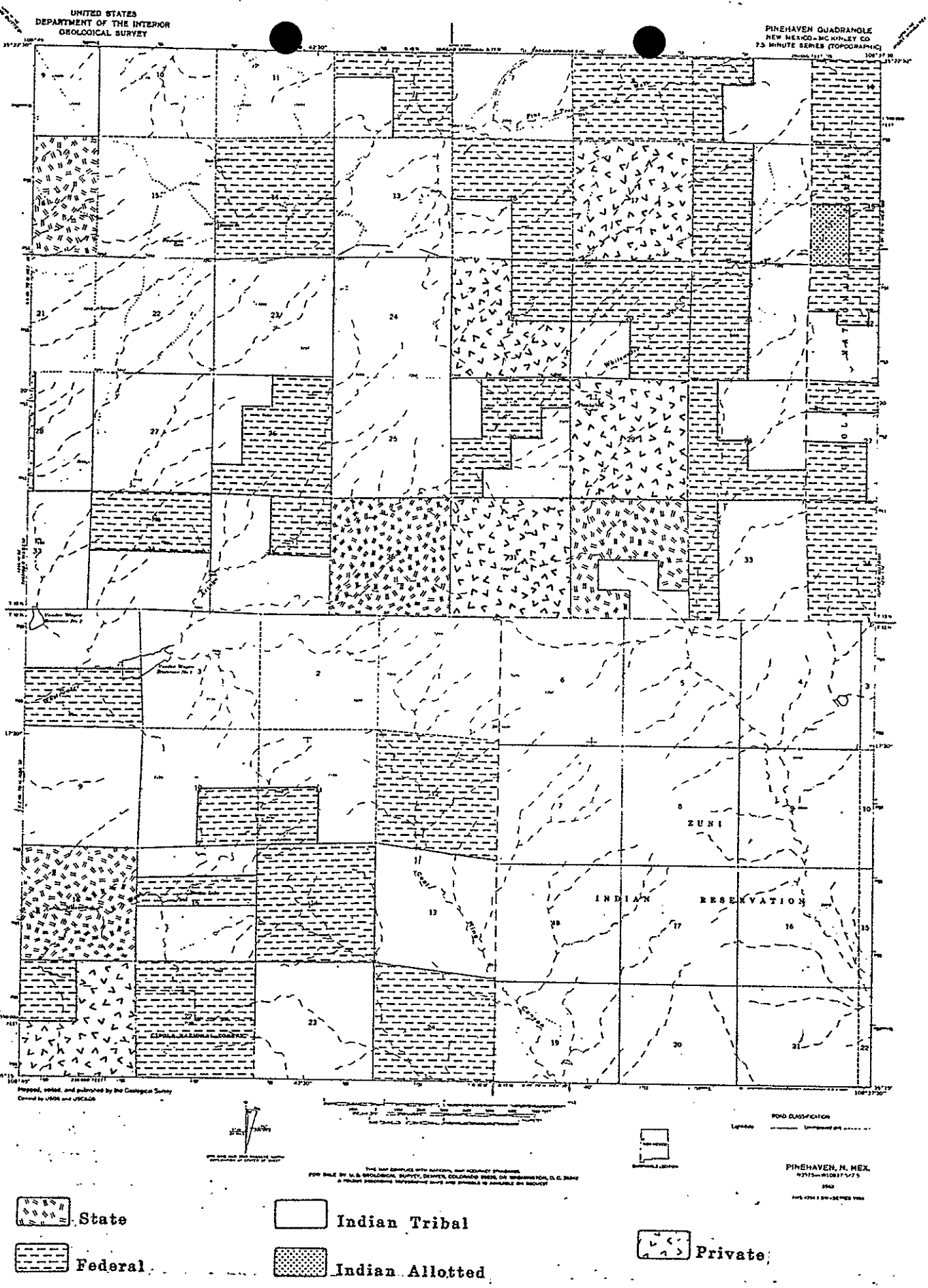

Figure 6--Coal ownership of the quadrangle.

Tabulation of measured coal resource data shows there are 34.65 million tons of in-place coal in this category. Of this amount, 15.34 million tons or 44% is from beds greater than 2.5 ft thick. The area covered by the measured coal resource calculations is small (Fig. 4) and probably only reflects 10% of the coal that may be present.

SURFACE AND COAL OWNERSHIP--Table 4 breaks down surface and coal ownership into percentages. Figure 5 shows the surface ownership by sections for the quadrangle and figure 6 does the same for coal ownership. The Zuni Tribe owns all of the surface and coal rights to approximately 20% of the Pinehaven quadrangle, the portion in T.12 N., R.17 W. Carbon Coal Company, a subsidiary of Hamilton Brothers Oil, has a coal exploration permit for that part of the Zuni Reservation and is in the process of trying to negotiate a lease and mining permit from the Zuni Indians.

Navajo Tribal trust or fee lands comprise 50% of the surface rights in the quadrangle, with holdings mainly in T. 12 N., R. 18 W. and T. 13 N., R. 18 W. The coal rights for 82% of these lands (41% of the quadrangle) are also vested with the Navajo Tribe; Tribal lands without coal rights for the most part have the coal rights held by the U.S. government. No known coal leases exist on any Navajo tribal lands.

Individual Navajo allotments make up 10% of the surface ownership, primarily in T.12N, R.18W. and T.13N., R.17W. No coal rights were conveyed with the allotments; the U.S. government reserved these rights. No leases are known for these lands.

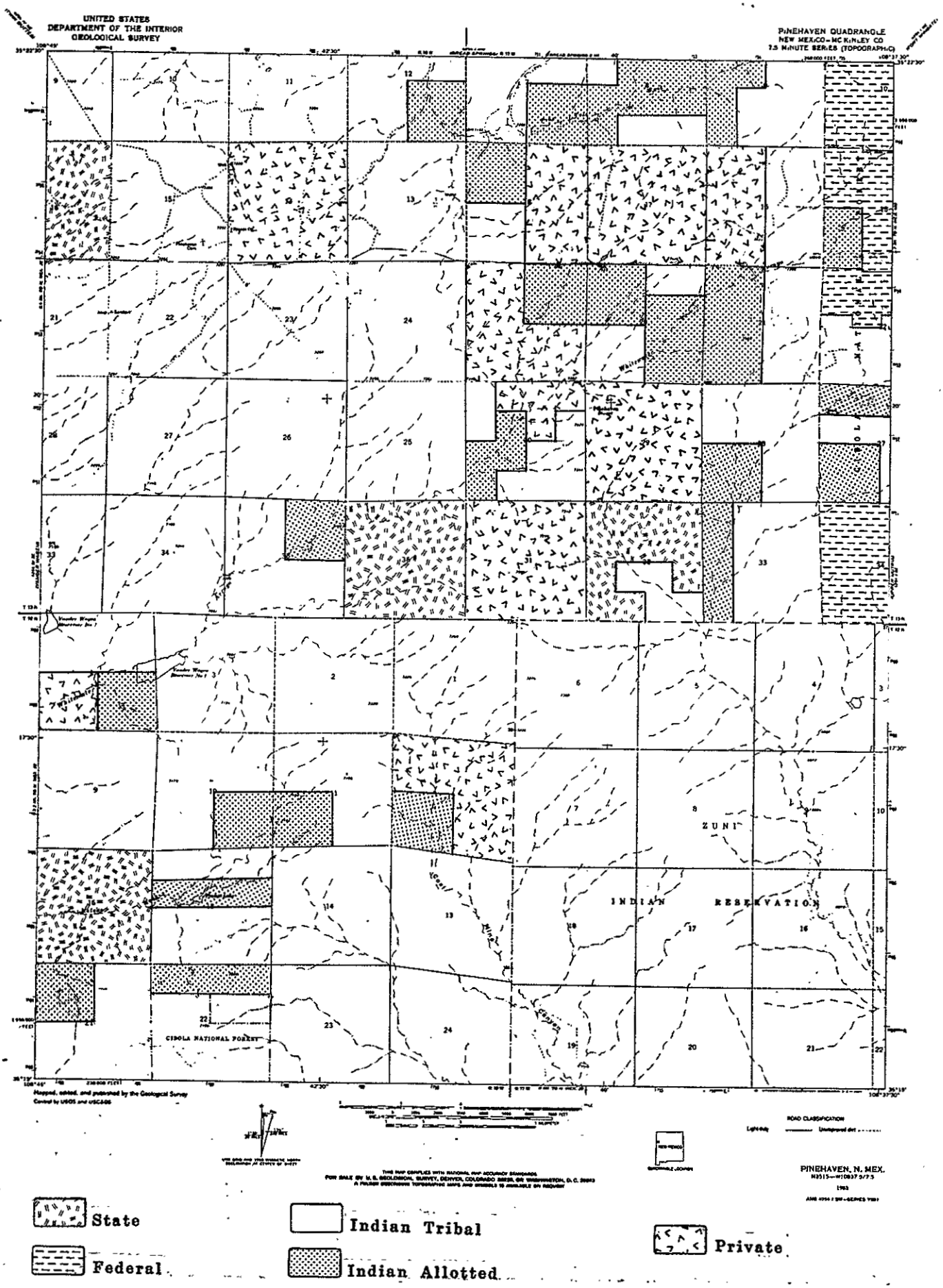

Figure 5--Surface ownership of the quadrangle.

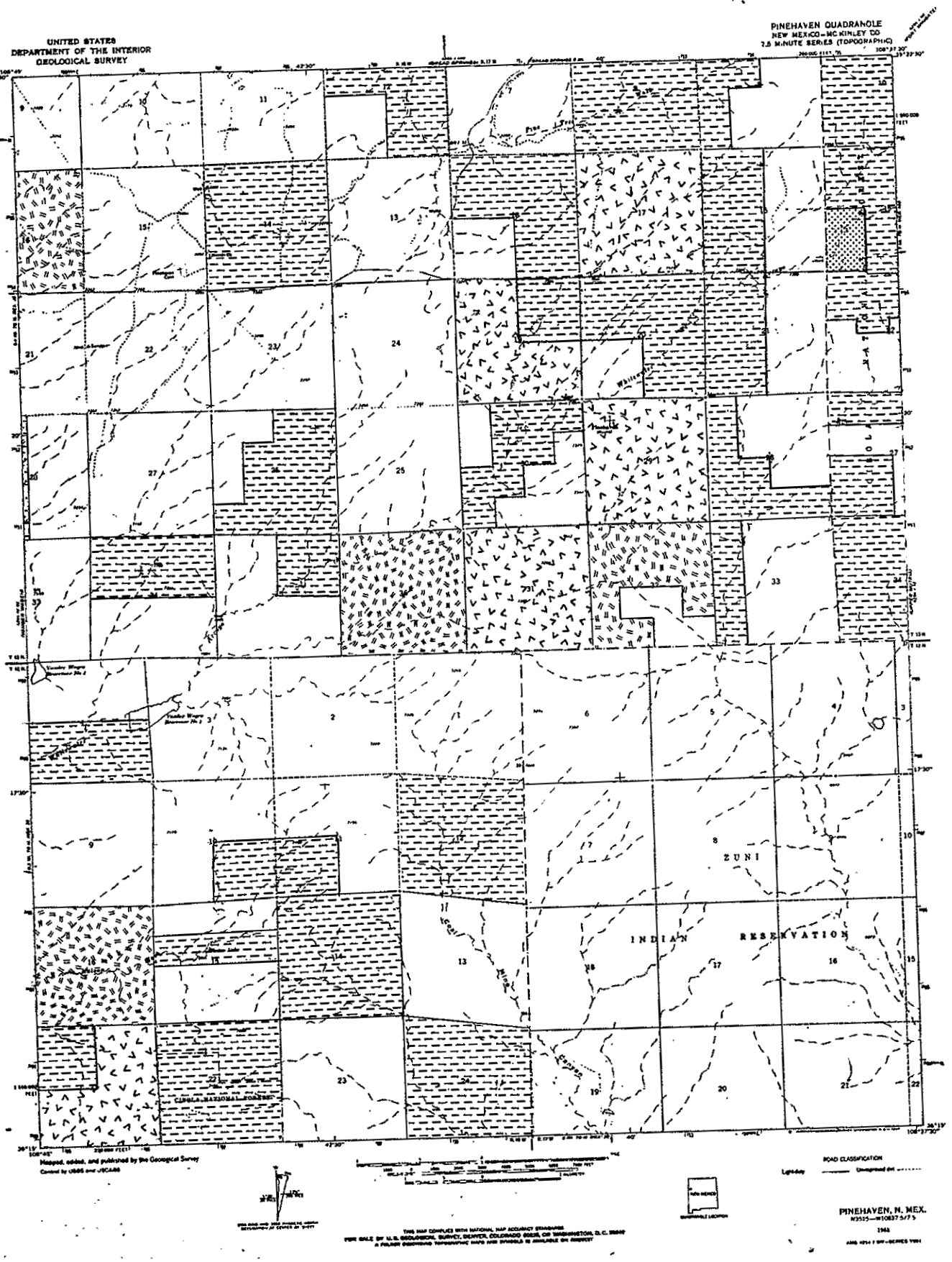

Figure 6--Coal ownership of the quadrangle.

Private individuals hold 13% of the surface rights and 8% of the coal rights for the quadrangle. The amount of private coal ownership is less than the amount of private surface ownership, because of the patents issued on some of these lands reserved the coal right to the federal government.

The federal government owns the smallest amount of surface rights, 2%, but is the second largest owner of coal, retaining rights to the coal under 26% of the quadrangle. These extra coal rights underlie Navajo tribal, Navajo allotment or private surface. None of this coal has been leased.

The State of New Mexico owns the surface and coal rights for about 5% of the quadrangle. Some of the lands were leased for coal to Utah International, Incorporated, and to Carbon Coal Company but the leases have all been dropped. Data from drilling on these leases was kindly furnished by the companies and is included in this report.

COAL MINES AND EXPLORATION--There are no active or inactive coal mines or prospects in the Pinehaven quadrangle. Several small abandoned mines occur about 2.5 miles south of the study area in secs. 6 and 7, T.11N., R.17W. (Sears, 1925). The three mines in sec. 6 occur below the pink sandstone which forms the top of the Gallup (Torrivio Sandstone Member of Molenaar, 1973) in the "School Mine coal group" as named by Winchester (Sears, 1925) for one of the small mines there. The beds mined there are described as thin, not much more than 3 ft thick, and irregular in thickness; none of these coals are exposed in the Pinehaven quadrangle.

The mine in section 7 occurs in a still lower coal interval, the Pescado coal group (Sears, 1925), which is about 70 feet below the preceding coal interval. The coals of this group are highly lenticular and broken by many partings. Where mined, the coal was about 3 feet thick. Coal from this interval and the ones above were apparently used for heating at the Indian school at Blackrock, on the Zuni Reservation.

Two industry-oriented drilling programs for coal have been carried out in the Pinehaven area, one by Utah International, Incorporated and the other by Carbon Coal Company. Utah International conducted exploration drilling during 1974 on some state leases which were subsequently dropped. Three holes were drilled in sec. 36, T. 13 N., R. 17 W.in the study area. Three other holes were drilled immediately west of the study area, one one in sec. 16, T. 13 N., R. 18 W. and two in sec. 32, T. 13 N., R. 18 W.

Carbon Coal also drilled on state leases, putting four holes in sec. 36, T.13 N., R. 18 W. and one in sec. 32, T.13 N., R.17 W. Carbon Coal also relinquished its leases following its exploration program. The drilling information from the above programs is included in the appendix.

In addition to the drilling on state coal leases, Carbon Coal has done extensive exploration drilling on the Zuni Reservation, beginning in 1975. Carbon Coal applied for a mining lease in

1977, under the terms of its exploration permit, as a result of its earlier drilling findings (Maxwell and Nonini, 1977). Negotiations are still pending on the mining lease so no drilling information has been released. Part of the area drilled is within the Pinehaven quadrangle in T. 12 N., R. 17 W. The only available drill hole data for this part of the Zuni Reservation is a uranium test hole drilled by Bokum Resources (see appendix).

CONCLUSIONS

Strippable coal resources on the Pinehaven quadrangle consists of 14.61 million tons of measured coal and 44.55 million tons of indicated coal. This leaves a total of 121.74 million tons of deep coals in both the measured and indicated categories. Even though these coals have a rather high ash content, the sulfur content is very low.

Further exploratory drilling is recommended to the east, towards the axis of the Allison Syncline. This would indicate whether of not the lower coal zone does extend in this direction. The quality of these coals should improve, specifically in reduction of the ash, towards the center of the basin.

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APPENDIX I

HOLE NO. 1218-14-1

CORED INTERVAL: 250-270'

FOOTAGE	DESCRIPTION
1" 250-250'1"	Gray shale, crumbled, earthy
2" 250'1"-250'3"	Brown/gray siliceous shale, erosional contact with lower sand, clasts of lower sand present, coal fragments
16" 250'3"-251'7"	Sandstone, fine grained, lt. gray, near base increased frequency of coal fragments, large clasts of lt. gray sandstone near base, well indurated
5" 251'7"-252'0"	Shale, gray/brown, coalified plant remains, well indurated, earthy texture, thin (0.5") coal seam
10" 252'0"-252'10"	Shale, gray/brown, coalified plant remains, soapy texture, friable
7" 252'10"-253'5"	Shale, dk. gray, waxy, indurated
33" 253'5"-256'2"	COAL, top 3" interlayered with dark shale, clarain (6-10mm) alternates with vitrain (6-12mm), no fusain pyrite masses (<4 mm) in clarain, vertical and horizontal calcite veins 4 mm thick, pyrite associated with calcite
12" 256'2"-257'2"	Shale, dk. gray/brown, soft, waxy
30" 257'2"-259'8"	Shale, lt. gray, indurated, earthy, coaly plant fragments
39" 259'8"-262'11"	Shale, gray to black, coaly
12" 262'11"-263'11"	Shale, gray/black
8" 263'11"-264'7"	Shale, gray, blocky fracture
14" 264'7"-265'4"	Shale, grades upward from gray/brown to dk. gray, waxy
11" 265'9"-266'8"	Siltstone, brown/gray, shale clasts, carbonaceous sandstone lenses
28" 266'8"-269'0"	Sandstone, gray, coarsens upward, 2.5-4.00, rnd, clay matrix grains in contact, top 7" thin carbonaceous streaks, 8" widely spaced, thin <.1" carbonaceous streaks, 4" thin carbonaceous streaks appear to be flow structures.
3" 269'0"-269'3"	Shale, brn/bray, carbonaceous fragments, earthy

HOLE NO. 1318-26-1C

CORED INTERVAL: 103-123'

FOOTAGE	DESCRIPTION
5" 103'-106'5"	Shale, dk, gray, N3, carbonaceous, slightly bioturbated (root casts), fissile, increasingly carbonaceous toward base
11" 106'5"-107'4"	Sandstone, light gray, N7, fine grained, slightly carbonaceous and micaceous
6'2" 107'4"-113'6"	Shale, dark gray, N3, carbonaceous, bioturbated especially at base
2'8" 113'6"-115'8"	Coal, black, N1, bright, with resin, banded, contains some shaly laminae
2'6" 115'8"-118'2"	Shale, brownish black, 5yr2/1, very carbonaceous, slighly coaly, with some resin, highly bioturbated
2'5" 118'2"-120'7"	Shale, olive gray, 5Y4/1, carbonaceous, bioturbated

HOLE NO. 1318-26-2C
CORED INTERVAL: 183-203′

FOOTAGE		DESCRIPTION
1′5"	183′-184′5"	Shale, dark gray, N3, carbonaceous
1′10"	184′5"-186′3"	Siltstone to very fine shandstone, light gray, N7, carbonaceous, cross-laminated
2′11"	186′3"-189′2"	Shale, dark gray, N3, carbonaceous
2"	189′2"-189′4"	Shale, grayish black, N2, coaly
3′8"	189′4"-193′	Coal, black, N1, bright, thin banded, pyrite along vertical cleat, shaly
5"	193′-193′5"	Shale, brownish gray, 5YR4/1, very carbonaceous bioturbated with roots
1′2"	193′5"-194′7"	Shale, dark gray, N3, carbonaceous
7′2"	194′7"-201′9"	Sandstone, very light gray, N8, silty, with carbonaceous cross-laminae, coarsens downward from fine to medium grained
9"	201′9"-202′6"	Shale, medium dark gray, N4, silty, carbonaceous
6"	202′6"-203′	Sandstone, light gray, N7, with carbonaceous cross laminae, very fine grained

APPENDIX II

Drilling Log Sheet

Hole No. 1218-9-1 Depth Drilled 250'

Area/Project Pinehaven Depth of water n/a

Date Started _____ Elevation 7100 ft.

Logged by D. Tabet

From	To	Rock Type
0	5	Fill
5	10	SH and buff SS
10	15	Iron stained BR DK SH
15	20	Yellow SH 1.5', DK GR SH to Coal 19'
20	25	DK SH & Coal interbedded, carb SH to 23 1/2' buff SH
25	30	Buff carb SH, becoming GR
30	35	Same
35	40	Same dry
40	45	Gray SH
45	50	46' SS 6' TH
50	55	GR SH
55	60	Very hard GR SH, coarsening, dry SS 59' GR
60	65	GR SHLY SS's
65	70	GR SH, DRY, HD
70	75	GR
75	80	Same
80	85	84' carb SH 6" then GR sandy SH (hard, dry), to BR

Drilling Log Sheet 1218-9-1

From	To	Rock Type
85	90	GR SS & SH
90	95	Same GR SH (Sandy)
95	100	Same
100	105	103'9" coal w/ carb SHS
105	110	GR SH
110	115	GR SH W 2" SS lens 112'
115	120	GR Sandy SH
120	125	GR
125	130	Carb SH 128'
130	135	DK Carb SH 2" coal
135	140	LT GR SH after 136' to 140'
140	145	LT GE Carb SH
145	150	LT W/S.S. interbedded tan to gray
150	155	Tan SS & SH
155	160	GR sandy shale & SS
160	165	Tan & GR Carb SS & SH
165	170	Same less carb
170	175	Buff SS
175	180	Same W/SH (GR)
180	185	BR & GR SS & SH
185	190	Buff SS
190	195	Buff
195	200	Buff
200	205	Same
205	210	Same
210	215	Same

Drilling Log Sheet 1218-9-1

From	To	Rock Type
215	220	Same
220	225	Same
225	230	Same
230	235	Same
235	240	Same W/Thin layer SH
240	245	Same
245	250	Same
250	255	Same
255	260	Same T.D.

Drilling log sheet

Hole No. 1218-14-1 Depth Drilled 304'

Area/Project Pinehaven Depth of water 105'

Date Started 12-4-79 Elevation 12-5-79

Logged by D. Tabet

From	To	Rock Type
0	4	Shale, tan, weathered
4	8	Shale, brown, carb. with thin coaly streaks
8	10	Sandstone, tan, fine grained
10	14	Shale, brownish-gray, carb.
14	16	Siltstone, tan
16	17	Shale, brownish-gray
17	21	Siltstone, gray-tan, sandy
21	22	Shale, grayish-brown, carb.
22	24	Siltstone, tan or gray
24	29.5	Shale, gray-brown, carb.
29.5	30.5	Shale, dark brown, very carb.
30.5	35	Siltstone, light gray, very hard 30.5-35.0
35	35.5	Shale, gray-brown, carb.
35.5	61	Siltstone, light gray or brown, very hard 37-45
61	62.5	Siltstone, dark brown, very carb.
62.5	70.5	Siltstone, light gray-brown
70.5	71.0	Coal
71	72	Siltstone, dark brown, very carb.

Drilling Log Sheet 1218-14-1

From	To	Rock Type
72	76.5	Siltstone, light gray
76.5	77	Coal
77	79	Siltstone, dark brown, very carb.
79	102.5	Siltstone, light gray-brown
102.5	103	Coal
103	104	Siltstone, dark brown, very carb.
104	114	Siltstone, light gray, shaley
114	115	Shale, dark brown, very carb.
115	116	Siltstone, light gray
116	116.5	Shale, brown, very carb.
116.5	117.5	Coal
117.5	118	Shale, brown, very carb.
118	126	Shale, gray, silty
126	146	Siltstone, gray, shaley, hard 139-141
146	156	Shale, gray, silty
156	167	Siltstone, gray, shaley
167	174.5	Shale, gray, silty, hard bed at 168
174.5	177	Coal
177	179	Shale, brown, very carb.
179	186	Shale, gray
186	188	Coal, shaley at top
188	190	Shale, brown, very carb., coaly
190	196	Shale, gray, silty
196	201	Siltstone, gray, shaley
201	203	Shale, gray, silty
203	206	Siltstone, gray, shaley

Drilling Log Sheet 1218-14-1

From	To	Rock Type
206	209	Shale, gray, silty
209	213	Siltstone, gray, shaley
213	219	Shale, gray, silty
219	221	Siltstone, gray, shaley
221	227	Shale, gray, silty
227	229	Shale, brown, carb., coaly
229	231	Shale, gray, silty
231	236	Siltstone, gray, shaley
236	241	Shale, gray, silty
241	248	Sandstone, gray
248	254	Siltstone, shaley
254	259	Coal, shaley
259	268	Siltstone, gray-brown, shaley
268	269	Shale, gray
269	276	Sandstone, silty
276	277	Shale, dark brown, carb., coaly
277	280	Siltstone, gray
280	283.5	Shale, gray, silty
283.5	295.5	Sandstone, light gray
295.5	296.5	Shale
296.5	304	Sandstone; T.D.

Drilling Log Sheet

Hole No. 1317-16-1 Depth Drilled 260'

Area/Project Pinehaven Depth of Water seep at 50'-55'

Date Started 11/14/79 Date Finished 11/15/79

Logged by D. Tabet

From	To	Rock Type
0	3	Alluvium, brown clay
3	8	Alluvium, brown sand
8	12	Siltstone, light gray, sandy, friable
12	23	Sandstone, tan, fine-medium grained, friable, silty
23	34	Shale, gray
24	51	Sandstone, tan to reddish-brown, silty, fine grained at top, coarsens downward
51	61	Siltstone, reddish-brown, sandy, hard
61	71	Shale, gray, carb., silty
71	81	Siltstone, gray, shaley at top
81	89	Shale, gray, silty
89	95	Siltstone, gray, shaley at top, sandy at base
95	127	Sandstone, gray, fine grained
127	131	Shale, silty
131	147	Sandstone, fine grained, very hard 138'
147	149	Shale, silty
149	151	Sandstone, silty at top, hard at base
151	153	Siltstone
153	157	Shale
157	165	Siltstone, gray-green, with concretions
165	176	Shale, silty, carbonaceous
176	176.5	Limestone concretion

From	To	Rock Type
176.5	192	Shale, carbonaceous, silty
192	203	Siltstone, gray-green, shaley
203	211	Shale, gray, silty, carbonaceous
211	224	Siltstone, gray-green, shaley
224	224.5	Shale, silty
224.5	226	Coal
226	231	Shale, coaly, silty
231	235	Coal
235	244.5	Shale, coaly, silty
244.5	245.5	Coal
245.5	248	Shale, coaly, silty
248	260	Siltstone, shaley, T.D.

Drilling Log Sheet

Hole No. 1318-13-1 Depth Drilled 260'

Area/Project Pinehaven Depth of Water seep at 30'

Date Started 11/13/79 Date Finished 11/13/79

Logged by D. Tabet

From	To	Rock Type
0	4	Alluvium, reddish or yellowish-brown, sandy clay
4	5	Alluvium, tan clay
5	19	Alluvium, yellow to reddish-brown fine sand
19	20	Siltstone, gray, shaley
20	23	Shale, gray
23	24	Siltstone, gray, shaley
24	24.5	Shale, gray, silty
24.5	25	Siltstone, tan
25	28	Shale, gray
28	31	Shale, gray, silty
31	33	Siltstone, tan-gray, small seep of water
33	36	Shale, gray, silty
36	40	Siltstone, gray, hard
40	51	Shale, gray
51	55	Siltstone
55	59	Sandstone
59	67	Shale
67	70	Siltstone
70	72	Shale, coaly, dark gray
72	80	Shale, gray
80	84	Siltstone

From	To	Rock Type
84	92	Shale, silty
92	95	Sandstone
95	100	Shale
100	102	Coal
102	138	Shale, silty, with interbedded siltstone
138	147	Siltstone
147	161	Sandstone
161	167	Shale
167	178	Sandstone
178	184	Shale
184	195	Sandstone and interbedded siltstone
195	199	Shale, silty
199	210	Siltstone
210	260	Sandstone, silty, very fine grained, T.D.

Drilling Log Sheet

Hole No. 1318-26-1 Depth Drilled 250'

Area/Project Pinehaven Depth of Water small seep~240'

Date Started 11-6-79 Date Finished 11-7-79

Logged by D. Tabet

From	To	~~Kind of rock~~ Rock type
0	19	Alluvium - some hard ss beds
19	20	Shale, yellowish tan
20	20.5	Sandstone, red
20.5	25	Shale, tan, silty
25	30	Shale, gray-tan, carb.
30	34	Sandstone, gray, v.f. grained
34	34.5	Sandstone, reddish brown, fine grained friable
34.5	35	shale, brown, carb.
35	44.5	Sandstone, tan, reddish, f. grained, friable
44.5	48	Shale, gray
48	55	Sandstone, red, f. grained
55	57	Shale, gray
57	60	Sandstone, gray, friable; hard at 60'
60	73	Shale, gray, carb. increasing silt downward
73	77	Siltstone, gray, sandy w/interlaminated shale
77	96	Sandstone, gray, fine grained

Drilling Log Sheet 1318-26-1

From	To	~~King~~ of rock ROCK TYPE
96	97	Shale, gray, silty
97	98	Sandstone
98	107	Shale, gray, silty
107	113	Siltstone, shaley
113	114.5	Shale, gray, silty
114.5	118	Coal, shaley
118	119	Shale, dark brown, very carb.
119	125.5	Shale, gray, slightly silty
125.5	139.5	Siltstone, gray-brown, sandy, hard
139.5	140	Shale, dk. brown, coaly v. carb.
140	142	Shale, gray, silty, carb.
142	145	Siltstone, gray, shaley
145	146	Shale, dark brown, v. carb.
146	147	Shale, gray-brown, silty
147	160	Sandstone, gray, silty, v.f. grained, somewhat shaley; brown and v. carb. 158'-160'
160	161.5	Shale, gray
162	163	Coal, shaley
163	165	Shale, dark brown, v. carb.
165	170	Siltstone, gray, shaley
170	181	Siltstone, gray-brown, slightly sandy, hard

Drilling Log Sheet 1318-26-1

From	To	Kind of rock Rock type
181	186	Shale, gray-brown, silty
186	189	Siltstone, gray-brown, carb., shaley
189	189.5	Shale, dark brown, v. carb.
189.5	190	Coal, shaley
190	190.5	Shale, dark brown, v. carb.
190.5	192	Coal, slightly shaley
192	194	Shale, dark grayish brown, carb.
194	194.5	Coal, shaley
194.5	195.5	Shale, dark brown, v. carb.
195.5	207	Siltstone, grayish brown, carb.
207	210	Shale, brown, silty
210	215	Siltstone, grayish brown, shaley, v. carb. at base
215	217	Shale, dark brown, v. carb., coaly
217	220	Shale, dark brown, carb., silty
220	240	Shale, grayish brown, carb., increasingly silty toward bottom
240	250	Sandstone, v.f. grained, silty, wet, slow seep. T.D.

Drilling Log Sheet

Hole No. 1318-28-1 Depth Drilled 260'

Area/Project Pinehaven Depth of water n/a

Date Started _____ Elevation 7260

Logged by D. Tabet

From	To	Rock Type
0	5	Yellow SH
5	10	BR SH
10	15	Tan to Buff SH sandy, to SS (Tan)
15	20	Hard HW SS to BR SH 19'
20	25	PK & Buff SHLY SS
25	30	GR, PK, Buff SHLY SS
30	35	Same
35	40	BR SS
40	45	LT BR SS
45	50	Same
50	55	SH-YEL W/Bl Mud stain (carb?) sandy layers below Mud cracks?
55	60	Red & Yel Clays W/Sandy layer
60	65	SH & SS Layers
65	70	SH & coarse SS layers
70	75	SH W/Bl stain mud crack
75	80	Coarse SS
80	85	Coarse
85	90	SS Tan

Drilling Log Sheet 1318-38-1

From	To	Rock Type
90	95	SS Tan
95	100	SS Tan W/Gray SH
100	105	Tan SS (coarser) & SH
105	110	108' red & GR SH W/SS, carb
110	115	Carb SS & SH
115	120	GR, Green, Red SH
120	125	Sandy DK Gray SH
125	130	PK & GR Sandy Shale
130	135	PK
135	140	PK
140	145	Gr Carb Sandy SH
145	150	GR SS W/Organic BR color liquid, FG
150	155	GR
150	155	FG GR SS W/BR carb liquid
155	160	PK & GR carb SH W/SS
160	165	GR SH W/FG SS
165	170	SS GR FG
170	175	Hardening GR SS minor SH
175	180	Gray carb SHLY SS
180	185	One bag-low returns of SS, SH, carb (minor)
185	190	
190	195	
195	200	
200	205	One bag-very low returns of SS, SH, carb (minor)

Drilling Log Sheet 1318-38-1

From	To	Rock Type
205	210	
210	215	
215	220	
220	225	One bag SS, SH Gray & Tan & pk
225	230	
230	235	One bag, SS, SH, Carb
235	240	
240	245	GR, SS, SH, Minor Carb
245	250	
250	255	
255	260	T.D.

APPENDIX III

WELL NAME: 1-16-13-18 COMPANY: UTAH INTERNATIONAL

LOCATION: SW CORNER SEC. 16 T. 13 N. R.18 W.

COUNTY: MCKINLEY ELEVATION: 7190'

SPUDDED IN: CREVASSE CANYON DATE DRILLED: 5/29/74

FORMATION	DEPTH	ELEVATION
DILCO	205'	
GALLUP	695'	6495'
TRES HERMANOS	710'	
MANCOS	897'	

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
212.0'	2.4'	6978'	614.0'	1.9'	6576'
216.0'	1.0'	6974'	686.0'	1.8'	6504'
454.0'	2.3'	6736'	694.0'	1.0'	6496'
515.0'	2.0'	6675'	713.0'	1.6'	6477'
583.0'	1.2'	6607'	928.0'	1.0'	6262'
612.0'	1.3'	6578'	962.5'	3.0'	6227'
614.0'	1.9'	6576'			

TOTAL COAL: 22.1'

Aggregate Thickness in beds > 1.2 ft. 0-250': 2.4' 250-500': 2.3' 500+: 13.4'

WELL NAME: 1318-13-1 COMPANY: NMBM & MR

LOCATION: SW,SW,SES13,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7290'

SPUDDED IN: DATE DRILLED: 11-15-79

FORMATION	DEPTH	ELEVATION

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
87.0'	0.7'	7203'			
101.0'	0.8'	7189'			
121.0'	0.4'	7169'			

TOTAL COAL: 1.9'

Aggregate thickness in beds > 1.2 ft.

WELL NAME: 1317-16-1 COMPANY: NMBM & MR

LOCATION: SE,SE,SES16,T13N,R17W

COUNTY: McKINLEY ELEVATION: 7425'

SPUDDED IN: DATE DRILLED: 11-15-79

FORMATION	DEPTH	ELEVATION

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
226.0'	0.6'	7199'			
233.0'	1.5'	7191'			
246.0'	1.0'	7178'			

TOTAL COAL: 3.1'

Aggregate thickness in beds > 1.2 ft. 0-250': 1.5' 250-500': 0.0' 500+: 0.0'

WELL NAME: 1318-26-1 COMPANY: NMBM & MR

LOCATION: NE,NE,NES26,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7245'

SPUDDED IN: DATE DRILLED: 11-7-79

FORMATION	DEPTH	ELEVATION

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
114.0'	3.8'	7130'			
162.0'	0.8'	7082'			
190.0'	3.4'	7054'			

TOTAL COAL: 8.0'

Aggregate thickness in beds > 1.2 ft. 7.2' 0-250': 7.2' 250-500': 0.0' 500+: 0.0'

WELL NAME: DH-2 COMPANY: CARBON COAL COMPANY

LOCATION: NW,NW,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7190′

SPUDDED IN: DATE DRILLED: 8-9-78

FORMATION	DEPTH	ELEVATION
DILCO	525′	6665′
GALLUP	820′	6370′

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
54.0′	0.9′	7135′	702.0′	1.0′	6487′
102.0′	2.1′	7088′	713.0′	1.0′	6476′
531.5′	1.7′	6658′			
540.0′	2.0′	6650′			
544.0′	1.3′	6645′			
632.0′	1.0′	6658′			

TOTAL COAL: 11.0′

Aggregate thickness in beds > 1.2 ft. 7.1′ 0-250′: 2.1′ 250-500′: 0.0 500+: 5.0′

WELL NAME: 3-36-13-18 COMPANY: UTAH INTERNATIONAL

LOCATION: NE CORNER,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7200'

SPUDDED IN: 5-21-74

FORMATION	DEPTH	ELEVATION
DILCO	620'	6580'
GALLUP	1040'	6260'

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
122.5'	2.0'	7077'	781.5'	1.3'	6418'
135.0'	2.7'	7065'	793.0'	1.7'	6407'
190.0'	2.0'	7010'	808.0'	1.2'	6392'
230.0'	1.2'	6970'	837.0'	3.0'	6363'
697.0'	1.2'	6503'	847.5'	5.5'	6352'
721.0'	1.2'	6478'	864.0'	2.0'	6336'
735.0'	1.0'	6465'	866.0'	2.0'	6333'
739.0'	1.0'	6461'	893.0'	3.2'	6307'
757.0'	2.6'	6443'			

TOTAL COAL: 35.3'

Aggregate thickness in beds >1.2 ft. 33.3' 0-250': 8.4' 250-500': 0.0 500+: 24.9'

WELL NAME: DH-3 COMPANY: CARBON COAL COMPANY

LOCATION: NE,NE,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7190'

SPUDDED IN: DATE DRILLED: 8-13-78

FORMATION	DEPTH	ELEVATION

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
127.0'	1.6'	7063'			
134.0'	1.7'	7056'			
146.0'	0.9'	7043'			
159.0'	1.0'	7031'			
186.7'	1.2'	7003'			

TOTAL COAL: 6.4'

Aggregate thickness in beds >1.2 ft. 4.5' 0-250': 4.5' 250-500': 0.0 500+: 0.0

WELL NAME: DH-1 COMPANY: CARBON COAL COMPANY

LOCATION: NW,SW,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7220'

SPUDDED IN: DATE DRILLED: 7-29-78

FORMATION	DEPTH	ELEVATION
GALLUP	800'	6420'
DILCO	433'	6787'

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
67.0'	2.1'	7253'			
476.0'	2.1'	6744'			
507.0'	3.4'	6712'			
597.0'	2.1'	6623'			

TOTAL COAL: 9.7'

Aggregate thickness in beds >1.2 ft. 9.7' 0-250': 2.1' 250-500': 2.1' 500+: 5.5'

WELL NAME: 1-36-13-18 COMPANY: UTAH INTERNATIONAL

LOCATION: SW CORNERS,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7225'

SPUDDED IN: DATE DRILLED: ?

FORMATION	DEPTH	ELEVATION
DILCO	449'	6776'

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
449.0'	2.5'	6776'			
492.0'	2.4'	6733'			
587.0'	4.0'	6638'			

TOTAL COAL: 8.9'

Aggregate thickness in beds > 1.2 ft. 8.9' 0-250': 0.0 250-500': 4.9' 500+: 4.0'

WELL NAME: 2-36-13-18 COMPANY: UTAH INTERNATIONAL

LOCATION: MIDDLE,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7250'

SPUDDED IN: DATE DRILLED: 3-15-74

FORMATION	DEPTH	ELEVATION
GALLUP	894'	6356'
DILCO	548'	6702'

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
77.0'	1.5'	7173'	688.0'	1.4'	6562'
81.0'	1.9'	7169'	776.0'	3.9'	6473'
142.5'	2.0'	7107'	855.0'	3.0'	6395'
643.0'	1.5'	6607'			
676.0'	1.2'	6574'			
680.0'	1.3'	6570'			

TOTAL COAL: 17.7'

Aggregate thickness in beds >1.2 ft. 17.7' 0-250': 5.4 250-500': 0.0 500+: 12.3'

WELL NAME: DH-4 COMPANY: CARBON COAL COMPANY

LOCATION: SE,SE,S36,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7265'

SPUDDED IN: DATE DRILLED: 8-6-78

FORMATION	DEPTH	ELEVATION

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
141.0'	1.4'	7124'			
294.0'	0.9'	6971'			

TOTAL COAL: 2.3'

Aggregate thickness in beds > 1.2 ft. 1.4' 0-250': 1.4' 250-500': 0.0 500+: 0.0

WELL NAME: DH-5 COMPANY: CARBON COAL COMPANY

LOCATION: NW,SW,SW,S32,T13N,R17W

COUNTY: McKINLEY ELEVATION: 7270'

SPUDDED IN: DATE DRILLED:

FORMATION	DEPTH	ELEVATION
GALLUP	1070'	6200'

COAL

DEPTH	THICKNESS	ELEVATION
269.0'	1.0'	7001'
321.5'	1.2'	6939'

TOTAL COAL THICKNESS: 2.2'

Aggregate thickness in beds > 1.2 ft. 1.2' 0-250': 0.0 250-500': 1.2' 500': 0.0

WELL NAME: 14C COMPANY: BOKUM RESOURCES

LOCATION: NE CORNER SEC. 5 T. 12 N. R. 17 W.

COUNTY: MCKINLEY ELEVATION: 7110'

SPUDDED IN: DATE DRILLED: 12/17/68

FORMATION	DEPTH	ELEVATION
BARTLETT	345'	
DILCO	643'	
GALLUP	1215'	
TRES HERMANOS	1287'	

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
92.0'	1.2'	7018'	770.0'	1.0'	6340'
197.0'	1.9'	6913'	779.0'	2.0'	6331'
212.0'	2.7'	6898'	830.0'	2.0'	6280'
249.0'	1.0'	6861'	834.5'	1.0'	6275'
300.0'	1.2'	6810'	842.5'	1.4'	6267'
303.0'	1.8'	6807'	848.5'	2.2'	6261'
306.0'	0.8'	6804'	851.5'	1.0'	6258'
655.0'	2.0'	6455'	853.0'	1.8'	6257'
673.0	1.0'	6437	885.0'	2.0'	6225
682.0	6.9'	6428	893.8'	0.9'	6216
754.0	1.2'	6356	898.0'	3.0'	6212

TOTAL COAL: 40.5'

Aggregate 33.3' 0-250': 5.8' 250-500': 3.0' 500+: 24.5'
thickness in beds 1.2 ft.

WELL NAME: 1218-9-1 COMPANY: NMBMMR

LOCATION: NE1/4, SW1/4, SEC. 9, T.12 N. R. 17 W.

COUNTY: MCKINLEY ELEVATION: 7150'

SPUDDED IN: DATE DRILLED: 5/19/80

FORMATION	DEPTH	ELEVATION

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
130.0'	4.2'	7020'			

WELL NAME: 1218-14-1 COMPANY: NMBMMR

LOCATION: NW1/4, NW1/4, SEC. 14, T. 12 N. R. 18 W.

COUNTY: MCKINLEY ELEVATION: 7150'

SPUDDED IN: CREVASSE CANYON DATE DRILLED: 12/4/79

FORMATION	DEPTH	ELEVATION
GALLUP	276'	6974'

COAL

DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
71.0'	1.0'	7079'			
78.0'	1.0'	7072'			
118.0'	1.1'	7032'			
175.0'	1.4'	6975'			
189.0'	0.8'	6961'			
256.0'	2.6'	6894'			

TOTAL COAL: 7.9'

Aggregate thickness in beds > 1.2 ft. 4.0' 0-250': 1.4' 250-500': 2.6' 500'+: 0.0

WELL NAME: 1318-28-1 COMPANY: N.M.B.M.M.R.

LOCATION: NE1/4,NE1/4,S28,T13N,R18W

COUNTY: McKINLEY ELEVATION: 7235

SPUDDED IN: CREVASSE CANYON DATE DRILLED: 6-14-74

COAL

NO COAL

WELL NAME: 2-32-13-18 COMPANY: UTAH INTERNATIONAL

LOCATION: NE 1/4, S.32, T. 13 N. R. 18 W.

COUNTY: MCKINLEY ELEVATION: 7190'

SPUDDED IN: DATE DRILLED: 6-14-74

FORMATION	DEPTH	ELEVATION
GALLUP	333'	6857'
MANCOS	483'	6707'
TRES HERMANOS	502'	6688'

COAL

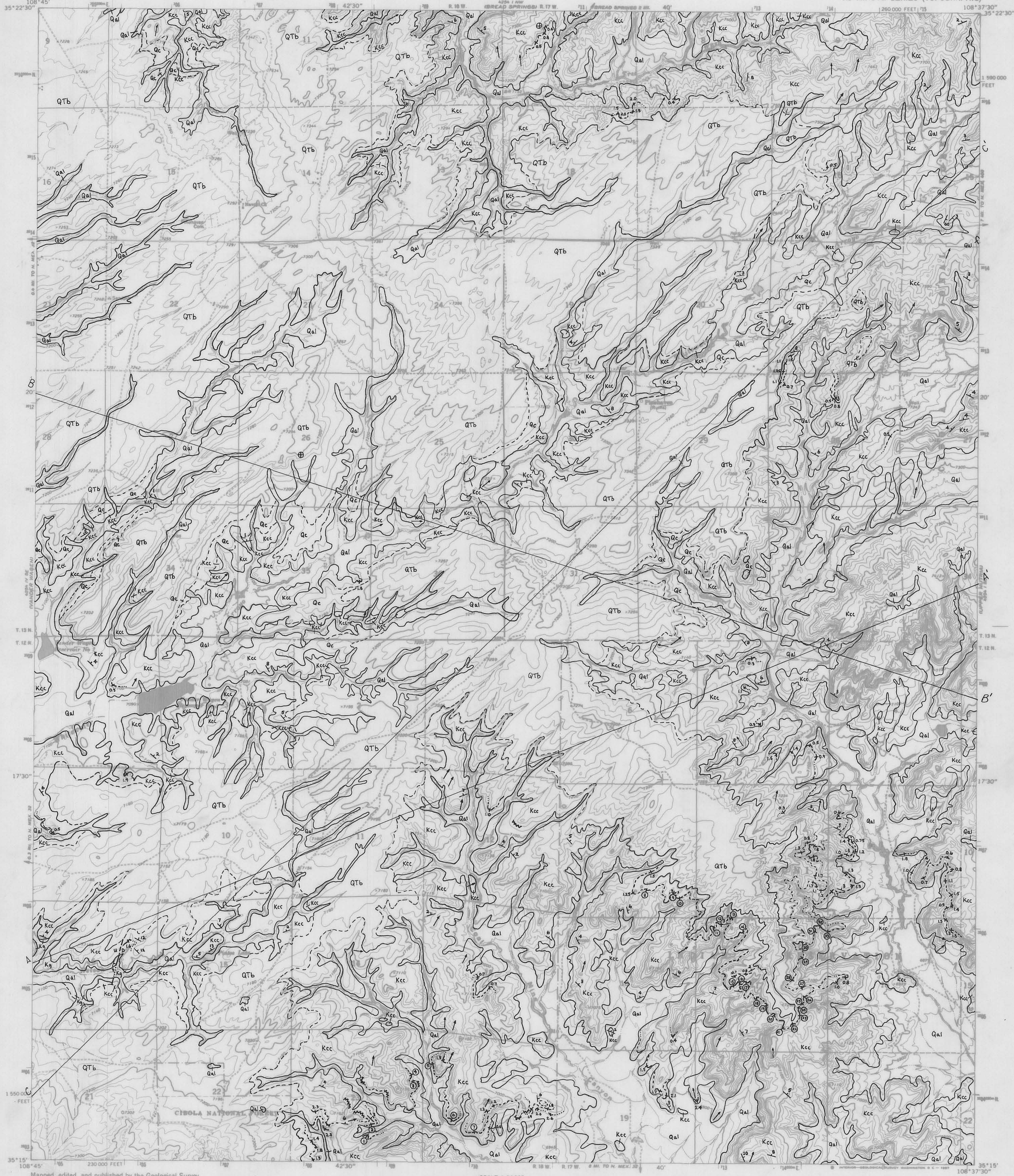
DEPTH	THICKNESS	ELEVATION	DEPTH	THICKNESS	ELEVATION
139.0'	2.0'	7051'			
269.0'	1.3'	6921'			
300.0'	1.2'	6890'			
308.0'	3.5'	6882'			
314.0'	1.4'	6876'			
542.0'	1.5'	6648'			

TOTAL COAL: 10.9'

Aggregate thickness in beds>1.2 ft. 10.9' 0-250': 2.0' 250-500': 7.4' 500'+: 1.5'

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PINEHAVEN QUADRANGLE
NEW MEXICO—MC KINLEY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1962. Field checked 1963

Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

Fine red dashed lines indicate selected fence lines

UTM GRID AND 1953 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24000

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION

Light-duty ——— Unimproved dirt - - - - - -

LEGEND

Qal = Quaternary Alluvium
Qc = Quaternary Colluvium
QTb = Quaternary/Tertiary Bidahochi Formation
Kcc = Cretaceous: Crevasse Canyon Formation
Kg = Cretaceous: Gallup Formation
= Paleocurrent Direction
= Measured Coal Section
= Fault
= Klinker Deposit

OF-12

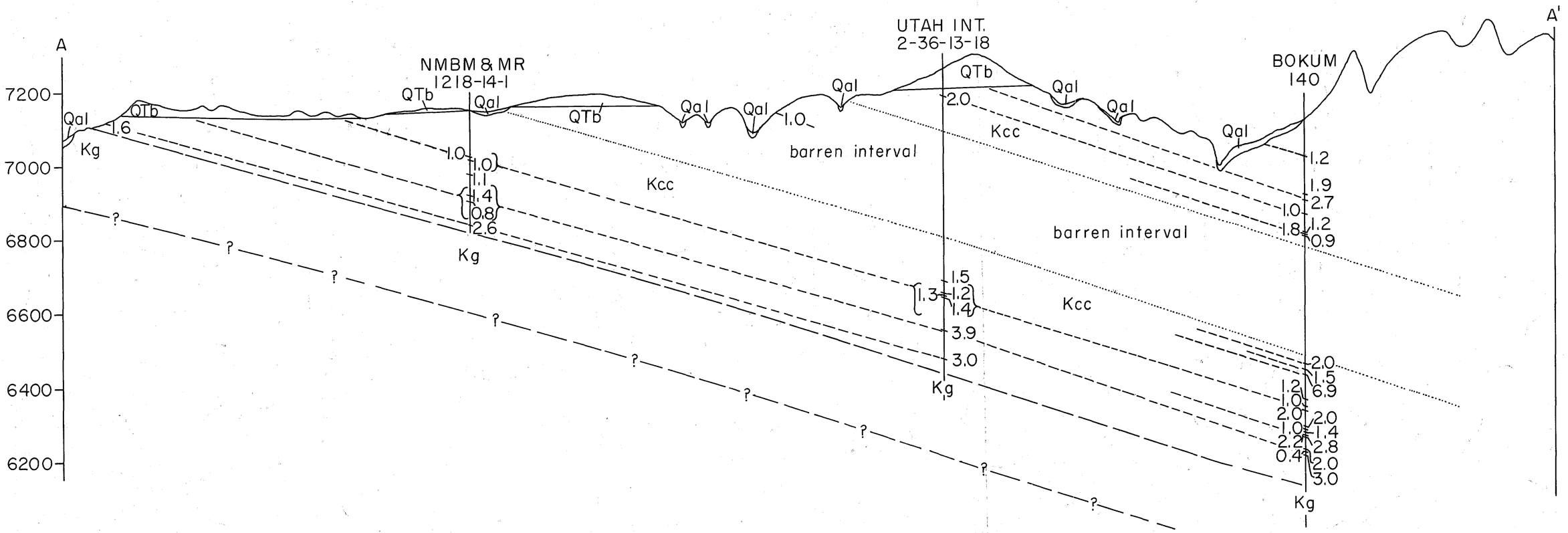


PLATE 2A

OF-154
SHEET 2 OF 5
OFW145

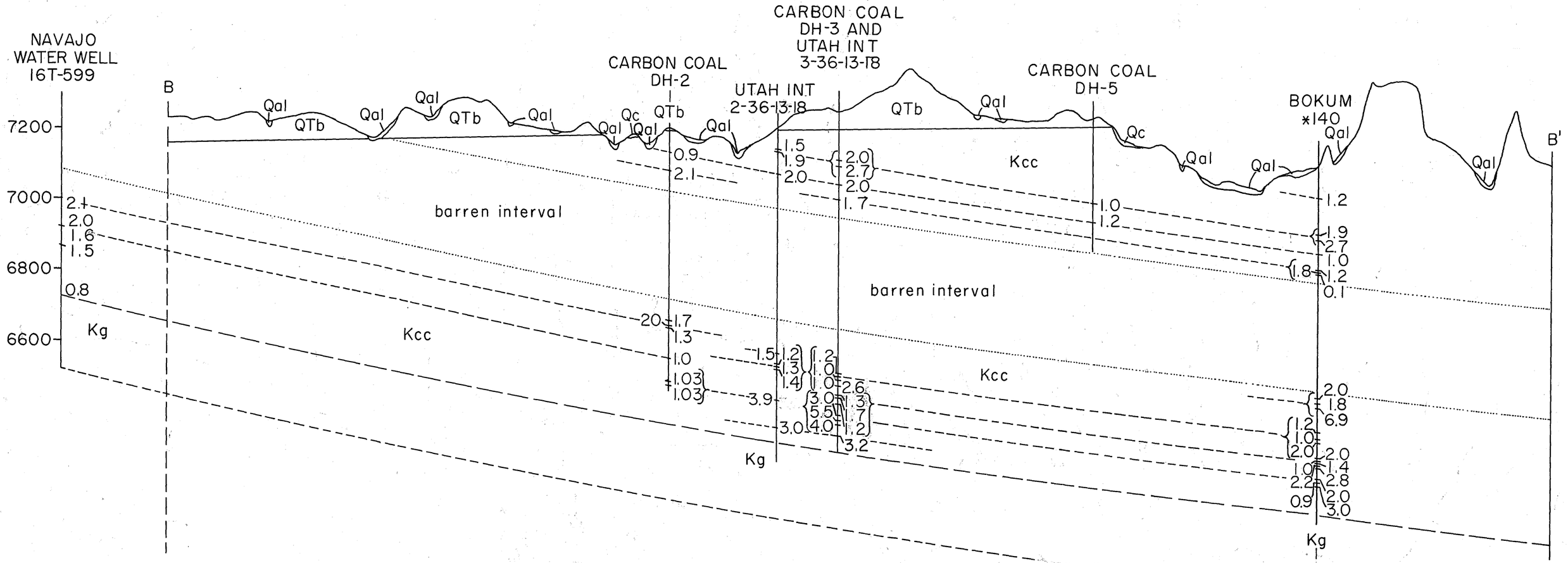

NAVAJO WATER WELL 16T-599
CARBON COAL DH-2
CARBON COAL DH-3 AND UTAH INT 3-36-13-18
UTAH INT 2-36-13-18
CARBON COAL DH-5
BOKUM *140
B
B'
7200
7000
6800
6600
Qal
QTb
Qc
barren interval
Kcc
Kg

PLATE 2B

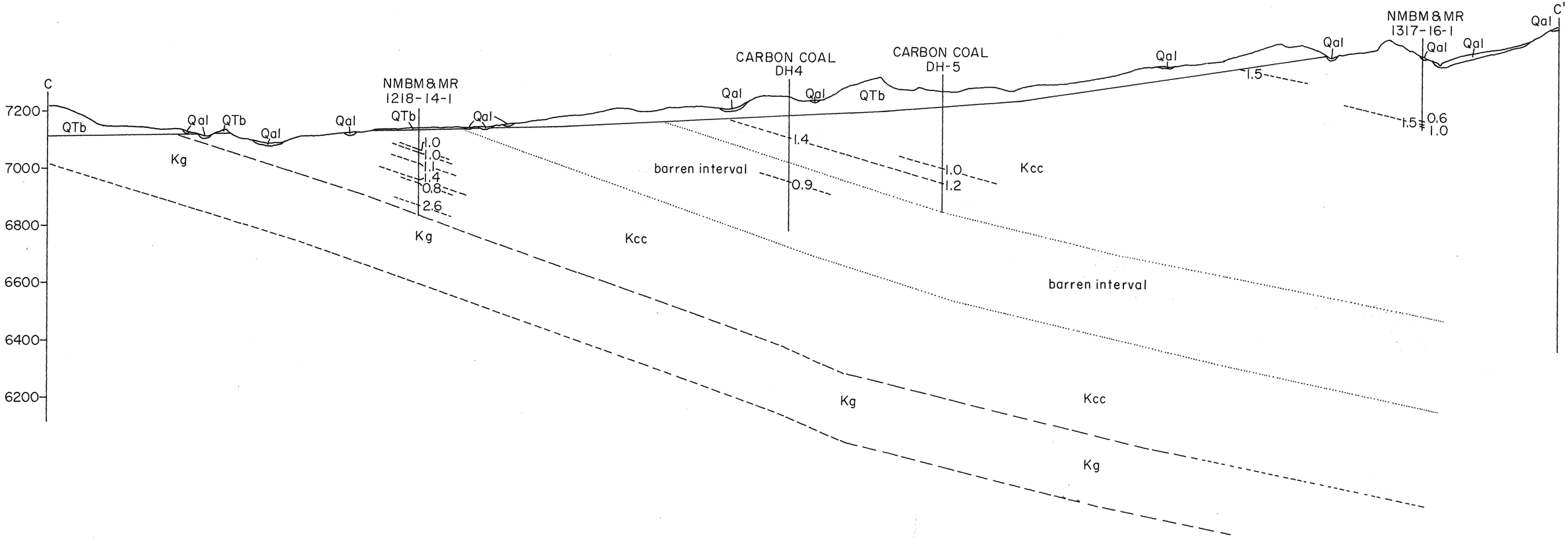
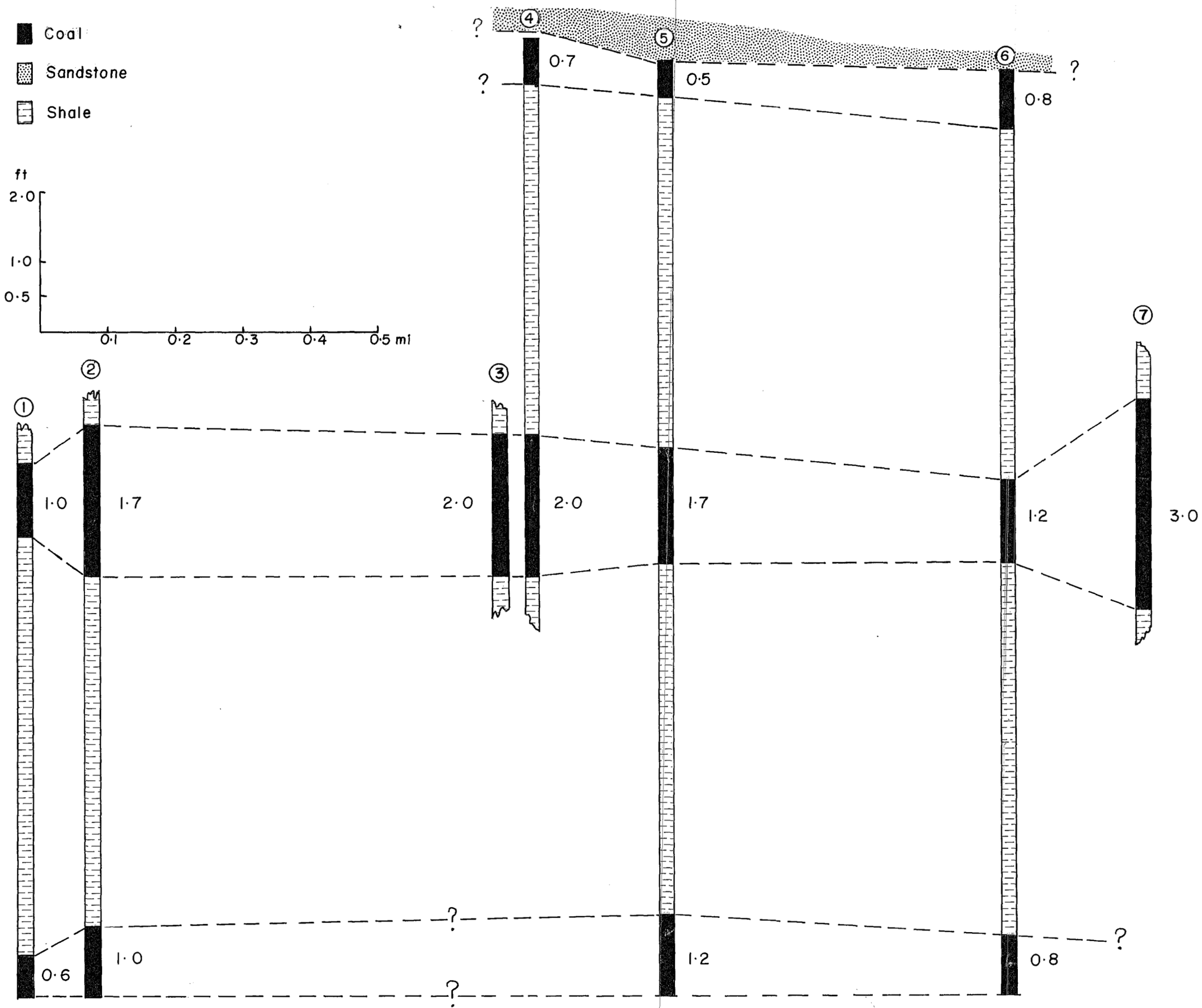


PLATE 2C

OF-154
SHEET 3 OF 5



OPEN FILE - 154
SHEET 5 OF 5
Plate 3