New Mexico State Bureau of Mines and Mineral Resources

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Coal Resources of Southern Ute and Ute Mountain Ute Indian Reservations, Colorado and New Mexico

by J. W. Shomaker and R. D. Holt

prepared in cooperation with the
United States Bureau of Indian Affairs and the
Colorado Geological Survey

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View of Public Service Coal Co. (now Western Coal Co.) prospcting permit area, Ute Mountain Ute Indian Reservation.

View of Peabody lease area, Southern Ute Indian Reservation.

Abstract

The Southern Ute and Ute Mountain Ute Indian Reservations, in southwestern Colorado and northwestern New Mexico, are underlain by coal in three formations of Late Cretaceous age. The Dakota Sandstone contains an estimated 11,733 million tons, the Menefee Formation 13,969 million tons, and the Fruitland Formation 25,331 million tons. About 471 million tons, mostly Fruitland coal, is mineable by stripping or augering. Water required for the most likely development of the coal is as much as 18,300 acre feet per year. Some of the remainder of the coal reserve may be mineable eventually, and would require far greater amounts of water.

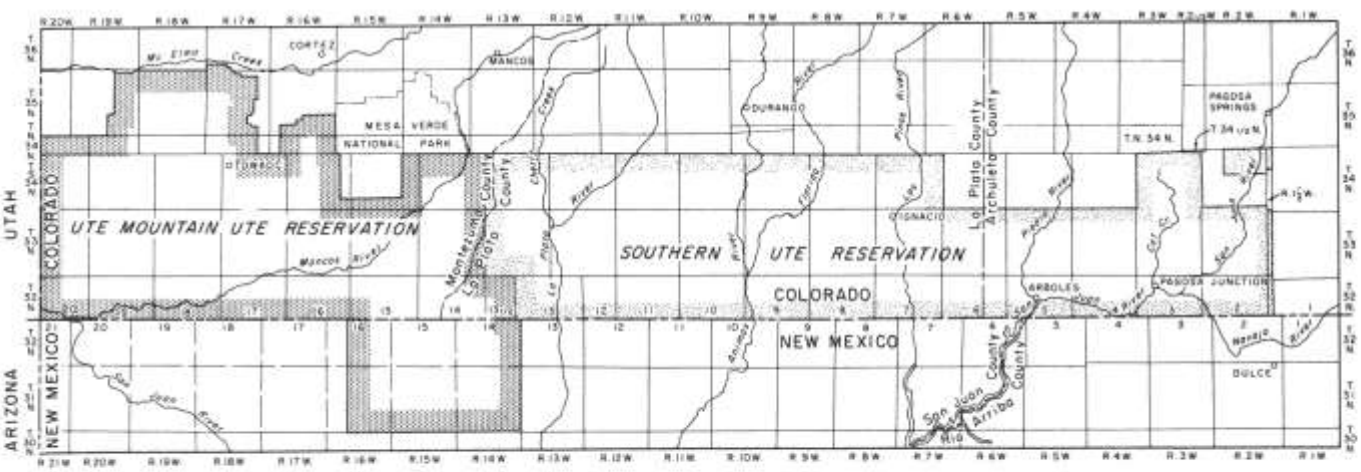


FIGURE I—Index and location map.

Introduction

PURPOSE AND SCOPE

This study was undertaken to define the coal resources belonging to the Southern Ute and Ute Mountain Ute Tribes of Indians. The study considers not only the gross amount of coal available, but also the distribution of coal including thickness of beds, depth, and other criteria of mineability. It also considers the chemical and physical characteristics of the various coal reserve blocks, the amount and quality of water that might be required for development of the coal resources, and the commercial potential and marketability of the coal.

The U. S. Bureau of Indian Affairs funded the entire study (Contract MOOC-14200798). A cooperative arrangement was made by the New Mexico State Bureau of Mines and Mineral Resources with the Colorado Geological Survey whereby the latter provided part of the study effort.

The report presents a practical evaluation of the coal resources. Information from every available source was compiled. Original exploratory work was done where needed. Coal reserves and other interpretive matter were then combined to produce the report desired.

Surface geologic mapping specifically oriented toward coal exploration was done in the eastern part of the Ute Mountain Indian Reservation by Wanek (1954), and in the New Mexico portion of the Reservation by Hayes and Zapp (1955). Similar mapping was done on the western end of the Southern Ute Indian Reservation by Barnes, Baltz, and Hayes (1954), in the Durango area by Zapp (1949), and in the Ignacio area by Barnes (1953). A general geologic map which includes the remainder of the Southern Ute Indian Reservation was prepared by Wood, Kelley, and MacAlpin (1948). Geologic mapping of the western part of the Ute Mountain Ute Indian Reservation was done by Ekren and Houser (1965) and by Irwin (1966).

Published work was supplemented by measurement of surface geologic sections where necessary, particularly in the eastern and western extremities of the study area. Coal beneath the surface was studied primarily through the use of oil and gas test logs. Some 700 electrical logs, and a number of older sample descriptions and driller's logs were examined to delineate the coalbeds penetrated. Unfortunately, such logs are available for only parts of the coal-bearing areas encompassed by the study; in the remaining area, surface information alone was used.

The study area was part of a larger examination and evaluation of the strippable coal reserves of the San Juan Basin (Shomaker, Beaumont and Kottlowski, 1971). The broad scope of that study did not permit a detailed examination of Ute lands. The present study represents a considerable refinement with respect to strippable reserves.

In the Ute Mountain Ute Indian Reservation minerals ownership coincides with surface ownership throughout the Reservation; mineral rights are exclusively Indian within the Reservation boundary. By contrast, the Southern Ute Indian Reservation is not a single block, but contains both non-Indian surface ownership and non-Indian mineral lands within its general boundaries. For the Southern Ute Indian Reservation, coal reserves were calculated and tabulated so that coal of tribal ownership could be distinguished, and maps of the Southern Ute coal areas show areas of tribal and non-Indian coal separately. Mineral ownership status was determined from plats provided by the U. S. Bureau of Indian Affairs.

In view of the current unsettled legal situation regarding coal mining methods, reclamation requirements, and water allocation, emphasis was placed on the technical aspects of exploitation of the coal and the corresponding water needs. For many reasons, not the least of which are the unresolved legal questions, the economic analysis of the Ute coal resources cannot be a clearly defined course of action. The discussion of economics is based on the premises developed in the geologic evaluation, and is necessarily inhibited by the fact that neither the Ute resources nor those of their potential competitors are fully explored; nor is the technology, which will be required to utilize most of the Ute coal, at a commercial stage of development.

During the course of field investigations, the possibility of finding deposits of minerals other than coal was kept in mind. No such deposits were found, however, largely because coal exploration techniques are quite different from those aimed toward search for other mineral commodities.

ACKNOWLEDGMENTS

The New Mexico State Bureau of Mines and Mineral Resources and Colorado Geological Survey were assisted in this study by officials of the U. S. Bureau of Indian Affairs Albuquerque Area Office and the Southern Ute and Ute Mountain Ute Agencies, and by officials of both tribes, and the U. S. Geological Survey. Western Coal Company provided data concerning its exploration of part of the Ute Mountain Ute Indian Reservation; Peabody Coal Company gave permission to use coal resource data with respect to leases on the Southern Ute Indian Reservation.

STUDY METHODS

Although the geologic methods used in this study were not unusual, the application of some general techniques is outlined. Electrical logs of oil and gas tests were used almost exclusively for data on coalbeds beneath the surface. About 700 wells were investigated, generally following the techniques described by Tixier and Alger (1968) and by Fassett and Hinds (1971). Coalbeds were identified on resistivity logs by high resistance peaks in the lateral curve, somewhat lower peaks in the short normal curve, and exceptionally low resistance indicated by the long normal curve. Most beds identified as coal had little or no effect upon the spontaneous potential curve unless more than 4 or 5 ft thick; thicker beds sometimes, but not always, were marked by a weak negative peak. In some instances the determination of coal was very questionable because of the character, and resulting electrical log response, of adjoining beds. Thicknesses of coalbeds were measured with a conscious effort to obtain conservative results.

Where formation density logs were available, the determination of coalbeds and their thicknesses was much more accurate because of the markedly lower density of coal compared with enclosing beds; density logs are a relatively new development and, unfortunately, only a few were available in the study area.

A few sonic velocity logs were available, and coals were determined with a fair degree of confidence where velocity was extraordinarily low.

Induction electrical logs constituted about half of the electrical logs available; coals were tentatively identified on them. Coals are characterized on these logs by sharp, high peaks in the induction curve corresponding with somewhat lower peaks in the normal curve and very low conductivity values. The response is not easily distinguished from that of fairly clean sandstone, so that the induction logs were used only where necessary and then with little confidence.

Radioactivity (gamma ray-neutron) logs are common in the study area, and are used in conjunction with other kinds of logs for coal determination. Virtually all coals in the study area are radioactively "dead," and so are represented by very low natural gamma ray count; but this factor does not permit them to be distinguished from clean sandstone or some shales, also very low in natural radioactivity. The neutron log is somewhat more useful because coal is an excellent moderator of induced radiation, and is represented by low radiation intensity. Where both curves are deflected far to the left (indicating low radiation intensity), coal is generally indicated.

Measurements of coal in surface exposures were made in many places to help fill in data. As expected, a pronounced discrepancy in coalbed thickness and distribution was noted between surface sections, even where the coals are very well exposed, and nearby drill-hole logs reliable. Surface measurements almost invariably indicated fewer, thinner coalbeds. Therefore, published mapping and reserve calculations based upon them indicate far less coal tonnage than drill-hole log interpretation seems to justify. The present study is necessarily incomplete in that drill holes are lacking over most of the coal-bearing areas of the Ute Mountain Ute Indian Reservation, and much of the Southern Ute Indian Reservation, and interpretations had to be made based on surface measurements known to be inadequate.

Coal quality was evaluated solely from published and unpublished analyses made by the U. S. Bureau of Mines, and analyses furnished by Western Coal Company and Peabody Coal Company.

LOCATION

The study encompasses all lands owned by the Southern Ute and Ute Mountain Ute Indian Tribes, with the exception of [certain] outlying ranches. The area lies in Montezuma, La Plata, and Archuleta counties, Colorado, and San Juan County, New Mexico (fig. 1 on page vi), occupying most of the area of Colorado south and west of Pagosa Springs, and a block of land northwest of Farmington, New Mexico, adjoining Colorado.

The area lies along the northern rim of the San Juan topographic basin, and includes a portion of the basin, part of the adjoining high Mesa Verde plateau, and, at the western end, a broad westward-draining plain. The only mountainous topography, the group of laccolithic intrusions that comprise Ute Mountain, lies in the northwest corner of the area.

GEOLOGY

The distribution of the various coal-bearing units in the area is shown by the geologic map (fig. 2 in pocket), a diagrammatic cross section representing an east-west slice across both reservations (fig. 3 in pocket), and the structure contour map (fig. 4 in pocket).

A principal factor controlling the depths at which the coal-bearing sequences lie is the structural deformation to which the rocks have been subjected since deposition. Fig. 4 shows, by means of structure contours, the elevation with respect to sea level of the base of the Dakota Sandstone, the lowest coal-bearing unit considered in the report. An understanding of the general shape of this surface is the first step in understanding the depth distribution of coal in all of the coal-bearing units. The study area can be divided readily into three principal structural segments:

1) the Four Corners platform, a monoclinal feature in which strata dip gently, and more-or-less uniformly, southeastward;
2) the Hogback monocline, and the continuation of it eastward and then southeastward, a steep to nearly vertical fold forming the rim of the San Juan basin; and
3) the basin itself.

The basin is asymmetric, with its center not far south of the Colorado-New Mexico boundary and its steeper dips on the north and east, so that the Reservations lie in an area of moderate to relatively steep dips.

The structural configuration indicates that the structurally highest areas, those from which the greatest thickness of strata has been eroded, are at the western extreme of the area, and that; in general, younger strata and additional coal-bearing units appear in the direction of the center of the basin.

Fig. 2 shows the geologic formations that are exposed at the surface, and how closely the distribution of formations follows the geologic structure.

The coal-bearing sequences considered in this report are all Late Cretaceous in age, and thus occupy only a small part of the total geologic section in the area. They are the products of depositional conditions prevailing at that time.

The coalbeds themselves were deposited under similar circumstances in all three coal-bearing units: The Dakota Sandstone, the Menefee Formation, and the Fruitland Formation. The organic material that eventually became coal settled on the floors of infilled coastal lagoons, which formed swamps behind one-time barrier beach ridges. The swamps were narrow and irregular, and tended to be elongate parallel with the shoreline; where smaller streams entered, sand and silt was deposited, interrupting the continuity of the coal swamps. Similarly, major rivers formed deltas, complex deposits of river-borne sand and silt, which contained ephemeral swamps but generally did not include swamps that lay stable long enough for much accumulation of organic matter.

One of the fundamental factors in coal distribution in the San Juan basin is that the position of the shoreline was almost constantly changing. The sea, which advanced from the northeast, moved erratically southwestward with many minor reversals, to some position beyond the present structural basin, then retreated entirely. The cycle was repeated several times, and in each major cycle, as well as in the uncounted minor movements, the coal-swamp environment moved along with the shoreline. When the shoreline advanced rapidly, time was insufficient for a stable coal swamp to develop and a sand-rich sequence developed; conversely, if the shoreline was static for a long period, a stable swamp environment prevailed, resulting in a thick, areally extensive coal deposit.

This model explains several characteristics common to the coals in the study area. The lens-like shape and discontinuous nature of the coal bodies is a consequence of their forming in rather small, irregular swamps. The trend of the long dimension of each of the bodies (thus the likelihood of successful correlation from one point of measurement to another) is generally northwest-southeast owing to the parallelism of the coal swamps with the shoreline. The present San Juan basin is a geologic structure imposed upon the rock strata mostly after deposition; the basin occupied by Cretaceous seas was considerably larger, and the coal-bearing rocks once occupied a far greater area than today.

Coal Resources

DAKOTA SANDSTONE

The Dakota Sandstone is the oldest of the coal-bearing units studied; it crops out at the western edge of the Ute Mountain Ute Indian Reservation and underlies all of the reservation lands to the east. Fig. 5 (in pocket) shows the area of outcrop, and the thicknesses and depths of coalbeds on the Ute Mountain Ute Indian Reservation. The coalbeds are thin and erratically distributed. A bed which reaches a thickness of 6.9 ft at one point in sec. 22 of T. 32 N., R. 20 W. diminishes to 3.5 ft in one direction and 1.0 ft in the other, all within a distance of less than 3,000 ft. In the drill-hole logs examined, the average bed thickness is 3.0 ft and the average total coal thickness is 7.1 ft. Approximately 300 square miles in the western part are underlain by coal at a depth of 1,000 ft or less, an area estimated to contain 2,409 million tons. About 612 square miles are underlain by coal deeper than 1,000 ft, an estimated total of 4,924 million tons.

Fig. 6 (in pocket) represents the same categories of data for the Southern Ute Indian Reservation. Virtually all of the Dakota coal lies below a depth of 3,000 ft; within the San Juan structural basin, the Dakota lies between 7,000 and 9,000 ft in depth. Thickness and distribution are very erratic, with single beds up to 20 ft thick found in some wells, while in others there is no coal at all. In a 4- to 6-mile wide strip west of the rim of the basin, along a line curving north-north-eastward and then northeastward from the south-central part of T. 32 N., R. 12 W., the Dakota commonly contains a single bed 5 to 8 ft thick. This area was estimated to contain 401 million tons. A second area, containing an average of two 7.2-ft beds, occupies most of T. 32 N., R. 8 W. and R. 9 W.; T. 33 N.; R. 7 W., R. 8 W., and R. 9 W.; the south half of T. 32 N., R. 7 W.; and perhaps part of T. 34 N., R. 7 W. and R. 8 W. This area was estimated to contain 3,752 million tons Eastward, data are very sparse. While much more coal doubtless exists, only 254 million tons were estimated in the north half of T. 32 N., R. 7 W. and in T. 32 N., R. 6 W. No attempt was made to separate the Ute-owned coal from other coal.

The quality of coal in the Dakota Sandstone is indicated by the analyses in table 1 (in the appendix at rear). All of the analyses are of samples taken near Cortez, north of the Ute Mountain Ute Indian Reservation, because of a lack of analyses of reservation coals. The coal sampled is generally similar to coals in the Menefee Formation near Mancos (see table 2 in appendix); probably the quality would prove to be similar throughout both reservations.

MENEFEE FORMATION

The New Mexico portion of the Ute Mountain Ute Indian Reservation (see fig. 7 in pocket) offers considerable promise of mineable coal in the Menefee Formation. In this area, published surface mapping (Hayes and Zapp, 1955) was of little value because the number and thicknesses of coalbeds are not consistently revealed at the outcrop; therefore, only a few measured sections of very well exposed sequences were considered reliable enough to include on fig. 7, and to be used in evaluating reserves. Though drill holes are lacking in many parts of the area, there are enough to provide a general picture.

In the northern part of the area, a good coal zone with potential for some auger mining occurs in the upper 200 to 400 ft of the Menefee.

Five oil tests and one measured section in the northern part of T. 32 N., R. 15 W. and the northeastern corner of T. 32 N., R. 16 W. penetrated a number of beds of mineable thickness, and suggest that a small reserve of coal suitable for auger mining may be present. The mineable beds lie below stripping depth, beneath a continuous cover of Cliff House Sandstone, but are probably too lenticular for efficient underground mining. However, the area is much dissected by Salt Canyon and Middle Canyon and their tributaries; depths in the 5 drill holes indicate that some of the coals penetrated can be expected to crop out in the canyon walls. Two favorable areas within this reserve were chosen by rather arbitrarily extending the drill-hole data about 1.5 miles in the direction of depositional strike and about 1.0 mile in the perpendicular direction; one area (fig. 7) lies between Salt Canyon and North Salt Canyon and involves about 4.5 miles of canyon wall which can be expected to expose about 10 coalbeds having an accumulated thickness of about 38 ft. The area should contain some 7,150,000 tons to an auger depth of 200 ft. Assuming about one-third recovery to allow for irregularities of the beds, the potential yield should be about

2,380,000 tons. The other area (fig. 7) encompasses about 5.1 miles of canyon wall in the upper extremities of Middle Canyon with 5 projected beds totalling about 28 ft, and should contain about 5,850,000 tons gross and 1,930,000 tons of recoverable coal. Drilling would probably reveal that the two areas are larger, and, in fact, contiguous.

A third favorable area (fig. 7) lies along the south side of Purgatory Canyon in sections 4 and 10 of T. 31 N., R. 15 W.

Much more coal susceptible to auger mining can be found in the canyons cutting through the Cliff House Sandstone well into the Menefee, and along the cliff which forms the southwestern edge of the Cliff House Sandstone outcrop in T. 31 N., R. 16 W. Some 45 miles of canyon wall and cliff exposures within the New Mexico part of the Ute Mountain Ute Indian Reservation—from North Salt Canyon south and eastward to Barker Canyon—are favorable, in addition to the areas mentioned specifically. If an average of 10 ft of coal is considered representative, then some 19,350,000 tons would be present, of which about 6,500,000 would be recoverable.

In the southern part of the area, roughly corresponding with the area of dense drill-hole control on fig. 7, many beds, some of mineable thickness, are at almost every point. As fig. 8 indicated, however, the coals are extremely irregular in thickness and distribution in the geologic section. Because unreachable by the relatively flexible auger method, this coal is not economically mineable at present.

An approximation of the amount of Menefee Formation coal present beneath the entire New Mexico portion of the Reservation is about 3,276 million tons, but only the small portion described above is suited to auger mining, hence currently marketable. In the part of the area in which the full section of Menefee is present less than 500 ft below the surface, the average bed thickness is about 4.3 ft, and the average number of beds about 8. This area contains an estimated 1,840 million tons. Where less than a full section is present, an average of three beds has an estimated reserve of 1,033 million tons.

Between depths of 500 and 1,000 ft, 109 million tons are estimated in beds averaging about 3.6 ft thick. Still deeper, 70 million tons are estimated between 1,000 and 1,500 ft, and 224 million tons deeper than 1,500 ft.

Menefee coal is present in the Colorado part of the Ute Mountain Ute Indian Reservation, exposed in canyon walls on Mesa Verde. Surface mapping by Wanek (1959) indicated that mineable beds are found principally near the New Mexico boundary (see fig. 7); suitable oil test logs are almost entirely lacking. Oil tests near the eastern boundary do indicate mineable beds in that area. Wanek estimated a total of 3,579 million tons of coal 14 inches and thicker in all categories. Of this, 747 million tons were interpolated from Wanek's tabulation to be in beds 3 ft or more thick. Probably little of this is recoverable under foreseeable economic conditions, largely because of the fact that no individual bed is of mineable thickness over a sufficiently large area. Auger mining is a possibility in canyons near the state line, but potential for strip mining is virtually nil.

Quality of Menefee coal on the Ute Mountain Ute Indian Reservation is indicated in table 2. All of the analyses are from the U. S. Bureau of Mines (1936 and 1937). The coal is high-volatile C bituminous or subbituminous A rank. No free-swelling index determinations were found; there is little reason to expect coal of coking quality.

The Menefee, or equivalent strate of the Mesaverde Formation, is present beneath virtually all of the Southern Ute Indian Reservation (see fig. 2). The Menefee bears coal in beds of mineable thickness from the western edge of the Southern Ute Indian Reservation to about the western edge of R. 6 W. The Menefee does not bear coal on the outcrop east of the Florida River (in section 8, T. 35 N., R. 8 *W.)*, nor is coal indicated in oil tests in the eastern part of T. 32 N., R. 7 W. (fig. 9). Though few well data are available east of T. 32 N., R. 7 W. to confirm the absence of coal, presumably significant coal is not present east of a line from the Florida River in T. 35 N., R. 8 W. to the southeast corner of T. 32 N., R. 7 W., with the exception of coal in a few tests in T. 33 N., R. 7 W.

The depth at which Menefee coal is found is determined generally by the geologic structure. Figs. 9 and 10 show the locations of drill holes for which logs were examined, the elevation of the base of the coal zone in each, and the number and aggregate thickness of coalbeds (3 ft or thicker above 1,000 ft, 5 ft or thicker below 1,000 ft).

Coal is available at less than 500 ft in two small areas of T. 34 N., R. 12 and 13 W. About 183 million tons were estimated, of which about 161 million belong to the Southern Ute Tribe. The major part of this area lies in T. 34 N., R. 12 W. within Peabody Coal Company lease tract 2; most of the remainder occurs beneath narrow canyon bottoms in T. 34 N., R. 13 W. West of a line trending roughly northeast from the southwest corner of T. 32 N., R. 13 W., the base of the Menefee coal zone is at a depth less than 1,000 ft; the average bed thickness is approximately 3.9 ft and the average number of beds encountered per hole is 7, with a range from 4 to 16. About 3,496 million tons were estimated, of which about 2,274 million belong to the Tribe. The coal zone varies in thickness from about 200 ft to about 400, and in much of the area coal is found less than 500 ft below the surface.

The difference between the results obtained from examination of oil test logs (summarized above) and those obtained by consideration of coal test holes drilled by Peabody Coal Company (also shown on fig. 9) is marked. The coal tests give a far less favorable picture, allowing for debate as to relative reliabilities of the two approaches. The coal tests were drilled with mud in a dominantly shale section with only driller's logs kept. Coalbeds could have been missed, particularly at the considerable depths reached by many of the holes.

East of the line diagonally across T. 32 N., R. 13 W. and T. 33 N., R. 12 W., the coal zone dips steeply eastward and southeastward into the San Juan basin and is flexed down in the abrupt boundary monocline. In the eastern part of R. 11 W., and from there eastward to the limit of coal-bearing rocks, the base of the zone occurs 5,500 to 7,000 ft below the surface. In this area, aggregate coal thickness and number of beds vary erratically; the maximum aggregate thickness is 42 ft, the maximum number of beds, 7. Some holes did not penetrate coal of mineable thickness, which, below 1,000 ft, is 5 ft. A total of 8,385 million tons were estimated; some 7,490 million tons were estimated beneath Ute lands.

Coal analyses typical of the Menefee outcrops north of the Southern Ute Indian Reservation are shown in table 3 (appendix). They appear similar to those of the Ute Mountain Ute Indian Reservation, except that in later years of operation of some of the mines in the Hesperus and Hay Gulch areas, free-swelling index determinations were often made. These determinations indicate values up to 7, representing coking coal.

In general, the coals are high-volatile A bituminous rank, though sometimes high-volatile B, with "as-received" heating value ranging from 12,500 to 14,000 Btu (British thermal units) per pound, with ash ordinarily well below 10 percent.

Coking coals, though known only near Hesperus, are possible in other areas.

FRUITLAND FORMATION

Figs. 11 through 17 (fig. 11 is on page 8, all others are in pocket) show the general distribution of coal of the Fruitland Formation within the two reservations. Tables 4 and 5 (appendix) summarize quality information. In gross structural aspect, the coals occur in the form of a great bowl whose rim cuts the southeast corner of the New Mexico part of the Ute Mountain Ute Indian Reservation, passes north-north-eastward across the western end of the Southern Ute Indian Reservation and curves eastward to pass just south of Durango, then passes eastward and then southward to cross the Reservation again between the northeast corner of T. 34 N., R. 5 W. and the southeastern corner of the Reservation. The rim of the bowl dips steeply, but within the bowl, the strata dip rather gently, with minor interruptions, toward the center of the San Juan basin.

The area of Fruitland Formation coal within the Ute Mountain Ute Indian Reservation is shown in fig. 11 (centerspread). Locations of coal drill holes and oil and gas tests are indicated, along with coal data for each; coal outcrops with coal thicknesses are shown for mineable beds visible on the surface. Within this area is the acreage covered by the prospecting permit issued to Public Service Coal Company (now Western Coal Company).

A total of 13 holes were drilled by Public Service Coal Company within the permit area, and a reserve of some 14.4 million tons was defined within the 120-ft overburden line for the uppermost of three mineable beds, and 200-ft overburden lines on the two lower mineable beds. The mineable area considered, about 620 acres, occurs entirely in relatively flat ground along the west side of the Ute Canyon arroyo in sections 24, 25, 34, 35, and 36 (as projected) of T. 32 N., R. 15 W. The combined thickness of beds (including only those present and considered mineable) ranges from 3.5 ft in a single bed to 20.5 ft where all three are at a combined maximum.

As-received heating value for the various beds ranges from 9,443 to 11,689 Btu per pound, and ash ranges from 8.1 to 19.8 precent in roughly inverse relationship with heating value. Sulfur content ranges from 0.88 percent to 1.25 percent. Analyses are shown in table 4.

To determine the amount of coal available to a depth of 250 ft, the structure contour and isopach data furnished by Public Service Coal were extrapolated to that depth, and additional reserves of about 3.9 million tons in the upper bed and about 5.1 million in the two lower were estimated.

Though Fruitland coal occurs at theoretically-strippable depth for some considerable distance eastward from the east end of the Public Service Coal permit area, the width of the strippable area is very small owing to the steep dip. Hence, the mineable coal in the Public Service Coal permit area is really a natural part of the company's much larger lease block with which it is contiguous along the southern boundary of the Reservation. The coal in the permit area is strippable in theory, but, in practical terms, too small to justify the large equipment necessary to mine to a depth of 120 ft, and too isolated from any reserve other than the holdings of Western Coal Company to be utilized in some other combination. In short, from both geologic and economic points of view, the two blocks of coal belong together. From a conservation standpoint the same is true; if not mined for the Public Service Company San Juan Station, the Ute block may not be mined at all.

Additional reserves of Fruitland coal within the Ute Mountain Ute Indian Reservation lie in a narrow band of strippable coal in T. 32 N., R. 14 W., and in a body of deep coal dipping basinward south of the strippable areas. The additional coal between the surface and 250 ft, in excess of that in the Public Service Coal permit, is estimated at 16.2 million tons. This coal occurs in a zone some 8 miles long, across T. 31 N., R. 14 W., and seldom much more than 1,500 ft wide; dip is generally somewhat more than 20 degrees. Two beds of mineable thickness generally occur.

The deep coal underlies an area of some 7,050 acres south and east from the band of shallower coal, and constitutes a reserve of some 227 million tons (as estimated from rather sketchy oil and gas test information). Of the total, 203 million are thought to be between 250 and 1,000 ft below the surface, and about 24 million below 1,000 ft. From 1 to 4 beds of mineable thickness are present. Except for the shallowest parts of this reserve, where dips range up to more than 20 degrees, the dips vary from flat to about 8 degrees. Quality of the coal is probably similar to that of the Public Service Coal permit area.

The details of the southern and northern parts of Peabody lease tract 1 in the western part of the Southern Ute Indian Reservation are shown on figs. 16 and 17. The locations and elevations of the drill holes are derived from field relocation of holes indicated on Peabody Coal Company maps. Holes were relocated in the field and spotted on the new topographic maps of the U. S. Geological Survey because the locations as shown on Peabody maps could not be reconciled with the topographic maps. Not all of the holes were found in the field, and for those that were, the accuracy of location and elevation was poor. Position of any particular hole is accurate only within several hundred feet, and many elevations are accurate only within about 40 ft.

The logs furnished by Peabody to the U. S. Geological Survey (obtained with Peabody's permission for use in this study) are all driller's logs. Though the logs often leave considerable room for interpretation, an effort was made to read them consistently.

In zones that contained multiple beds of coal, the aggregate thickness used for reserve computation was determined in the following way: the highest bed in the zone that was thicker than 3 ft, and thicker than the parting below it, was the highest bed included; the lowest bed thicker than 3 ft, and thicker than the parting above it, was the lowest bed included; the total thickness of coal in these two beds and in all coalbeds between them, plus the total thickness of partings less than 0.7 ft thick, was taken as the aggregate thickness.

The southern part of tract 1 (fig. 17) contains about 174 million tons in two zones; the total is not accurate because of uncertainty of elevations, irregularity of coal thicknesses, extrapolation of data over long distance, and steep dip and rough topography. The coal dips up to 18 degrees beneath the dissected backslope of a north-north-east-trending asymmetric ridge. At its widest, a pit extending from the outcrop of the lowest bed to the 250-ft overburden line on the highest would be 6,500 ft wide; and the average width of pit would be about 2,300 ft. The length of the mineable area, from the Reservation boundary at the southern end, to the point where the mineable area narrows to less than 800 ft at the north end, is about 9 miles.

Each coal zone consists of several beds separated by sandy partings. The coal itself, when mined in such a way as to exclude most of the thickness of partings, is high-volatile A bituminous rank with as-received heating value of somewhat less than 13,000 Btu per pound, and ash on the order of 9 percent (see table 5). If the coal were strip-mined, either the partings would

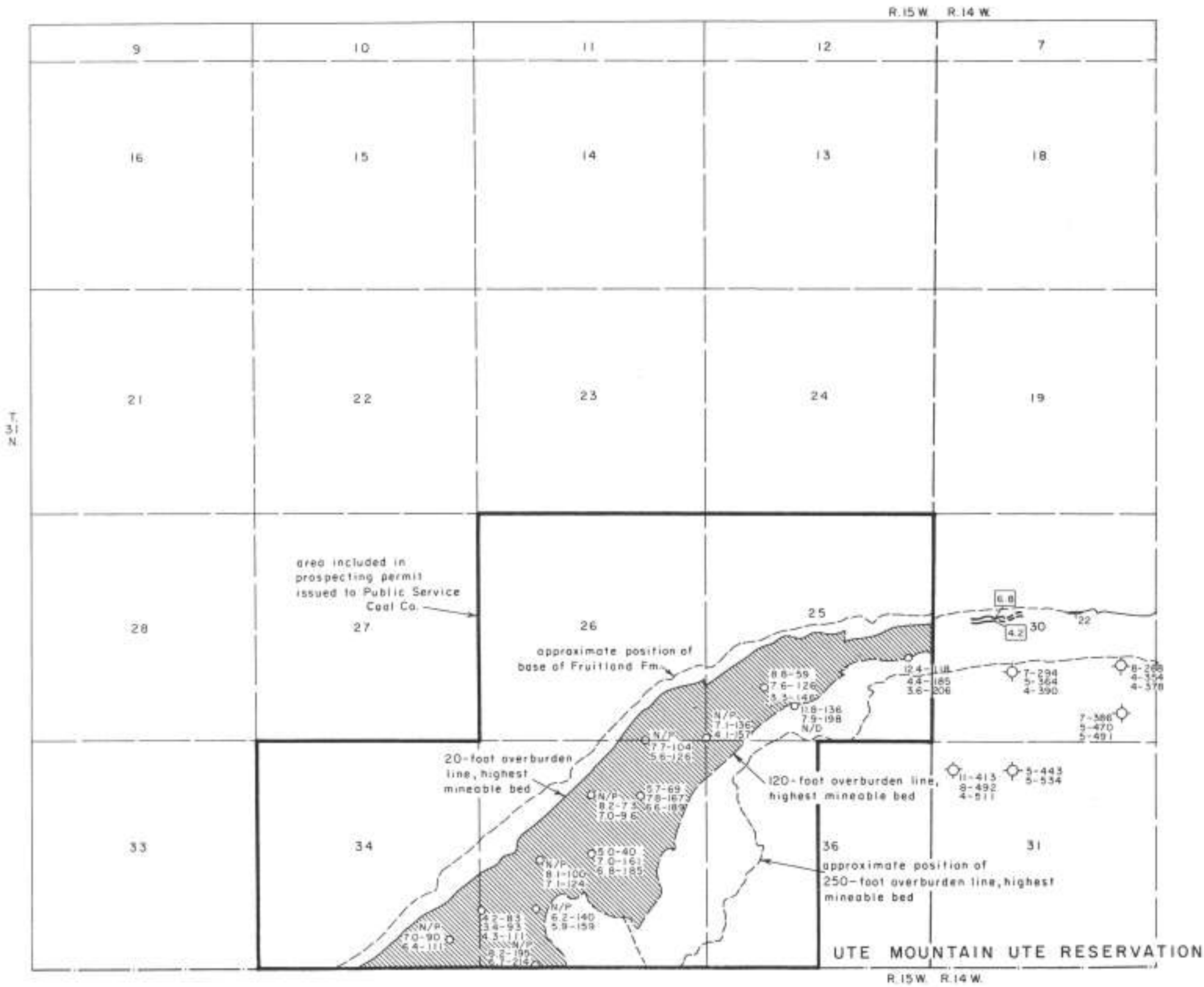
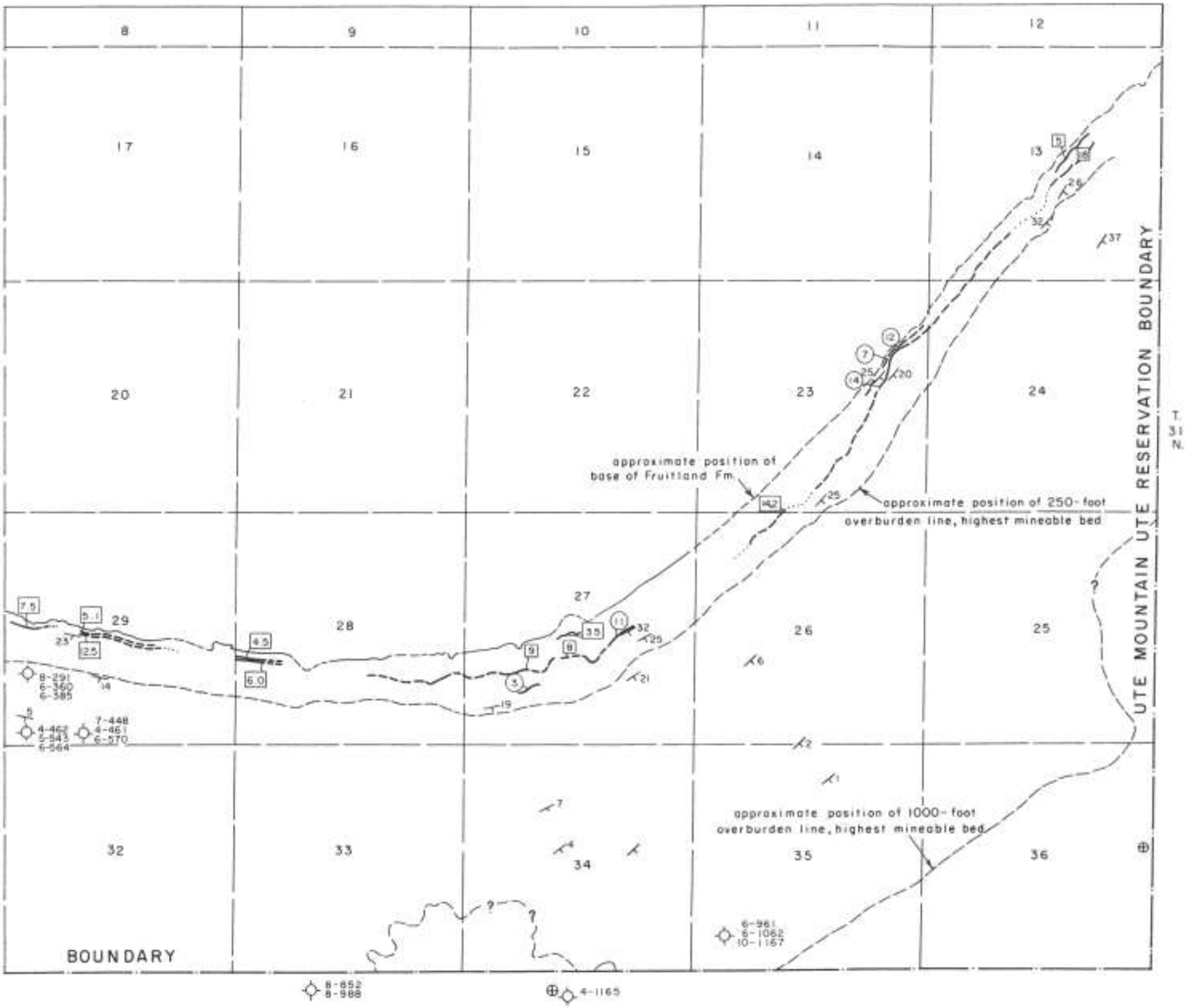


FIGURE 11—Distribution of coal in Fruitland Formation, New Mexico part of Ute Mountain Ute Indian Reservation.



EXPLANATION

4-462
5-543
6-564

Oil or gas test hole,
showing thicknesses and depths of principal coal beds

6.3 5.1

Outcrop of coal bed,
dashed where uncertain, dotted where covered. Numbers in boxes indicate thicknesses measured by Hayes and Zapp, 1955. Circled numbers indicate thicknesses measured for this report.

8.8-59
7.6-126
3.3-146

Coal test hole,
showing thicknesses and depths of upper, middle, and lower beds recognized in Public Service Coal Co. prospecting permit area; N/P indicates bed not present; N/D indicates hole not deep enough to reach bed.

Area considered strippable within Public Service Coal Co. prospecting permit area.

23

Strike and dip of formations;
dip shown in degrees.

0 0.5 1.0 Mile

Scale 1:42,240 (1 mile = 1½ inches)

have to be included, with consequent high and erratic ash content, or the partings would have to be extracted in mining, or by washing.

Though the steep dip and abundance of partings in some areas would present some mining problems, the coal in the southern part of Peabody lease tract 1 probably warrants consideration from an economic point of view.

The northern part of Peabody tract 1 (fig. 16) contains 3 fairly well-defined zones, which average 13.4, 16.6, and 20.9 ft net coal thickness. At the southern end of this part of the tract, only the lowermost zone is present, but elsewhere all three are present. A total of some 3,450 acres appears mineable, and probably contains about 226 million tons, though drill-hole data are not sufficient to estimate reserves with certainty. The irregular band of coal beneath less than 250 ft of overburden (on the highest bed) is 900 to 8,000 ft wide and about 6 miles long. The reserve estimated is limited on the north by the boundary of the Southern Ute Indian Reservation, and on the south by absence of drill-hole data. The dip is 6 to 14 degrees. This area would logically be included with the southern part of the tract in a development program, forming a combined gross reserve of about 400 million tons.

Basic data for Fruitland Formation coal eastward and downdip from Peabody lease tract 1 are shown on figs. 12 and 14; isopachs of total coal thickness and indication of coal ownership are shown on figs. 13 and 15. Reserve estimates are summarized in table 6. As many as 9 beds of mineable thickness (5 ft or more) are present at depth, and 5 or more are present at most locations. The thickest bed measured is 45 ft, and the greatest aggregate thickness, 121 ft.

Aggregate coal thickness diminishes from west to east, but even at the eastern extremity of the area, 1 bed of mineable thickness can be expected. The quantity of strippable coal in the eastern portion of the Southern Ute Indian Reservation is not known because of lack of drilling data; but the quantity is not likely to be very great because of the usual position of the coal outcrop well below the crest of a high ridge held up by thick sandstones higher in the geologic section. No attempt was made to separate coal at strippable depth from the coal between the outcrop and the 1,000-ft overburden line, except for the Peabody lease tract.

An indication of quality of the coals at depth can be gained from analyses of outcrop samples and from drill-cuttings analyses reported by Fassett and Hinds (1971). These data are summarized in table 5. Nothing suggests these Fruitland coals are of metallurgical quality.

Mining of the deep Fruitland Formation coals is not now economically feasible, even though they constitute such a vast reserve (see table 6). In fact, the enormous strippable reserves in the San Juan basin and the probability of nuclear domination of the energy budget a few decades hence indicate that the deep coals may never be of economic interest. On the other hand, efforts now being made to develop in situ mining and extraction techniques may well lead to a process by which coal is burned in the ground, or extracted by solution or as a mechanical slurry, and the energy or hydrocarbon feedstock be brought to the surface without mining in the conventional sense. If such a process were made economically desirable, then the usual criteria for judging coal reserves would be in large part reversed; deep, lenticular bodies might be in demand, and high ash content might prove advantageous. The deep Fruitland reserves should be seriously considered in this context.

A summary of the distribution of coal reserves within the two Ute reservations is shown as table 7. A total of some 62,607 million tons lie within the general boundaries, of which about 51,033 million tons belong to the Ute tribes.

Current Marketability

ALTERNATIVE MINING METHODS

At present two general coal-mining techniques are in wide use: stripping or surface mining, and underground mining. A third method, auger mining, is finding some application in the eastern United States.

Strip mining is the most efficient in terms of cost per ton mined, and permits very high production rates from a particular facility; but its use is restricted by several limitations. Some of the general requirements of a deposit to be strip mined are:

1) Overburden thickness must be rather low. Major mines in the southwest are only recently being planned for removal of as much as 200 ft of overburden; and to reach this depth probably will require rehandle, or moving part of the overburden material more than once.

2) Coalbed thickness must generally exceed 3 ft for efficient handling. Thinner beds require smaller machines and slower, more careful operation, so that only unusually valuable metallurgical coals can be considered.

3) The overall ratio of cubic yards of overburden to be removed for each ton of coal probably should not be more than 10, approximately the same as a ratio of 10 to 1 in terms of feet of overburden per foot of underlying coal. Thus, a ratio of 20 to 1 (which, when averaged with the less than 1 to 1 ratio near the outcrop, would yield an overall ratio on the order of 10 to 1) would probably define the greatest economic pit depth. For example, if a 6-ft bed were being mined, probably no more than 120 ft of overburden would be removed. This factor is modified by several considerations, as topography, nature of overburden material, and availability of deeper mineable beds.

4) Uniformity and continuity of beds are highly desirable, though considerable thickness variation can be tolerated. Faulted or folded beds present great problems, and cause the loss of significant amounts of coal because the pit floor must adjust to abrupt changes in the vertical position of the coal through use of rather gentle grades.

5) Dip of the coal has an effect on mining economics; a steep dip causes the pit to be relatively narrow, and requires loading equipment to work on a side slope.

6) The topography must allow efficient backfilling of the pit. In areas of gentle slope a number of cuts can be made side-by-side, with spoil from each cut filling the one previous, so that rehandle must be employed only for the final downdip cut and the topography can be smoothed with minimum work after mining. Conversely if dips are steep, or if the topographic surface rises rapidly above the coalbed, few cuts can be made and less coal can be removed in proportion to the amount of overburden that must be rehandled to backfill.

Though actual operating figures are highly variable and difficult to obtain, a steam-coal mining operation on the Ute Indian Reservations would have to cost less than $2.25 per ton including royalty to be competitive. This figure is near the lower end of the range of strip mine operating costs.

A variation of strip mining known as contour mining involves removal of coal in a narrow band following the outcrop around the contour of the land surface. The technique is applicable where the topography is irregular, the relief considerable, and coalbeds are more or less flat lying. This method is somewhat less efficient than large-scale strip mining, and reclamation is very difficult and costly. Because mining follows a long, narrow, sinuous path rather than occupying a confined area, the effect on the environment-hydrologic problems, soil conservation, and esthetics-is proportionately higher. Contour mining is illegal now in several states, and may be prohibited elsewhere in a few years.

Underground mining, in a number of variations, represents the opposite of strip mining. Underground mining is the more costly, but more acceptable from an environmental standpoint. The likelihood of a competitive underground mine producing steam coal in the Southwest is very remote under current economics, but for metallurgical (coking) coal, underground mining can be economically feasible.

At present, the so-called longwall method is the optimum underground mining program from a standpoint of cost per ton. This method utilizes a continuous coal-cutting machine which operates back and forth across a face 300 to 600 ft wide, cutting coal almost the full thickness of the bed and loading onto a conveyor belt just behind the machine. The narrow passage in which the machine and conveyor operate is supported by a parallel line of hydraulic jacks, and as the machine advances into the coal, the entire system is advanced in increments of a few feet and the roof is allowed to collapse behind. This method requires a highly regular coalbed; although the dip may be steep (up to 30 degrees), dip and bed thickness must be relatively uniform.

Production rate from longwall workings can be quite high. In a 6-ft coalbed, employing a 550-ft panel width and a length of 2,000 ft for a complete panel, production can be 700 tons per 8-hour shift. The panel would contain 265,500 tons and would be mined out in approximately 380 shifts, about 4-1/2 months.

A somewhat less efficient, but more flexible, mining plan is the room-and-pillar method in which coal is mined systematically from rooms turned at regular intervals from haulageways. Irregularities in thickness and dip, and minor faults and folds can be accommodated more readily than in longwall mining. The Kaiser Steel Company York Canyon mine, near Raton, New Mexico, is a relatively new and efficient room-and-pillar operation mining metallurgical coal. Because the coal has proved to be quite uniform, a longwall program is contemplated for mine expansion.

A hybrid method of mining coal known as auger mining combines surface and underground techniques. The following information on auger mining is taken from manufacturers' technical bulletins. A bench about 40 ft wide is cut along the outcrop (in the same pattern as for contour strip mining) and a horizontal auger drill moves along the outcrop, drilling parallel holes and extracting coal. The system is applicable in flat-lying beds thicker than 24 inches, particularly if the outcrops are exposed on hill slopes in a highly dissected terrain. Penetration of the augers is limited to about 200 ft. Production efficiency is high, but percentage recovery of reserves is rather low due to the need for a "rib" of coal left between holes to prevent collapse. For example, in a 48-inch coalbed, production would be about 800 tons per shift with a single 42-inch auger, but recovery of the coal between the outcrop and a 200-ft depth limit would be only 51 to 64 percent (depending upon the thickness of rib left). The recoverable coal in a 48-inch seam (at a 60 percent rate corresponding to a 6-inch rib) would be about 100,000 tons per mile of outcrop to a depth of 200 ft. Auger mining is applicable under the highwall of any kind of strip mine prior to backfill.

Auger mining suffers from two principal limitations: the 200-ft depth allows recovery of only a small fraction of the coal available in a bed, and recovery efficiency drops markedly in beds with irregular thickness and dip. The 40-ft bench required can be difficult to backfill in a reclamation program, especially on a steep slope.

WATER REQUIREMENTS

The quantity of water that may be required for development of the Ute Tribe coals can be estimated only between very broad limits; if coal is to be shipped by rail to some distant market, only insignificant amounts of water will be needed. On the other hand, on-site liquefaction demands large quantities of water, and the amount of coal present and which could conceivably be mineable for that purpose is far in excess of the amount of water that could be utilized. In the following discussion, the general water requirements for alternative uses of coal are considered (table 8), the amounts of water needed for specific blocks of coal in various kinds of development are estimated (table 9), and a speculation is made as to the order of mining and tonnage that might be removed, and the uses of the coal. From this, a range of water requirements is deduced.

Coal mining on the reservations for rail or truck shipment elsewhere would require little water from the Tribes, unless water were sold to another user as a separate commodity. The only exceptions would be a possible need for domestic or municipal-type supplies for the mining operation, and a possible need for irrigation water in some form of surface reclamation.

Pipeline transportation of coal, as is in use in northern Arizona between Peabody Coal's Black Mesa mine and a generating plant on the Colorado River, is a feasible method. The 18-inch Black Mesa pipeline is about 273 miles long, and moves coal at the rate of about 5 million tons per year." Coal is crushed at the mine to an average of 200 mesh, cleaned, and mixed with water in about equal proportion by weight. The resulting suspension is transported through the pipeline. The one-to-one proportion of water to coal amounts to about 0.000736 acre ft per ton, or about 3,680 acre ft for the 5 million ton-per-year operation; the operator is actually planning to use somewhat less (about 3,100 acre ft). For the purposes of this discussion and table 9, the exact one-to-one relationship will be used. Water quality is important from the standpoint of disposal at the delivery end of the pipeline, but otherwise the quality criteria are broad.

At present, nearly all western coals mined are fueling electricity-generating plants. Existing and projected major coal-fired plants in the Arizona, New Mexico, southern Nevada, and southern Utah area probably typify a generating plant utilizing Ute coal. Water needs ought to be similar. For the 6 plants considered (Fruitland, N. M.; Mohave, Nev.; Page, Ariz.; Kaiparowits, Utah; Huntington, Utah; and Waterflow, N. M.) coal use ranges from 2,810 to 3,870 tons per year per megawatt of nominal capacity. Water use ranges from 16.3 to 19.5 acre ft per year per megawatt. For tables 8 and 9, averages of 3,269 tons of coal per year per megawatt, and 16.9 acre ft of water per year per megawatt were used. Water quality must be fairly good. Treatment costs for boiler feed increase considerably for poorer water, and the progressive deterioration of recycled cooling water aggravates any quality problem already present.

The major thrust of new coal development in the San Juan basin is toward Lurgi-process gasification in large-scale operations. Although the Lurgi process is by no means new, and is less efficient than some newer processes, it is in a later developmental stage and will be used in the first plants. Two complexes have been announced for the basin, one by El Paso Natural Gas Company, and the other by Utah International Inc., Pacific Lighting Systems and Texas Eastern Gas. The first is to have an ultimate annual capacity of 750 MMCF (million cubic ft) of gas per day. An application for 28,250 acre ft per year of San Juan River water has been made. The second is to have a capacity of 1,000 MMCF gas; water requirements have not been made public, but an uncommitted reserve of 61,000 acre ft per year is already held. For tables 8 and 9, a figure of 36.7 acre ft per year per MMCF per day nominal plant capacity was used. The corresponding coal requirement is about 20,308 tons per year per MMCF. Water quality must be good; much of the water must be up-graded to very high quality boiler feed, and treatment costs constitute a significant part of operating expense.

Somewhat further in the future are more advanced gasification and liquefaction processes just now in the pilot plant stage. The COED (Char Oil Energy Development) process yields synthetic crude oil, char, pipeline gas, and hydrogen in varying proportions depending on modifications made for economic reasons. Plant capacities are expressed in terms of the principal product, oil, as barrels of oil per day (BOPD). In a report on the projected economics of the process (Eddinger, Strom, and Bloom, 1970) a plant of 14,200 BOPD required 3.5 million tons per year of coal yielding 13,500 Btu per pound dry, and 2.22 acre ft of water per year per BOPD capacity. The plant also produced 3,670 tons of char per day and 141.4 MMCF per day of hydrogen. Correcting to allow for 10,000 Btu per pound (moisture-free basis) Fruitland Formation coal, some 4.7 million tons per year would be required for this plant, or 331 tons per year per BOPD. The water requirement would remain the same.

The Institute of Gas Technology Hygas process, now in the pilot plant stage of development, will produce pipeline-quality gas and requires about 20,000 tons of coal per year per 1 MMCF gas per day plant capacity. This figure is very imprecise because the quality of coal used in the pilot plant is somewhat better than the San Juan basin coals and only a rough conversion was made to represent the use of Ute coals. The absolute water requirement is estimated at 17,700 gpm (7,150 acre ft per year) for a 250-MMCF per day plant; of that amount, up to about 4,700 gpm can be recycled. Thus, the minimum make-up amount would be 13,000 gpm, or about 5,025 acre ft per year. About 8,000 gpm of the 13,000-gpm requirement is actually process water used in the gasification itself, and the remainder is cooling water for the associated power plant which furnishes electricity for the process. If the power plant were air-cooled, the requirement would be reduced to 4,400 acre ft per year.

For comparative purposes in speculating on water needs, the following assumptions were made:

1) Coal availability, used as a basic parameter of magnitude of the resource, was taken at the full amount estimated for each block, with mineability ignored and recovery factors calculated later in the scheme. The reserve blocks are ranked in table 9 according to the authors' opinion as to likelihood of development, with the shallow Fruitland Formation coal of the Western Coal permit area first, and the deep Dakota Sandstone coals of the Southern Ute Indian Reservation last. Clearly the ranking of the blocks is arbitrary, and for the lower two-thirds of the list, academic.

2) Mine and plant life was set at 35 years in each case and also at 25 years for the Hygas and COED processes. These figures are common for such plants on an individual basis, and also indicate that most foreseeable use of coal as an energy resource (as opposed to chemical feedstocks) is likely to take place in the next 3 to 4 decades.

3) Recoverability factors of 80 percent for strippable coal, 30 percent for deep coal, and 33 percent for coal recovered by auger mining were established. These factors are applied to the entire "coal available" amount, and represent only coal which can actually be extracted. Coal within stripping depth that is weathered, or not mineable because of structure or unfavorable topography, or left behind in mining, is excluded. Similarly, pillars, thin zones, and wasted coal are excluded for deep coal. For auger mining, the coal available includes only coal to a distance of 200 ft from the outcrop; the ribs between auger holes, the coal above and below the holes, and areas unreachable because of unfavorable topography or thick partings, are excluded. In the first five blocks shown in table 9, the recovery factor is prob-

ably conservative; below that point, the factor is more and more liberal until, for the lowest 6 or 7 entries, it is relatively meaningless.

4) Minimum plant sizes were chosen near the large end of the present range of capacities; both the relatively weak competitive position of Ute coals and the steadily increasing capacities of new plants indicate that only plants as large as the largest currently built can be reasonably expected.

In an attempt to reach more specific conclusions as to overall water requirements, the following admittedly speculative projection was made as to the order and nature of the first few development steps:

1) Lease of 14.4 million tons of Fruitland Formation coal (to depth of 120 ft below surface) at southern edge of Ute Mountain Ute Indian Reservation. This reserve is naturally associated with the Western Coal Company properties south of the Reservation, and cut off by many miles from other Ute coal of remotely comparable economic favorability. The reserve is too small to be operated separately for an industrial application. The new New Mexico Public Service Company San Juan generating station, for which Western Coal's property is being opened, is the logical market. If the 14.4 million tons are not committed to it, another market is difficult to imagine. Water for the plant is already committed; therefore, no Ute water should be needed.

2) Mining of part of remaining 25.2 million tons of strippable coal (to 250 ft) in Ute Mountain Ute Indian Reservation. The Western Coal operation could reasonably extend somewhat deeper as work proceeds. The same situation prevails for the deeper coal as for the initial 14.4 million tons, and no Ute water would be needed.

3) Mining of southern part of Peabody lease tract 1 (Rocky Ridge area) on Southern Ute Indian Reservation. This block of 174 million tons is large enough to support a generating plant of the 1,000-megawatt size, if mined to the full 250-ft depth; together with the northern part of the lease (Basin Mountain area), it could be ample for any of the kinds of development considered. The southern part appears slightly more favorable and is likely to be mined first, however. The demand at present would seem to slightly favor a gasification plant over a generating station, and a combination of the most readily mineable areas of both north and south blocks could probably support a Lurgi-process plant of 400 MMCF gas per day capacity, which would require 14,680 acre ft water per year for 35 years.

4) Mining of 226 million tons in the northern part of Peabody lease tract 1 (Basin Mountain area) on Southern Ute Indian Reservation.

5) Auger mining of 32 million tons in Salt Canyon and Middle Canyon areas of Ute Mountain Ute Indian Reservation.

6) Mining of Menefee Formation coals near the northwest corner of Southern Ute Indian Reservation, if of coking quality. If not, mining of this coal would be deferred to a much lower rank in the list.

ENVIRONMENTAL CONSIDERATIONS

Any plan for utilization of coal must consider the effects of both mining the coal and the process in which it is utilized upon the quality of air, water and land surface, and upon aesthetic values.

At present, Colorado law, with regard to strip mining, requires filing of descriptions of land and reclamation plan, as well as a number of other specific requirements such as: Tops of ridges left in mining must be reduced to a width of 15 ft or more; final cuts must be compartmented with earth dams; acid-forming materials (which would include coal and coal-containing waste) must either be covered with fill to a depth sufficient to protect surface drainage from pollution, or be covered with at least 4 feet of water; refuse must be disposed of so as to control stream pollution and unsightliness; water must be diverted to control erosion and silting; trees must be planted on 10-ft centers, with the operator allowed to choose the kind of tree (fire access to be provided); and, reclamation must be completed within 3 years.

The recently passed New Mexico law does not contain specific provisions as to reclamation, but allows the matter of detailed regulations to a commission established for the purpose. Some other State laws, notably the Kentucky code, impose much more stringent and detailed provisions. For Indian Reservation lands, the reclamation requirements can be determined to suit the particular case by the Tribe, the Bureau of Indian Affairs, and the U. S. Geological Survey.

The two general areas considered strippable under present economic conditions are the Public Service Coal Company permit area and the Peabody lease tract 1. The two areas are very different in topography and vegetation, but some general observations apply. In both cases, the material left on the surface after mining would constitute very poor soil. Topsoil worth preserving is not present, and the deeper strata which would be brought up and then leveled after mining are very nearly sterile. Neither area has rainfall sufficient for natural revegetation to take place rapidly.

Strip mining should be seen in its proper perspective as a temporary use of the land, and, as a source for generating income to finance land improvement. Rangeland worth a few dollars per acre can be improved significantly if the opportunity is taken to recover the coal beneath it and apply some of the resulting income to reclamation. For example, one square mile of poor range worth $25 per acre or a total of $16,000, could easily overlie $28,000,000 worth of coal, assuming a 10-ft bed and a sale price of $2.50 per ton. At an assumed royalty of $0.25 per ton, the gross royalty alone would amount to 177 times the value of the unmined land. In addition, regrading to a gentle natural contour, adding some soil conditioning, and controlling drainage will, within a few years, restore grazing land. With careful range management, the range eventually might be superior to the original tract worth $16,000.

Strip mining undeniably destroys some aesthetic attributes of a tract of land. In deciding how land should be used, however, consideration must also be given to opportunities to make the surface more productive than before.

Regrading of strip-mined lands to contours aesthetically acceptable, and which will provide control of drainage and blowing dust, is readily done. Establishing vegetation is a long process, but results at Pittsburg and Midway Coal Mining Company's McKinley mine near Gallup indicate restoration can be accomplished. Meager rainfall is an advantage because severe acid mine-drainage, as in eastern United States coalfields, is not likely to be a problem. In the case of the Peabody lease, the wisdom of full regrading is questionable; Sawyer and Crowl (1968) point out that tree survival and growth are better if the surface is not graded, primarily because compaction resulting from grading reduces infiltration of moisture, and because puddling on flat surfaces drowns young trees and seedlings. The cost of regrading varies widely, from as little as $25 per acre for striking the top of ridges under good conditions, to about $1,000 per acre for full re-contouring.

In the event auger mining is undertaken, very severe reclamation problems would result. The auger benches are made by opening cuts along fairly steep valley or canyon walls and dumping the material below the cut. Thus, no material is available for refilling the bench cuts and about all that can be done is to fill the openings of the auger holes themselves.

Perhaps the most vigorous objection to strip mining is brought about by the installations that use coal. In this connection, several great strides are being made in the cleaner use of coal. However, some air pollution will doubtless result and must be considered. To consider the nature and quantity of pollutants emitted by various plants, or to suggest what levels might be acceptable, is not within the scope of this report.

Summary and Recommendations

The two Ute Reservations contain approximately 51 billion tons of coal, not including some 11.6 billion tons beneath non-Ute lands within the overall Ute boundaries. Almost all is steam coal, as opposed to metallurgical or coking coal, and is distributed in three formations of Late Cretaceous age: the Dakota Sandstone (23 percent), the Menefee Formation (27 percent), and the Fruitland Formation (50 percent). Of this enormous total, only about 471 million tons (0.9 percent) can be considered mineable under present economic conditions, i.e., by strip or auger mining.

Most of the coal considered mineable by stripping lies in the Fruitland Formation, near the outcrop, in the southeastern corner of the New Mexico part of the Ute Mountain Ute Indian Reservation and in a band across the western part of the Southern Ute Indian Reservation. A small additional reserve of coal suited to the auger mining technique lies in the northwest corner of the New Mexico part of the Ute Mountain Ute Indian Reservation. Exploration may possibly reveal significant tonnages of strippable coal along the Fruitland Formation outcrop in the eastern part of the Southern Ute Indian Reservation, and some coal of metallurgical quality may be found in the northwestern corner in the Menefee Formation. In the latter case, however, the coal would have to be mined by underground methods; the greater price commanded by coking coal might make mining economically feasible.

Aside from a small reserve (14 million tons) in the southern extremity of the Ute Mountain Ute Indian Reservation, logically associated with an adjoining non-Indian reserve presently under development, the most likely utilization of strippable coal would seem to be gasification. The advanced "Hygas" process would require for each MMCF per day of plant capacity, if consuming typical Fruitland Formation coal, about 20,000 tons of coal per year, and about 28.3 acre ft of water per year. If all of the 400 million tons of Fruitland Formation reserve in the western part of the Southern Ute Indian Reservation were committed to this use over a 25-year life, a maximum of about 18,300 acre ft of water per year would be needed. Recycling of some of the water and air-cooling of the electricity generating plant required as part of the gasification plant could, theoretically, reduce the water need to about 11,260 acre ft per year.

Long-range consideration leads to speculation as to new mining techniques which will permit in situ extraction of some sort. Therefore, water requirements were examined for a variety of uses and for development of various blocks of coal (table 9 in appendix).

The effect of mining on the environment is profound, but if mining and reclamation are properly done, the effect is mostly temporary. The enormous difference between royalty income and the present productivity of the surface of most (if not all) of the strippable lands makes reasonable several years' disruption of the surface, especially when sale of the coal generates revenue which may be in part applied to improvement of the surface beyond its original state.

During the course of this study, several ideas emerged which could assist in development of the Ute coals. If feasible, future oil and gas leases might be written so that formation density logs would be required for all holes drilled. These logs provide the best delineation of coal thickness, and are probably the most reliable indicators of coal.

A program of prospecting permits at fairly low rentals and for one- to two-year terms would speed exploration and encourage leasing in the long run. This sort of program would have greatest use along the Fruitland outcrop in the eastern part of the Southern Ute Indian Reservation. Rentals should be high enough to pay for administration, and to discourage undesirable speculation, but low enough so that a bona fide operator can risk the capital to finance a good exploration program. The permit system, with a preference right for leasing, would provide otherwise costly information on resources to the Tribes.

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Appendix follows

Appendix

TABLE 1—Analyses of coal samples from Dakota Sandstone, Cortez area (analyses by U. S. Bureau Mines Laboratory)

Location	Kind of sample	Condition[1]	Sample No.	Lab. No.	Proximate % Moisture	Proximate % Volatile matter	Proximate % Fixed carbon	Proximate % Ash	Ultimate % H_2	Ultimate % C	Ultimate % N_2	Ultimate % O_2	Ultimate % S	Ultimate % Ash	Heating value British thermal units per pound	Fusibility of ash °F Initial deformation	Fusibility of ash °F Softening temp.	Fusibility of ash °F Fluid temp.	Remarks
SE¼NE¼ Sec. 29,	tipple	1	Y-397	C-28505	6.8	33.3	54.0	5.9	-	-	-	-	0.5	-	12,860	2910+	-	-	Montezuma mine;
T. 36 N., R. 15 W.		2			-	35.7	58.0	6.3	-	-	-	-	0.6	-	13,800				1" slack
		3			-	38.1	61.9	-	-	-	-	-	0.6	-	14,730				
SE¼NE¼ Sec. 29,	tipple	1	3971	C-28504	7.7	32.0	56.8	3.5	5.5	74.8	1.2	14.4	0.6	3.5	13,190	2850	2900	2910	Montezuma mine;
T. 36 N., R. 15 W.		2			-	34.6	61.7	3.7	5.1	81.1	1.3	8.2	0.6	3.7	14,290				1" slack
		3			-	36.0	64.0	-	5.3	84.2	1.4	8.5	0.6	-	14,850				
SE¼NE¼ Sec. 29,	tipple	1	6089	E-58657	4.8	33.9	56.5	4.8	5.5	76.5	1.3	11.3	0.6	4.8	13,650	2760	2890	2910+	Montezuma mine;
T. 36 N., R. 15 W.		2			-	35.6	59.4	5.0	5.2	80.4	1.3	7.5	0.6	5.0	14,340				1½" lump
		3			-	37.5	62.5	-	5.5	84.7	1.4	7.7	0.7	-	15,100				
SE¼NE¼ Sec. 29,	tipple	1	4565	F-44727	5.0	39.8	49.0	16.2	-	-	-	-	0.6	-	11,580	2910+	-	-	Montezuma mine;
T. 36 N., R. 15 W.		2			-	31.4	51.5	17.1	-	-	-	-	0.6	-	12,200				1½" x 0 coal;
		3			-	37.8	62.2	-	-	-	-	-	0.7	-	14,700				Hardgrove grindability index 59; free-swelling index 1
SE¼NE¼ Sec. 29,	tipple	1	4567	F-44726	5.5	30.5	52.7	11.3	-	-	-	-	0.5	-	12,400	2910+	-	-	Montezuma mine;
T. 36 N., R. 15 W.		2			-	32.3	55.7	12.0	-	-	-	-	0.5	-	13,120				1½" lump
		3			-	36.7	63.3	-	-	-	-	-	0.6	-	14,900				Equilibrium
NE¼NE¼NE¼	Core, test	1	8254	J-63511	3.5	19.1	31.0	46.4	3.1	40.2	0.5	9.5	0.33	46.4	6,810	2910+	-	-	moisture 3.75%
Sec. 18 T. 36 N.,	hole No. 8	2			-	19.8	32.1	48.1	2.8	41.6	0.5	6.7	0.35	41.8	7,060				Hardgrove grind-
R. 14 W.	NMBM	3			-	38.2	61.8	-	5.4	80.2	1.0	12.7	0.66	-	13,590				ability index 59; free-swelling index 1

[1]Condition: 1, as received; 2, moisture-free; 3, moisture- and ash-free

TABLE 2—Typical analyses of coal samples from Menefee Formation, Ute Mountain Ute Indian Reservation (analyses by U. S. Bureau Mines Laboratory)

Location	Kind of sample	Condition[1]	Lab. No.	Proximate %: Moisture	Proximate %: Volatile matter	Proximate %: Fixed carbon	Proximate %: Ash	Ultimate %: H_2	Ultimate %: C	Ultimate %: N_2	Ultimate %: O_2	Ultimate %: S	Ultimate %: Ash	Heating value British thermal units per pound	Remarks
NE¼NE¼ Sec. 25, T. 35 N., R. 16 W.	mine	1	16476	11.0	40.3	42.2	6.5	-	-	-	-	0.8	6.5	11,630	Todd mine
NE¼NE¼ Sec. 25, T. 35 N., R. 16 W.	mine	1	20267	12.1	37.7	44.1	6.1	6.0	64.4	1.4	21.5	0.6	6.1	11,390	Todd mine
		2		-	42.9	50.2	6.9	5.3	73.3	1.6	12.2	0.7	6.9	12,960	
		3		-	46.1	53.9	-	5.7	78.7	1.7	13.2	0.7	-	13,930	
NW¼SE¼ Sec. 19[2] T. 30 N., R. 16 W.	mine	1	A-46364	9.8	38.7	46.5	5.0	-	-	-	-	-	-	11,870	Shiprock School mine
		2		-	42.9	51.5	5.6	-	-	-	-	-	-	13,170	
		3		-	45.4	54.6	-	5.7	77.5	1.7	13.6	1.5	-	13,940	
NW¼NW¼ Sec. 20[2] T. 30 N., R. 16 W.	tipple	1	C-31312	11.3	39.3	46.0	3.4	-	-	-	-	-	-	12,090	Davidson mine
		2		-	44.3	51.9	3.8	-	-	-	-	-	-	13,630	
		3		-	46.1	53.9	-	5.5	80.1	1.6	12.0	0.8	-	14,170	

[1]Condition: 1, as received; 2, moisture-free; 3, moisture- and ash-free
[2]Near but not within Reservation

TABLE 3—Typical analyses of coal samples from Menefee Formation, Southern Ute Indian Reservation (analyses by U. S. Bureau Mines Laboratory)

Location	Kind of sample	Condition[1]	Lab. No.	Proximate %: Moisture	Proximate %: Volatile matter	Proximate %: Fixed carbon	Proximate %: Ash	Ultimate %: H_2	Ultimate %: C	Ultimate %: N_2	Ultimate %: O_2	Ultimate %: S	Ultimate %: Ash	Heating value British thermal units per pound	Remarks
NE¼SE¼ Sec. 3 T. 35 N., R. 13 W.	mine	1	4225	5.4	38.7	50.1	5.8	5.8	72.3	1.5	13.6	1.0	5.8	12,910	Old Spencer mine
		2		-	40.9	53.0	6.1	5.5	76.4	1.6	9.3	1.1	6.1	13,650	
		3		-	43.6	56.4	-	5.9	81.4	1.7	9.9	1.1	-	14,530	
NE¼SE¼ Sec. 3 T. 35 N., R. 13 W.	mine	1	20498	8.5	39.3	45.9	5.3	6.0	70.0	1.3	16.4	1.0	5.3	12,560	Old Spencer mine
		2		-	40.6	50.0	9.4	5.3	74.0	1.4	9.1	0.8	9.4	13,720	
		3		-	44.8	52.2	-	5.8	81.7	1.6	10.0	0.9	-	14,570	
SW¼NW¼ Sec. 2 T. 35 N., R. 13 W.	mine	1	20500	7.0	38.4	50.1	4.5	5.7	72.6	1.3	15.3	0.6	4.5	12,940	Spencer mine
		2		-	41.2	54.0	4.8	5.3	78.0	1.4	9.8	0.7	4.8	13,900	
		3		-	43.3	56.7	-	5.6	81.9	1.5	10.3	0.7	-	14,600	
NE¼SW¼ Sec. 35 T. 36 N., R. 13 W.	mine	1	20499	5.5	38.4	47.2	8.9	5.6	69.9	1.3	13.5	0.8	8.9	12,550	Fielding-Spencer mine
		2		-	40.6	50.0	9.4	5.3	74.0	1.4	9.1	0.8	9.4	13,280	
		3		-	44.8	55.2	-	5.8	81.7	1.6	10.0	0.9	-	14,650	
NW¼SE¼ Sec. 36 T. 36 N., R. 13 W.	mine	1	A-99881	6.9	36.4	52.2	4.5	5.9	72.0	1.5	15.6	0.5	4.5	12,860	Mancos Hill mine
		2		-	39.1	56.1	4.8	5.5	77.4	1.6	10.2	0.5	4.8	13,810	
		3		-	41.0	59.0	-	5.8	81.3	1.7	10.6	0.6	-	14,520	
NW¼NW¼ Sec. 32 T. 35 N., R. 11 W.	tipple	1	K-62266	1.6	38.2	51.8	6.4	5.7	74.2	1.4	11.7	0.6	6.4	13,360	Burnwell No. 2 mine; free-swelling index 4½
		2		-	39.6	53.8	6.6	5.5	76.9	1.5	8.9	0.6	6.6	13,860	
		3		-	42.4	57.6	-	5.9	82.4	1.6	9.4	0.7	-	14,840	
NE¼NE¼ Sec. 21 T. 35 N., R. 10 W.	tipple	1	F-44237	2.9	37.9	53.6	5.6	5.7	77.1	1.5	9.1	1.0	5.6	13,940	Victory No. 3 mine; free-swelling index 7
		2		-	39.0	55.2	5.8	5.5	79.4	1.5	6.8	1.0	5.8	14,350	
		3		-	41.5	58.5	-	5.9	84.3	1.6	7.2	1.0	-	15,240	

[1]Condition: 1, as received; 2, moisture-free; 3, moisture- and ash-free

TABLE 4—Typical analyses of coal samples from Fruitland Formation, Ute Mountain Ute Indian Reservation (analyses by Commercial Testing and Engineering Co., furnished by Western Coal Co.)

Location	Kind of sample	Condition[1]	Lab. No.	Proximate %: Moisture	Proximate %: Volatile matter	Proximate %: Fixed carbon	Proximate %: Ash	Ultimate %: H_2	Ultimate %: C	Ultimate %: N_2	Ultimate %: O_2	Ultimate %: S	Ultimate %: Ash	Heating value British thermal units per pound	Remarks
SE¼NE¼SE¼ Sec. 25 T. 31 N., R. 15 W.	core	1	72-4338	12.47	-	-	17.64	-	-	-	-	0.88	-	9,670	Hardgrove grind- ability index 44.2
		2		-	-	-	20.15	-	-	-	-	1.00	-	11,048	
SW¼NE¼SW¼ Sec. 35 T. 31 N., R. 15 W.	core	1	72-4259	9.16	-	-	8.08	-	-	-	-	1.14	-	11,689	Hardgrove grind- ability index 39.1
		2		-	-	-	8.90	-	-	-	-	1.25	-	12,868	
SW¼NE¼SW¼ Sec. 35 T. 31 N., R. 15 W.	core	1	72-4260	13.21	-	-	18.66	-	-	-	-	1.25	-	9,443	Hardgrove grind- ability index 40.4
		2		-	-	-	21.50	-	-	-	-	1.44	-	10,880	
SE¼NE¼NW¼ Sec. 35 T. 31 N., R. 15 W.	core	1	72-4336	12.57	-	-	14.29	-	-	-	-	1.09	-	10,193	Hardgrove grind- ability index 41.8
		2		-	-	-	16.34	-	-	-	-	1.25	-	11,659	
SE¼NE¼NW¼ Sec. 35 T. 31 N., R. 15 W.	core	1	72-4334	8.55	-	-	18.04	-	-	-	-	0.90	-	10,221	Hardgrove grind- ability index 39.6
		2		-	-	-	19.73	-	-	-	-	0.98	-	11,177	
NE¼SE¼SW¼ Sec. 25 T. 31 N., R. 15 W.	core	1	72-4337	10.44	-	-	19.84	-	-	-	-	0.99	-	9,669	Hardgrove grind- ability index 45.6
		2		-	-	-	22.15	-	-	-	-	1.11	-	10,796	
NE¼SE¼SW¼ Sec. 25 T. 31 N., R. 15 W.	core	1	72-4335	11.02	-	-	11.83	-	-	-	-	0.81	-	10,871	Hardgrove grind- ability index 40.8
		2		-	-	-	13.29	-	-	-	-	0.91	-	12,217	

[1]Condition: 1, as received; 2, moisture-free

TABLE 5—Typical analyses of coal samples from Fruitland Formation, Southern Ute Indian Reservation (analyses by U. S. Bureau Mines Laboratory)

Location	Kind of sample	Condition[1]	Lab. No.	Proximate % Moisture	Proximate % Volatile matter	Proximate % Fixed carbon	Proximate % Ash	Ultimate % H_2	Ultimate % C	Ultimate % N_2	Ultimate % O_2	Ultimate % S	Ultimate % Ash	Heating value British thermal units per pound	Remarks
SE¼NW¼ Sec. 36,	washed	1	H-38041	0.9	20.8	51.7	26.6	-	-	-	-	0.8	-	11,230	
T. 34 N., R. 10 W.[2]	drill	2		-	21.0	52.2	26.8	-	-	-	-	0.8	-	11,330	
	cuttings	3		-	28.7	71.3	-	-	-	-	-	1.1	-	15,480	
NE¼ Sec. 5,	washed	1	H-55350	0.8	21.5	56.4	21.3	-	-	-	-	0.7	-	12,140	
T. 32 N., R. 7 W.[2]	drill	2		-	21.6	56.9	21.5	-	-	-	-	0.7	-	12,240	
	cuttings	3		-	27.6	72.4	-	-	-	-	-	0.8	-	15,600	
NE¼ Sec. 15,	washed	1	H-46452	2.3	23.6	54.6	19.5	-	-	-	-	0.7	-	12,070	
T. 32 N., R. 10 W.[2]	drill	2		-	24.2	55.9	19.9	-	-	-	-	0.7	-	12,360	
	cuttings	3		-	30.2	60.8	-	-	-	-	-	0.9	-	15,440	
NE¼NE¼NE¼ Sec. 1	tipple	1	C-8677	3.9	39.0	49.0	8.1	5.5	71.0	1.6	11.8	2.0	8.1	12,850	Dufur or Fort Lewis
T. 32 N., R. 12 W.		2		-	40.5	51.1	8.4	5.3	73.8	1.6	8.8	2.1	8.4	13,370	mine
		3		-	44.3	55.7	-	5.8	80.7	1.8	9.4	2.3	-	14,600	
NE¼NE¼NE¼ Sec. 1	tipple	1	C-10142	3.6	40.6	47.0	8.8	5.8	71.8	1.5	11.3	0.8	8.8	12,980	Dufur or Fort Lewis
T. 32 N., R. 12 W.		2		-	42.1	48.7	9.2	5.5	74.4	1.6	8.5	0.8	9.2	13,460	mine
		3		-	46.4	53.6	-	6.1	81.9	1.7	9.4	0.9	-	14,820	
SW¼SW¼SW¼ Sec. 36,	channel	1	A-3402	5.4	36.8	49.0	8.8	-	-	-	-	0.9	-	12,660	Wood or Henderson
T. 33 N., R. 12 W.		2		-	38.9	51.8	9.3	-	-	-	-	0.9	-	13,380	mine
		3		-	42.9	57.1	-	-	-	-	-	1.0	-	14,760	
SE¼SE¼ Sec. 27,	mine	1	3551	3.1	32.7	47.4	16.8	-	-	-	-	-	-	11,900	La Plata mine
T. 35 N., R. 9 W.		2		-	33.7	49.0	17.3	-	-	-	-	-	-	12,270	
		3		-	40.8	59.2	-	5.5	80.1	1.8	11.0	1.6	-	14,840	

[1]Condition: 1, as received; 2, moisture-free; 3, moisture- and ash-free
[2]Fassett and Hinds, 1971

TABLE 6—Estimated coal reserves, and ownership, of Fruitland Formation, Southern Ute Indian Reservation.
Limited to beds 5 feet or more thick; overburden categories based on depth to top of uppermost bed. Reserves in millions of tons

Township	Less than 1,000 Ute	Less than 1,000 Non-Ute	1,000 to 2,000 Ute	1,000 to 2,000 Non-Ute	2,000 to 3,000 Ute	2,000 to 3,000 Non-Ute	More than 3,000 Ute	More than 3,000 Non-Ute
T. 32 N., R. 1 W.[1]	28	1	-	-	-	-	-	-
1½ W.	9	-	-	-	-	-	-	-
2 W.	75	-	-	-	-	-	-	-
3 W.	-	-	206	72	-	-	-	-
4 W.	-	-	357	80	-	-	-	-
5 W.	-	-	-	-	277	352	-	-
6 W.	-	-	-	-	42	1,017	-	-
7 W.	-	-	-	-	1,168	438	91	-
8 W.	-	-	-	-	22	-	1,220	-
9 W.	-	-	-	-	323	37	1,268	-
10 W.	-	-	-	-	642	27	674	-
11 W.	127	-	312	-	1,475	-	34	-
12 W.	328	-	20	-	-	-	-	-
T. 33 N., R. 2 W.	35	17	-	-	-	-	-	-
3 W.	74	6	170	28	-	-	-	-
4 W.	21	1	511	21	-	-	-	-
5 W.	-	-	-	-	930	170	-	-
6 W.	-	-	-	-	1,268	3	-	-
7 W.	-	-	-	-	1,622	1,131	-	-
8 W.	-	-	-	-	1,727	639	-	-
9 W.	-	-	-	-	1,360	401	377	18
10 W.	-	-	-	-	2,151	199	170	-
11 W.	595	-	314	-	674	-	24	-
12 W.	19	-	-	-	-	-	-	-
T. 34 N., R. 3 W.	3	-	-	-	-	-	-	-
4 W.	74	-	-	-	-	-	-	-
5 W.	-	-	-	-	15[2]	417[2]	-	-
6 W.	-	-	-	-	3	699	-	-
7 W.	-	-	-	-	585	953	-	-
8 W.	-	-	-	-	740	1,091	-	-
9 W.	-	-	18	10	733	1,365	-	-
10 W.	348	16	335	53	1,309	172	-	-
11 W.	144	-	18	-	-	-	-	-
Totals	1,880	41	2,261	264	17,066	9,111	3,858	18
Grand total	34,499							

[1]Ute Reservation only
[2]Also includes coal beneath less than 2,000 feet overburden

TABLE 7—Distribution of coal reserves, Southern Ute and Ute Mountain Ute Indian Reservations; reserves in millions of tons

Depth (ft) beneath surface	Formation					
	Dakota Sandstone		Menefee Formation		Fruitland Formation[2]	
	Ute	Non-Ute	Ute	Non-Ute	Ute	Non-Ute
Southern Ute Indian Reservation						
Above 250	–	–	161[1]	22[1]	400[3]	
250- 500	–	–			1,880[4]	41
500-1,000	–	–	2,274[1]	1,222[1]		
1,000-2,000	–	–			2,261	264
2,000-3,000	–	–	7,490[2]	896[2]	17,066	9,111
Below 3,000	4,400[1,5]	–			3,858	18
Ute Mountain Ute Indian Reservation						
Above 250			3,641[1]	–	39	–
250- 500	2,409[1]	–			203	–
500-1,000			109[1]	–		
1,000-2,000						
2,000-3,000	4,924[1]	–	294[1]	–	24	–
Below 3,000						
Totals	11,733	–	13,969	2,140	25,331	9,434
Total Ute 51,033						
Grand total 62,607						

[1]Includes beds 3 feet or more thick
[2]Includes beds 5 feet or more thick
[3]Western end of Reservation only
[4]Includes 400 million tons at western end; and unknown amount to a depth of 250 feet at eastern end
[5]Includes some non-Ute coal

TABLE 8—Rates of coal and water consumption for various uses

Use	Minimum plant size[4]	Life of plant (yrs)	Coal consumption (tons/yr)	Water consumption[1] (acre ft/yr)
Generation of electricity	1,000 MW	35	3,269,000	16,900
Gasification (Lurgi process)	250 MMCF	35	5,077,000	9,175
Gasification (hygas process)	250 MMCF	25 & 35	5,000,000±	7,150[3]
Liquefaction (COED)[2]	10,000 BOPD	25 & 35	3,310,000	22,200
Pipeline transport	–	35	–	7.36×10^{-4} (acre ft/ton)

[1]Assumes plants entirely water cooled; new developments in air cooling may reduce this greatly
[2]Production also includes 0.258 tons per day char, and 0.01 million cubic feet per day hydrogen
[3]Assume no recycling, all water cooling. Consumption 17.6 acre feet if required power plant facility is air cooled
[4]MW = megawatt; MMCF = million cu ft per day; BOPD = barrels oil per day

TABLE 9—Approximate water requirements for various uses of Ute coal reserve blocks. Coal in millions of tons, pipeline capacity in millions of tons of coal, gas in millions of cubic feet per day (MMCF), electricity in megawatts (MW), oil in barrels per day (BOPD), water in acre feet per year. See table 8 for coal and water consumption rates assumed

Reserve block designation[1]	Depth	Coal available		Electricity generation		Lurgi gasification		Pipeline transport		35 year				25 year			
										Hygas gasification		COED liquefaction		Hygas gasification		COED liquefaction	
		Ute	Non-Ute	Plant capacity (MW)	Water required	Plant capacity (MMCF)	Water required	Annual capacity	Water required	Plant capacity (MMCF)	Water required	Plant capacity (BOPD)	Water required	Plant capacity (MMCF)	Water required	Plant capacity (BOPD)	Water required
Ute Mtn.-Fruitland[2]	120	14	–	–[4]	–[5]	–[4]	–	0.3	242	–[4]	–	–[4]	–	–[4]	–	–[4]	–
Ute Mtn.-Fruitland[3]	250	25	–	–[4]	–[5]	–[4]	–	0.6	424	–[4]	–	–[4]	–	–[4]	–	–[4]	–
Sou. Ute-Fruitland																	
Peabody lease, south	250	174	–	1,219	20,577	196[4]	14,515	4.0	2,932	199[4]	13,070	12,035	26,719	279[4]	18,298	16,849	37,407
Peabody lease, north	250	226	–	1,578	26,638	254		5.2	3,827	258		15,585	34,598	361[4]		21,819	48,437
Ute Mtn.-Menefee																	
auger coal	200	32	–	94[4]	1,587	12[4]	–	0.3	182	12[4]	343	743[4]	1,656	17[4]	480	1,046[4]	2,322
Sou. Ute-Menefee	<1,000	2,435	1,244	6,385[8]	107,772	1,028[8]	37,718	20.9[8]	15,161	1,044[8]	29,858	63,053	139,977	1,462[8]	41,801	88,274	195,968
Ute Mtn.-Fruitland	250 to 1,000	203	–	533[4]	9,002	88[4]	3,150	1.7	1,283	87[4]	2,480	5,267[4]	11,693	122[4]	3,483	7,374[4]	16,370
Ute Mtn.-Menefee, NM	<1,000	2,971	–	7,819	132,139	1,259	46,191	32.6	18,812	1,273	36,408	77,220	171,420	1,782	50,971	108,108	240,000
Sou. Ute-Fruitland																	
west end of Res.	250 to 1,000	1,161	16	4,135[7]	69,798	497[7]	18,232	13.5[7]	9,949	504[7]	14,414	40,035	90,654	706[7]	20,180	57,169	126,915
Sou. Ute-Fruitland																	
east end of Res.	<1,000	319	25	902[4,7]	15,225	145[4,7]	5,329	2.3[7]	2,170	147[4,7]	4,204	8,958[4]	19,776	206[4,7]	5,886	12,471	27,686
Sou. Ute-Fruitland	>1,000	23,185	9,393	60,791[8]	1,026,166	9,766[8]	359,136	198.7[8]	146,264	9,936[8]	284,170	600,359	1,332,797	13,910[8]	397,838	840,502	1,865,916
Sou. Ute-Menefee	>1,000	7,490	896	19,639[8]	331,899	3,161[8]	126,020	64.2[8]	47,251	3,210	91,806	191,957	430,506	4,494[8]	128,528	271,540	602,818
Ute Mtn.-Menefee	>1,000	294	–	771[4]	13,028	124[4]	4,554	2.5	1,855	126[4]	3,604	7,613[4]	16,902	176[4]	5,046	10,658	23,661
Ute Mtn.-Fruitland	>1,000	24	–	63[4]	1,071	10[4]	–	0.2	153	10[4]	286	626[4]	1,391	14[4]	400	904[4]	2,008
Ute Mtn.-Dakota	<1,000	2,409	–	6,316	106,748	1,017	37,315	20.6	15,179	1,032	29,515	62,382	138,489	1,445	41,321	87,335	193,883
Ute Mtn.-Dakota	>1,000	4,924	–	12,911	218,196	2,078	76,273	42.2	31,063	2,110	60,346	127,510	283,072	2,954	84,484	178,514	396,301
Ute Mtn.-Menefee, CO	all	747	–	1,958	33,101	315	11,571	6.4	4,713	320	9,152	19,344	42,944	448	2,813	27,082	60,121
Sou. Ute-Dakota	all	4,400	7	11,537	194,974	1,857	68,156	37.7	27,758	1,886	53,932	113,940	252,948	2,640	75,504	159,516	354,127
Total Ute coal		51,033 million tons															

[1]Ranked according to likely order of development
[2]Public Service Coal Co. (Western Coal Co.) prospecting permit area, to 120 foot depth only
[3]Public Service Coal Co. (Western Coal Co.) prospecting permit area, 120 to 250 feet; less than 250 feet in remainder of Ute Mtn.-Fruitland area
[4]Insufficient reserve if considered alone
[5]Water not required, if leased to Western Coal Co.
[6]Rank in list would be much lower if coal not of coking quality
[7]Combined Ute and non-Ute reserve
[8]Ute reserve only

Figures in Pocket

Note: Each separate group of figures appears together on a separate sheet.

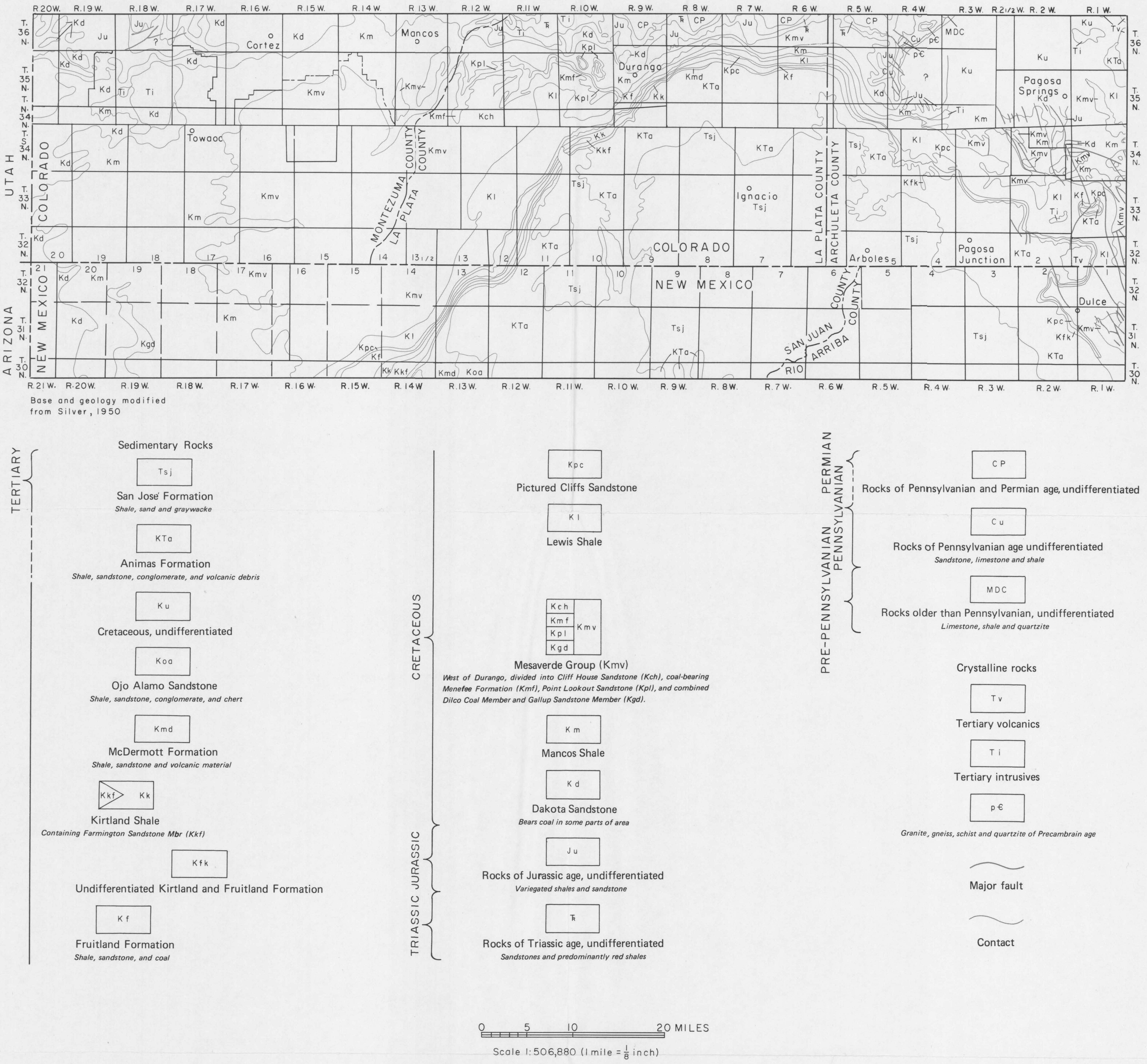


FIGURE 2—Geologic map of Southern Ute and Ute Mountain Ute Indian Reservations, and vicinity.

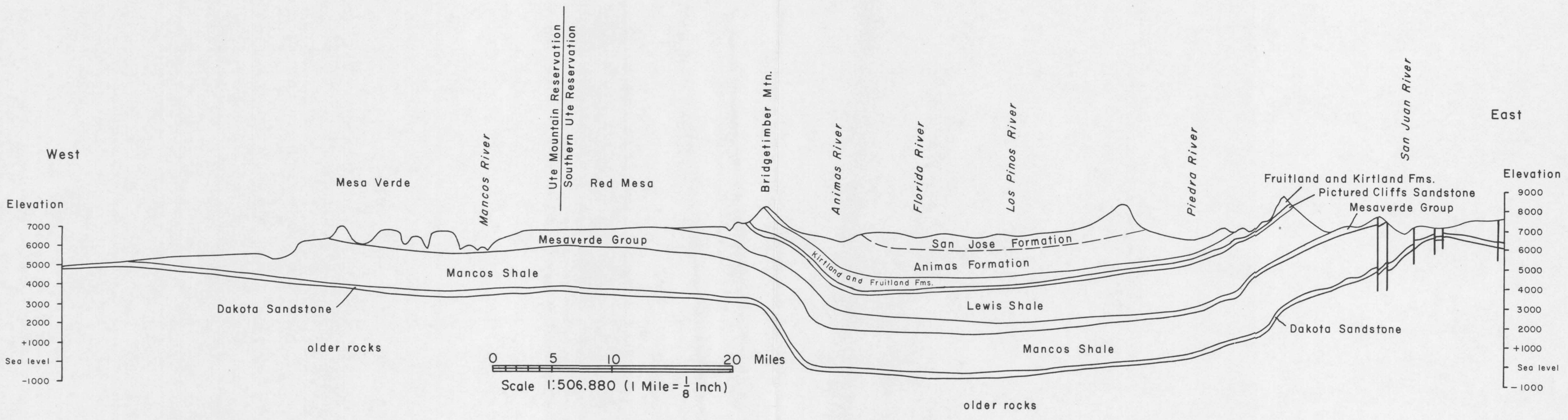


FIGURE 3—Diagrammatic cross section along boundary between T. 33 N. and T. 34 N., across Southern Ute and Ute Mountain Ute Indian Reservations.

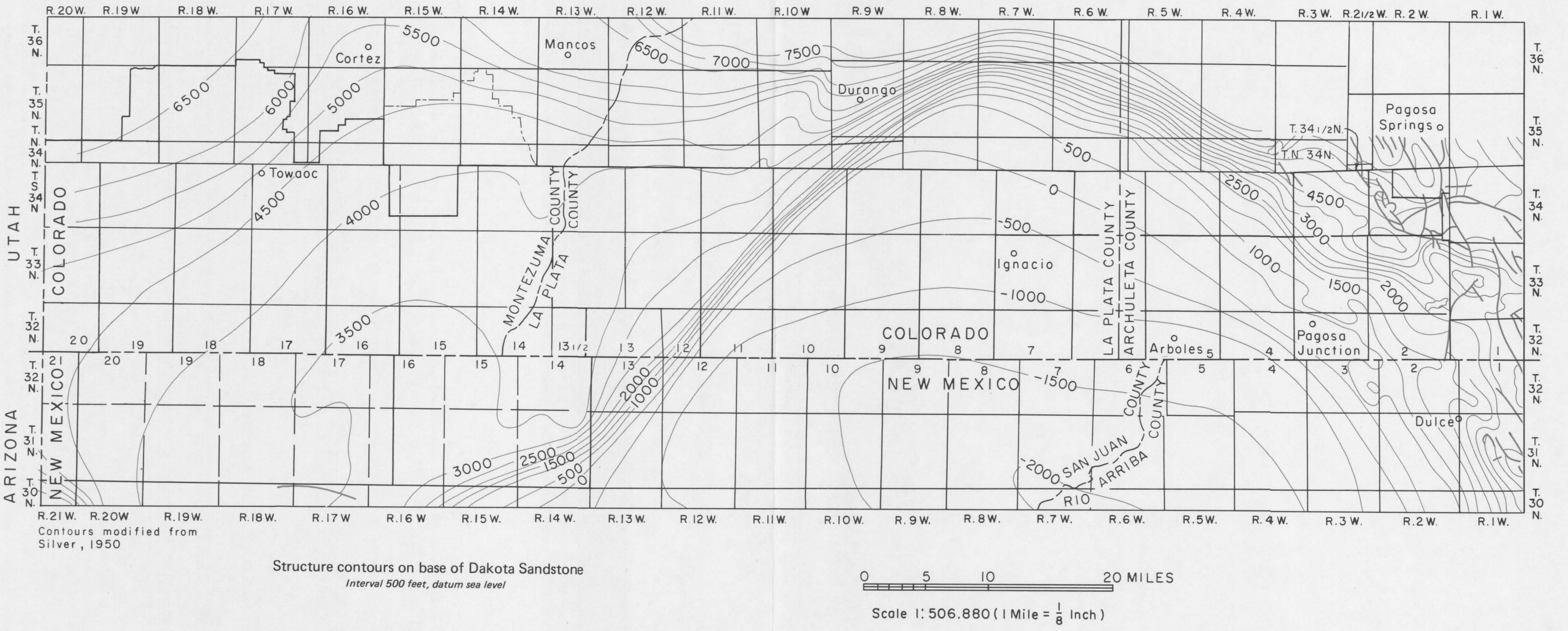


FIGURE 4—Structure of part of northern San Juan basin, New Mexico and Colorado.

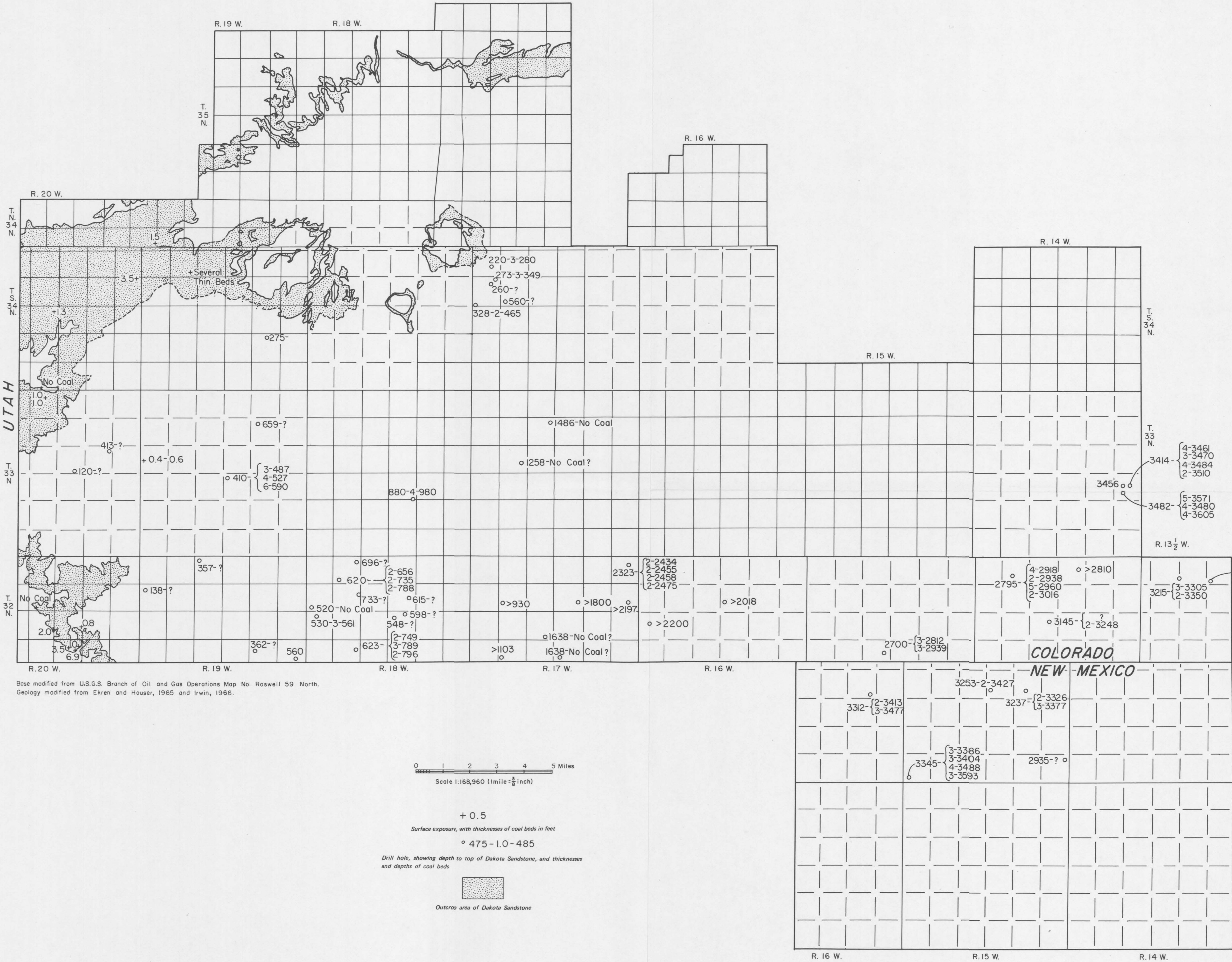


FIGURE 5— Outcrop areas and coal bed thicknesses for Dakota Sandstone, Ute Mountain Ute Indian Reservation.

EXPLANATION

○ +3414-8-3432 *

Drill hole, showing elevation of top of Dakota Sandstone (sea level datum) and thicknesses and depths of coal beds. Asterisk indicates incomplete section.

1 0 1 2 3 4 5 MILES

Scale 1: 168,960 (1 Mile = $\frac{3}{8}$ Inch)

FIGURE 6—Coal bed thicknesses for Dakota Sandstone, Southern Ute Indian Reservation.

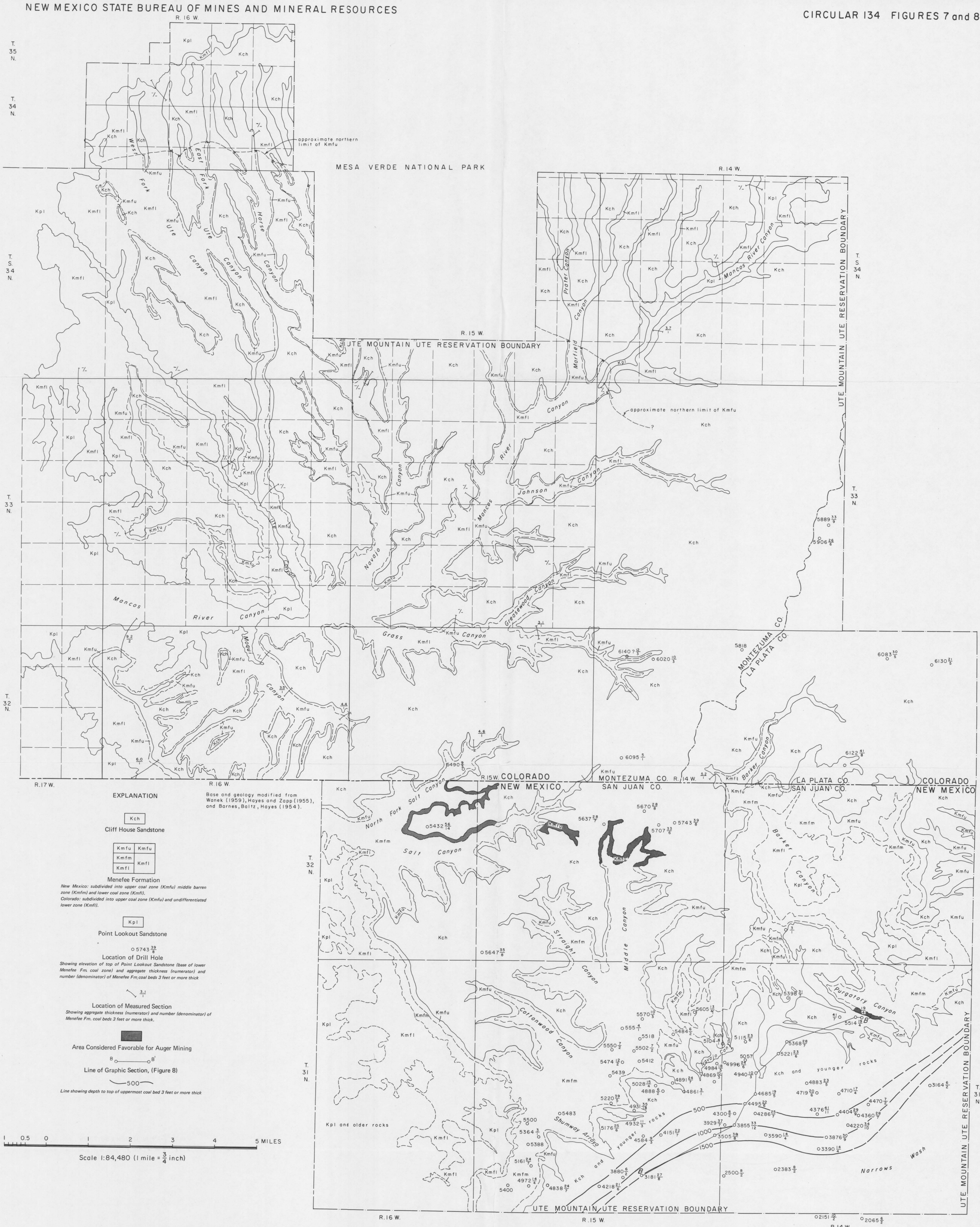


FIGURE 7—Distribution of coal in Menefee Formation, Ute Mountain Ute Indian Reservation, Colorado and New Mexico.

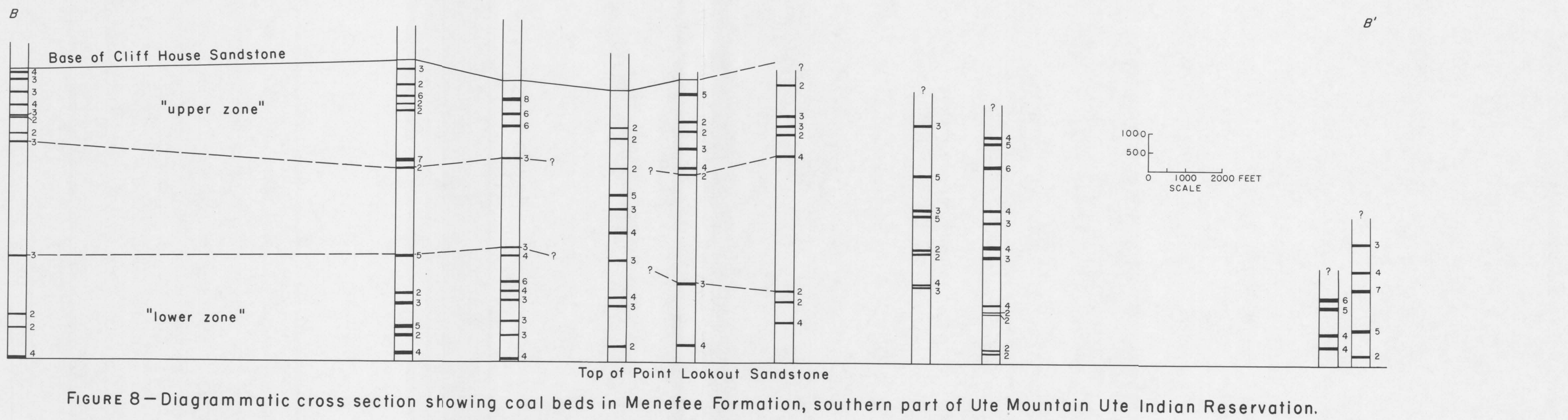


FIGURE 8—Diagrammatic cross section showing coal beds in Menefee Formation, southern part of Ute Mountain Ute Indian Reservation.
(In Township 31 North, Ranges 14 and 15 West—Figure 7 above)

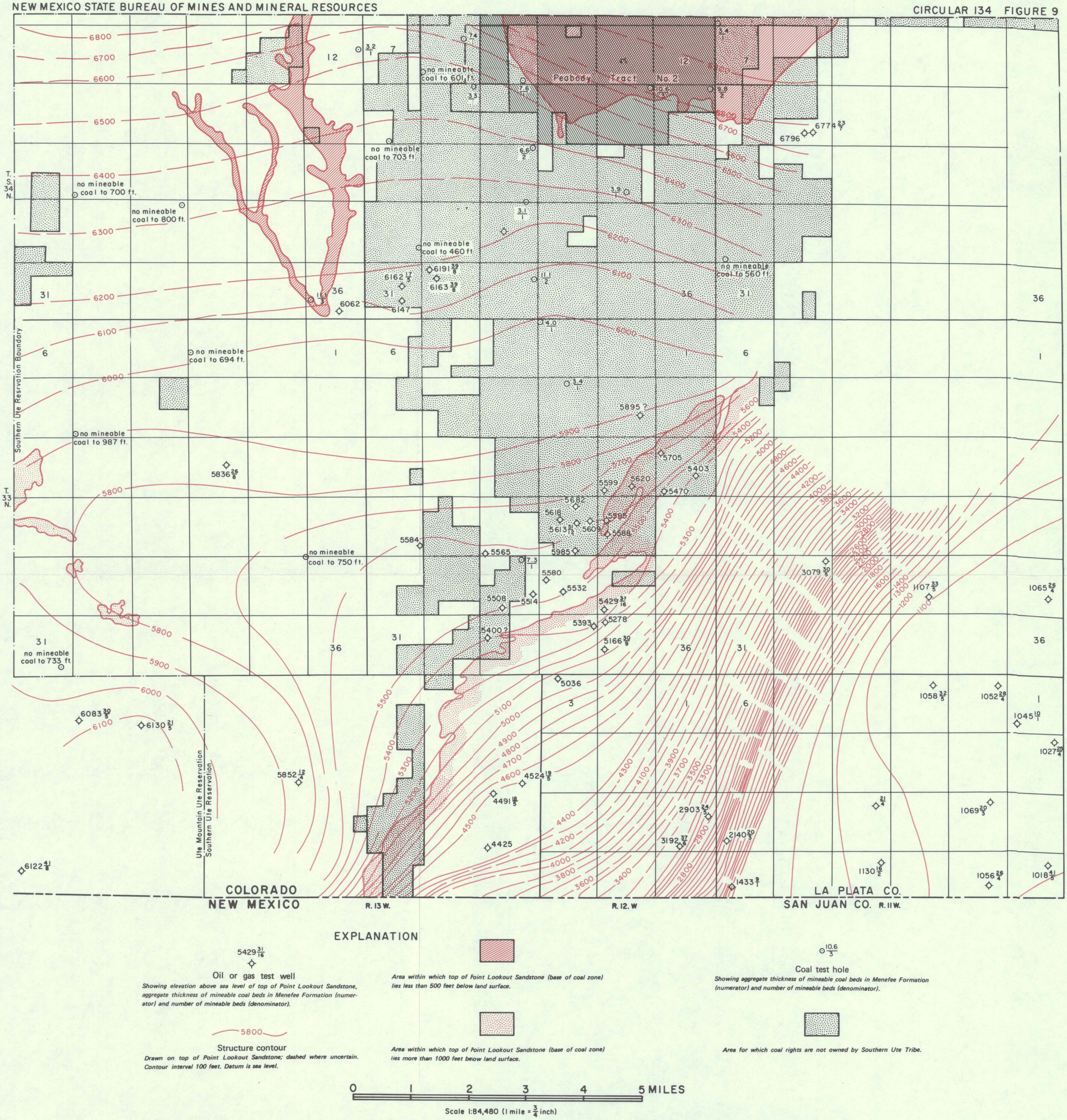
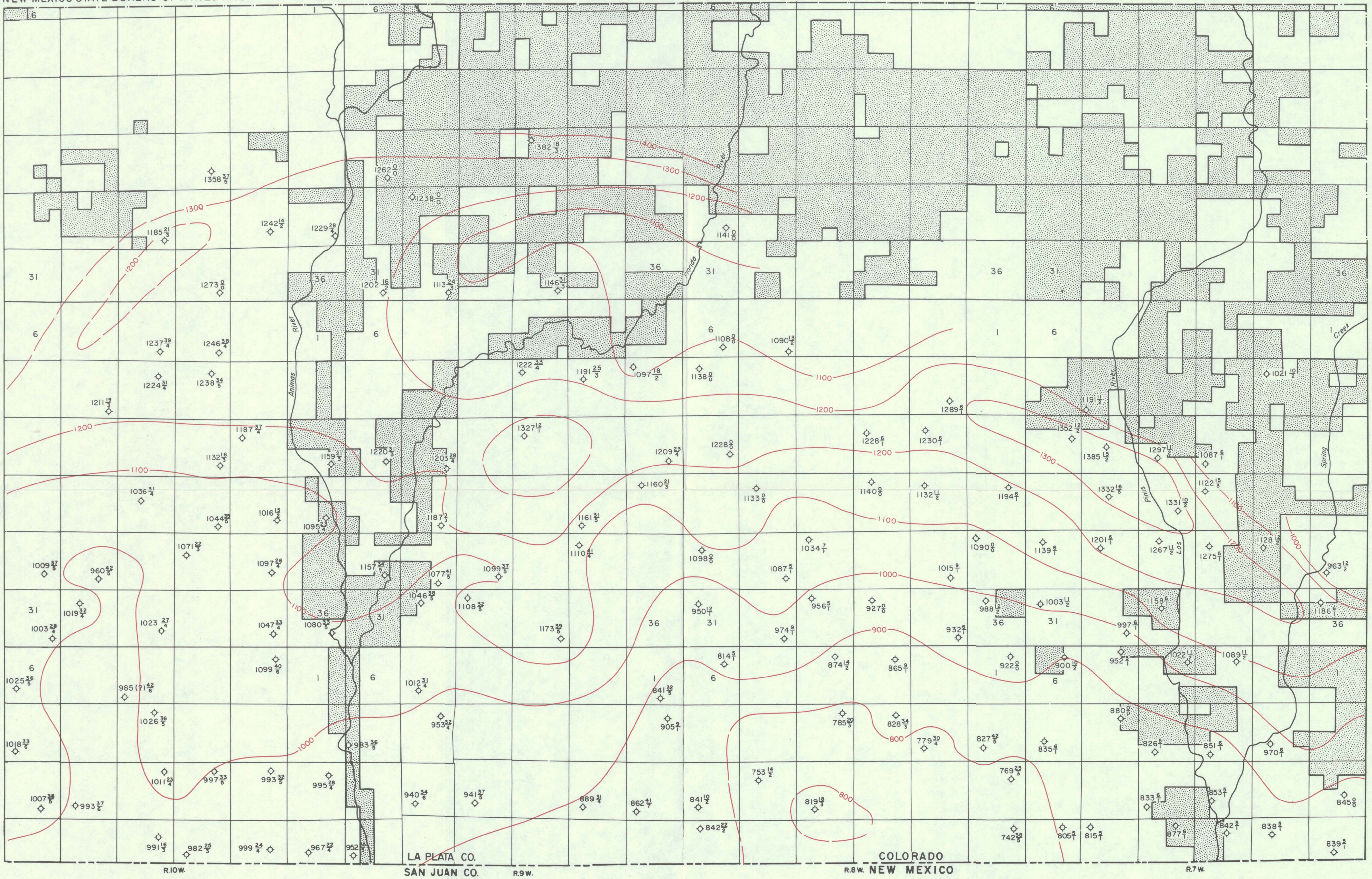


FIGURE 9—Distribution of coal in Menefee Formation, western part of Southern Ute Indian Reservation.



EXPLANATION

5429 $\frac{31}{16}$

Oil or gas test well

Showing elevation above sea level of top of Point Lookout Sandstone, aggregate thickness of mineable coal beds in Menefee Formation (numerator) and number of mineable beds (denominator).

Area for which coal rights are not owned by Southern Ute Tribe.

—1200—

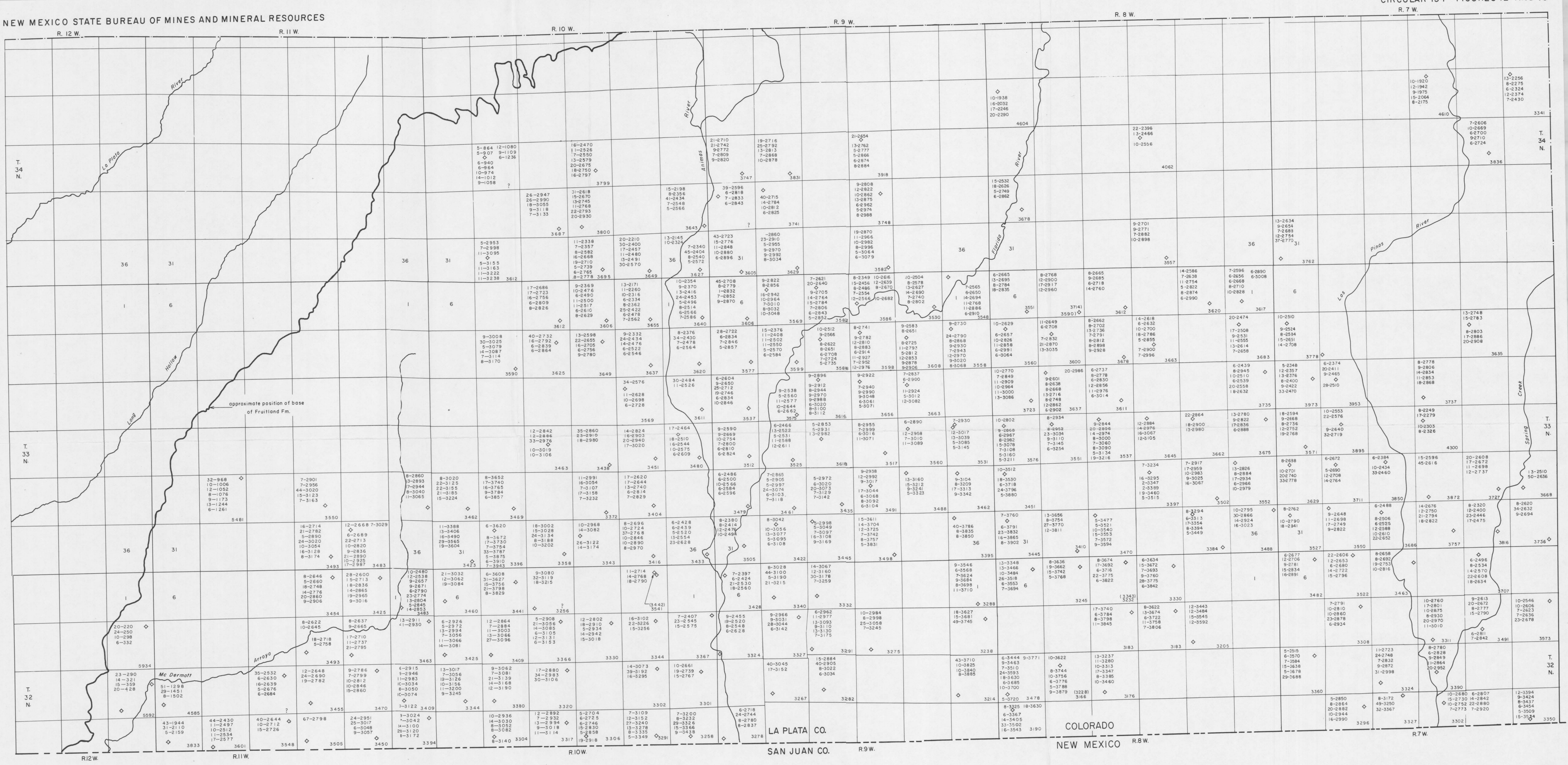
Structure contour

Drawn on top of Point Lookout Sandstone; dashed where uncertain. Contour interval 100 feet. Datum is sea level.

0 1 2 3 4 5 MILES

Scale 1:84,480 (1 mile = $\frac{3}{4}$ inch)

FIGURE 10—Distribution of coal in Menefee Formation, eastern part of Southern Ute Indian Reservation.



EXPLANATION

thickness and depths of coal beds more than 5 feet thick

20-2623
18-2664

location of well within section

3450

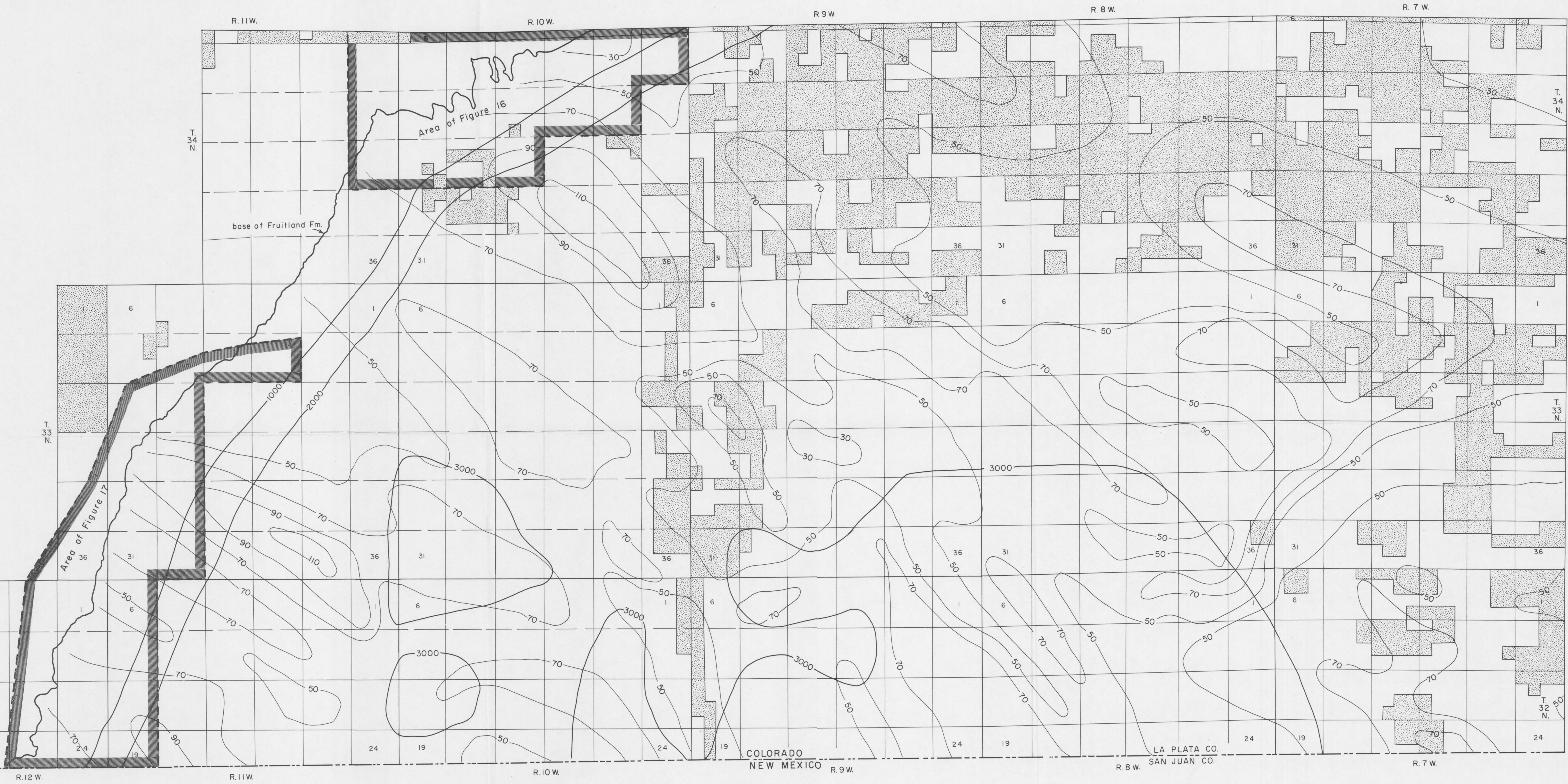
elevation of top of Pictured Cliffs Sandstone

Diagram of section containing oil or gas drill hole

FIGURE 12—Depths and thicknesses of coal beds of Fruitland Formation western part Southern Ute Indian Reservation.

0 1 2 3 4 5 MILES

Scale 1:84,480 (1 mile = 3/4 inch)



50 — Line showing aggregate thickness in feet of Fruitland Formation coal; beds less than 5 feet thick excluded

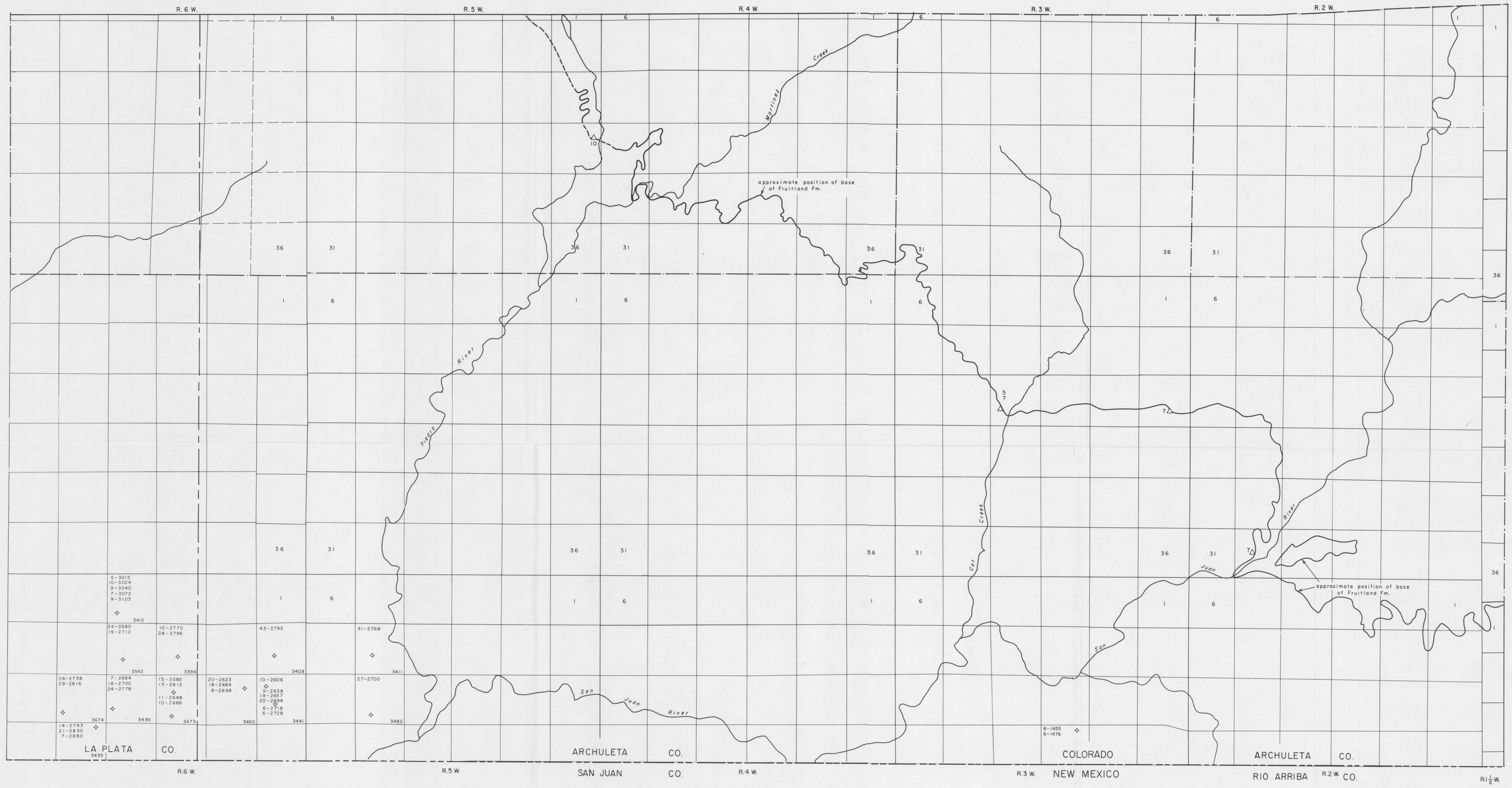
3000 — Line indicating depth in feet to top of uppermost Fruitland Formation coal bed

FIGURE 13—Aggregate thickness and ownership status of Fruitland Formation coal, western part of Southern Ute Indian Reservation.

0 1 2 3 4 5 MILES

Scale 1:84,480 (1 mile = 3/4 inch)

Area beneath which coal is not owned by Southern Ute Tribe



EXPLANATION

thickness and depths of coal beds more than 5 feet thick

20-2623
18-2664

location of well within section

3450 elevation of top of Pictured Cliffs Sandstone

Diagram of section containing oil or gas drill hole

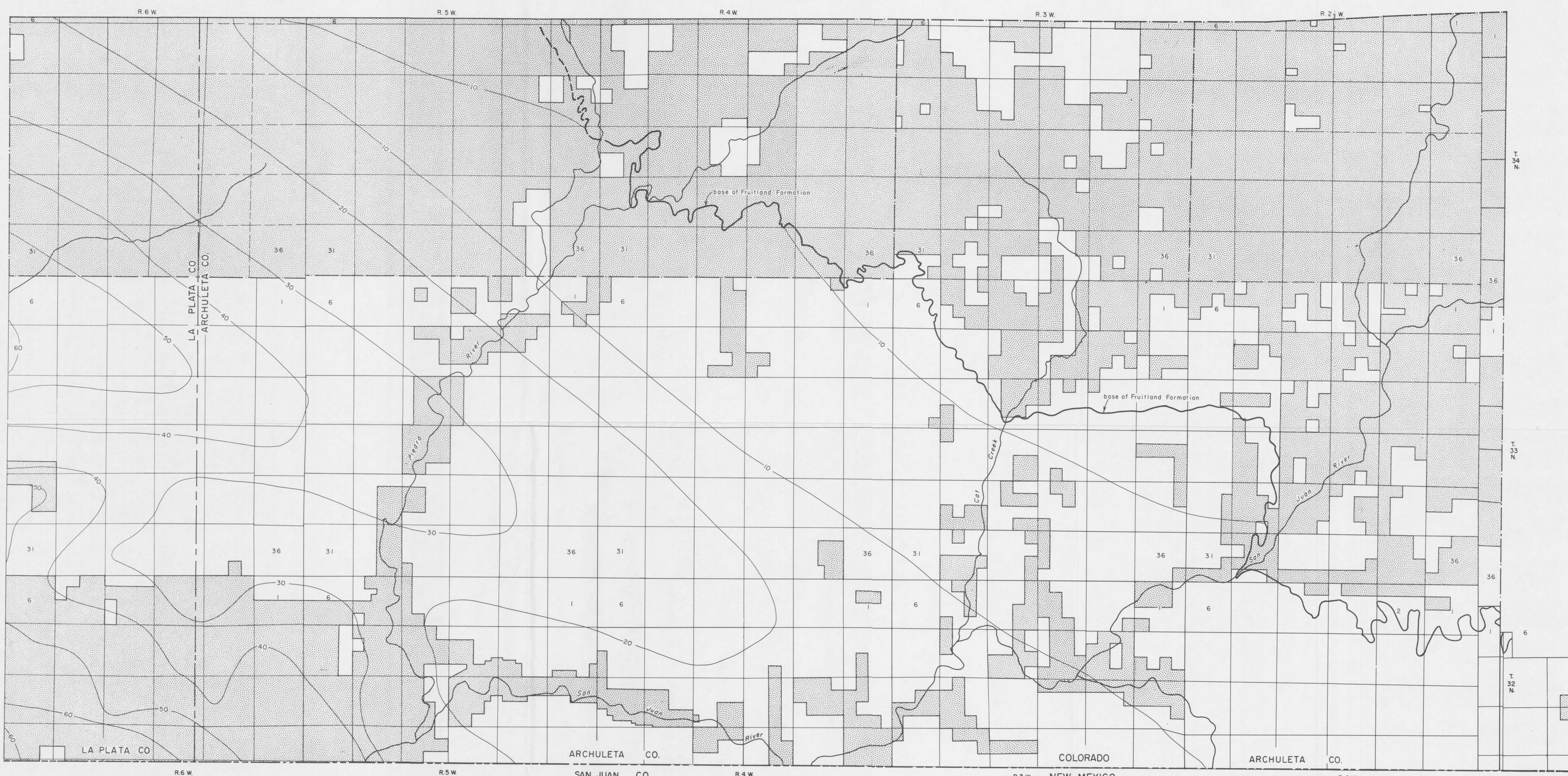
△10

Location of surface measurement, showing thicknesses of beds thicker than 5 feet

FIGURE 14—Depths and thicknesses of coal beds of Fruitland Formation eastern part of Southern Ute Indian Reservation.

0 1 2 3 4 5 MILES

Scale 1:84,480 (1 mile = ¾ inch)



EXPLANATION

—40—

Line showing aggregate thickness in feet of Fruitland Formation coal; beds less than 5 feet thick excluded

Area beneath which coal is not owned by Southern Ute Tribe

FIGURE 15—Aggregate thickness and ownership status of Fruitland Formation coal, eastern part of Southern Ute Indian Reservation.

0 1 2 3 4 5 MILES

Scale 1:84,480 (1 mile = ¾ inch)

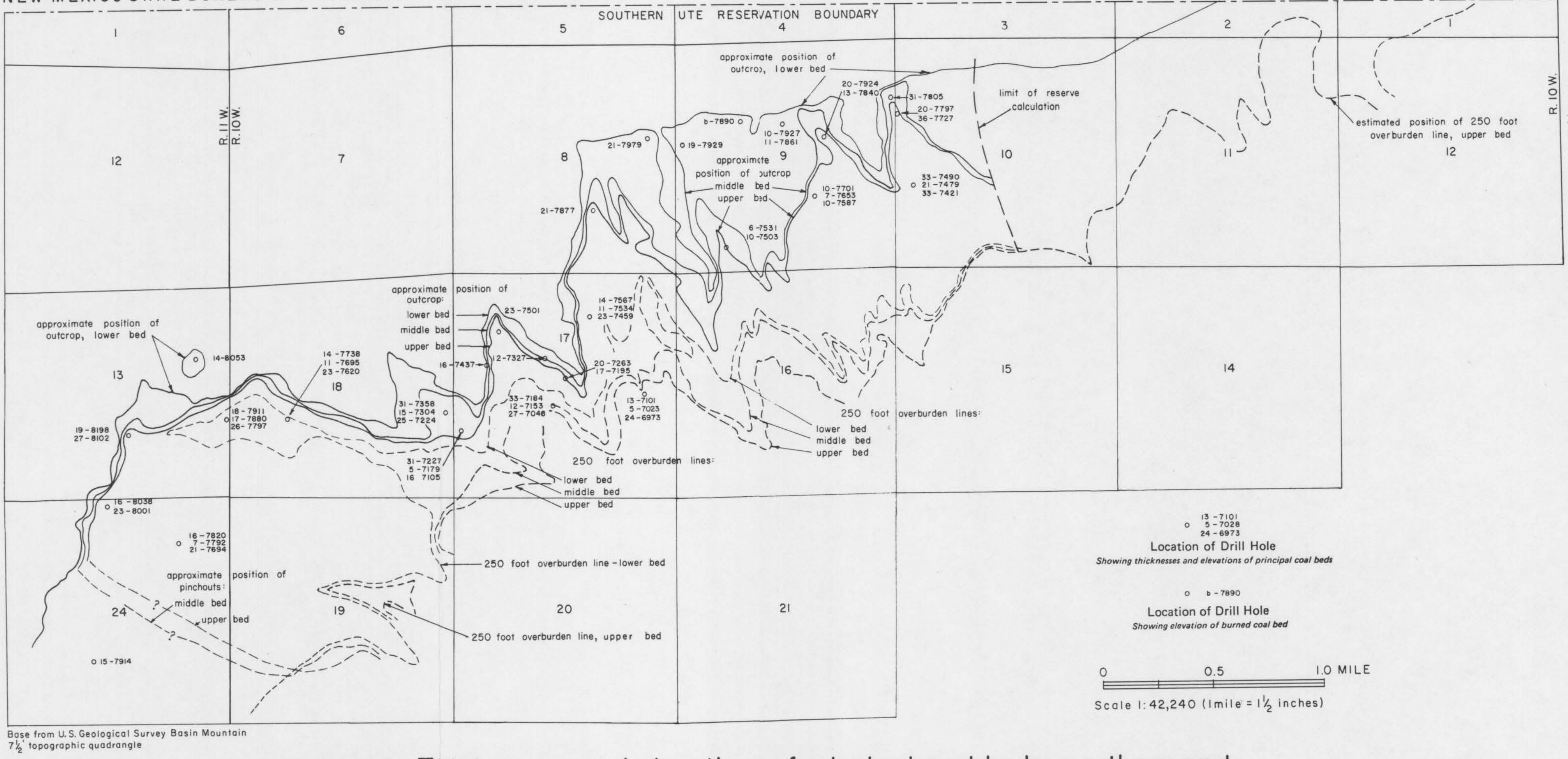


FIGURE 16—Thicknesses and elevations of principal coal beds, northern part of Peabody lease, tract 1, Southern Ute Indian Reservation.

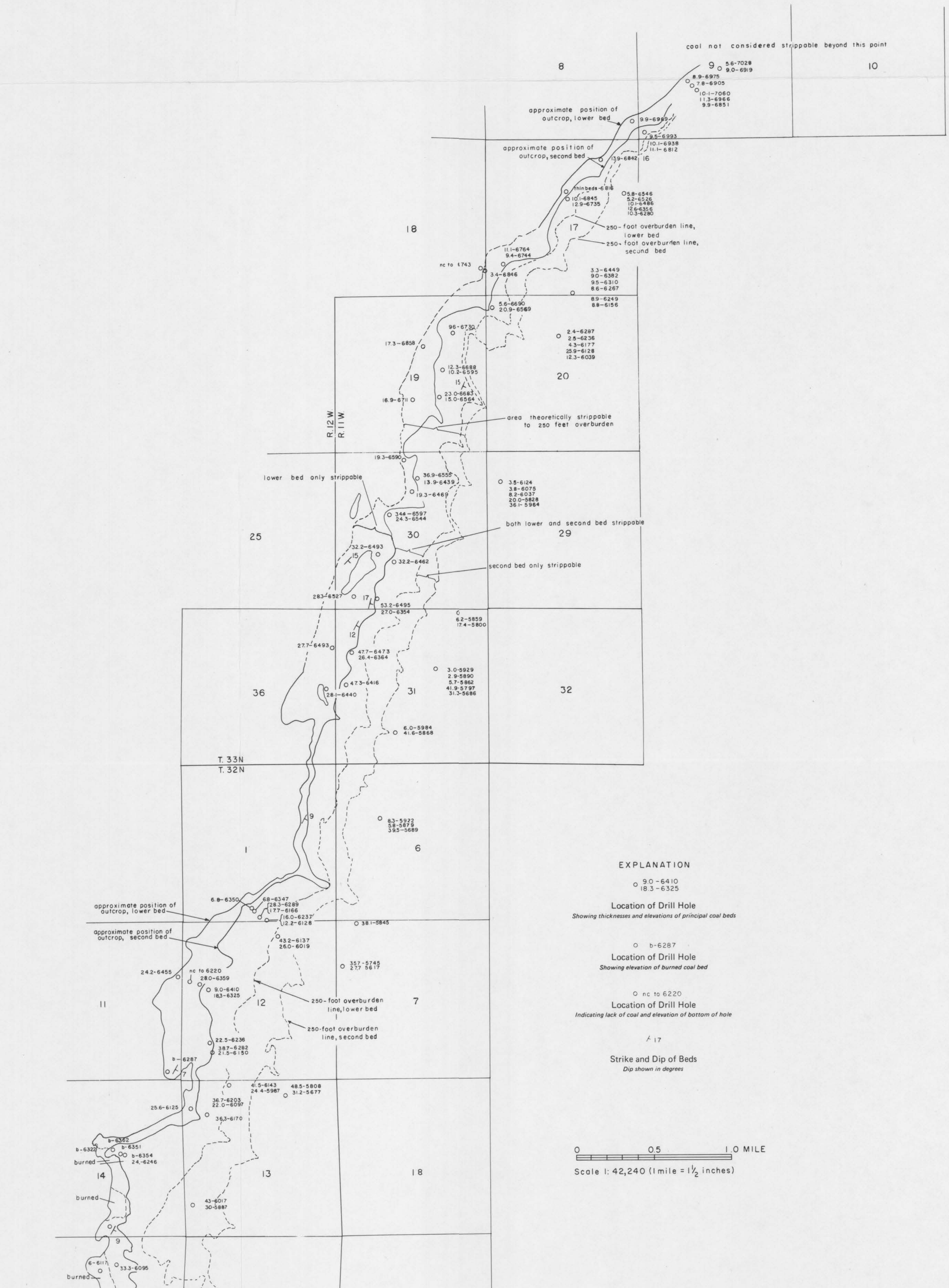


FIGURE 17—Thicknesses and elevations of principal coal beds, southern part of Peabody lease, tract 1, Southern Ute Indian Reservation.