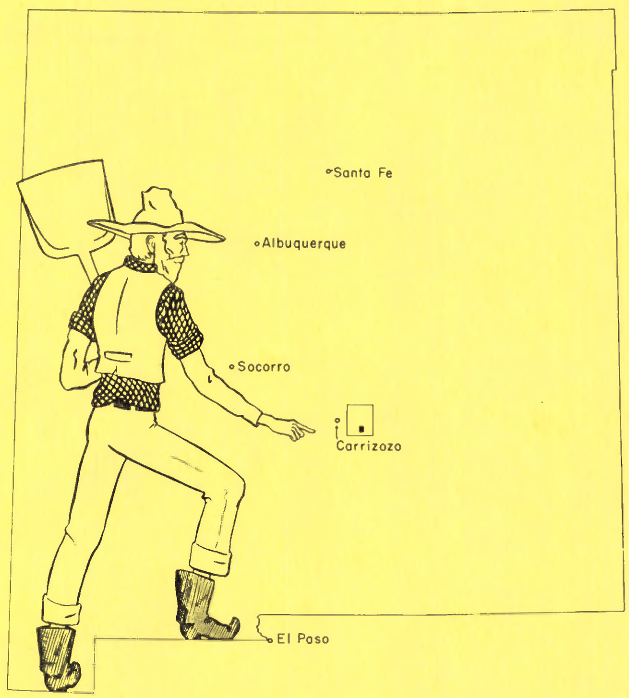
CIRCULAR 35

GEOLOGY OF CAPITAN COAL FIELD LINCOLN COUNTY, NEW MEXICO

by

Marc W. Bodine, Jr.



NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

E. J. Workman, President

STATE BUREAU OF MINES AND MINERAL RESOURCES

Eugene Callaghan, Director

Socorro
January 1956

Circular 35

GEOLOGY OF CAPITAN COAL FIELD
LINCOLN COUNTY, NEW MEXICO

By MARC W. BODINE, Jr.

1956

NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES NEW
MEXICO INSTITUTE OF MINING AND TECHNOLOGY
SOCORRO, NEW MEXICO

THE REGENTS

Members Ex Officio

The Honorable John F. Simms	Governor of New Mexico
Mrs. Georgia L. Lusk	Superintendent of Public Instruction

Appointed Members

Robert W. Botts	Albuquerque
Holm O. Bursum, Jr.	Socorro
Thomas M. Cramer	Carlsbad
John N. Mathews, Jr.	Socorro
Richard A. Matuszeski	Albuquerque

CONTENTS

ILLUSTRATIONS

ABSTRACT

The Capitan coal field, situated west of Capitan, Lincoln County, New Mexico, on the east flank of the Sierra Blanca syncline, contains coal within the Mesaverde group of Upper Cretaceous age. The intertonguing Mancos shale and Mesaverde group include three mappable units of the Mesaverde and are correlated tentatively with the Upper Cretaceous of northwestern New Mexico. Above the Mesaverde lie Cub Mountain terrestrial sediments believed to be of Tertiary or Upper Cretaceous age, possibly correlative with the Galisteo and Baca formations to the north and west or with the McRae formation to the southwest. Igneous dikes, sills, and flows are later than the sediments. The igneous activity is post-Cub Mountain and prefaulting. Three large normal faults, which trend northeast, and numerous small faults were found, but most of them could not be traced, because of a cover of later sediments. Mining at Capitan, once very active, has ceased, in part because of faulting, and in part by reason of the presence of many dikes, which increased mining costs beyond economic limits. One coal seam of minable quality and thickness has been mapped. It is improbable that the mines could be reopened and operated profitably under present conditions.

INTRODUCTION

The purpose of this project was to determine the structural and stratigraphic relationships of coal horizons in the Mesaverde group near Capitan, Lincoln County, New Mexico. In addition to the stratigraphic work, it was necessary to map an area of 16 square miles in the south-central portion of Capitan quadrangle (fig 2). The area consists of sections 4, 5, 6, 7, 8, 9, 16, 17, and 18 in T. 9 S., R. 14 E.; sections 31, 32, and 33 in T. 8 S., R. 14 E.; sections 1, 12, and 13 in T. 9 S., R. 13 E.; and section 36 in T. 8 5., R. 13 E. The last four of these sections, the most westerly, are within Lincoln National Forest.

The small town of Capitan, situated near the eastern edge of the area, can be reached by automobile or bus on U. S. Highway 380 from Socorro and Carrizozo to the west and Roswell to the east. State Highway 48, a well-graded dirt road, passes through Capitan from Ruidoso on the south to Encinoso on the north. Several primitive roads are present in the area, but for the most part are unmapped.

Air photographs (scale of 1:30,250) were used as a base for geologic mapping. It was hoped that the Mesaverde group could be mapped and described very thoroughly, but cover prevented the execution of the anticipated detail. The Capitan topographic quadrangle (1:62,500) indicates the location and general features of the area.

Previous Work

The area was investigated initially by Campbell in 1907, in a rapid reconnaissance of the coal resources. Wegemann (1914) contributed a fairly detailed study of the Sierra Blanca coal field; however, his measured sections and faunal collections were made near White Oaks, New Mexico, some 20 miles to the north of Capitan. Allen and Jones (1951) mapped in detail the eastern part of Capitan quadrangle in the summer of 1950 and 1951. Petrographic contributions on the alteration of the sediments by dikes were made by Sidwell (1946).

Acknowledgments

The writer wishes to extend his sincere thanks to Dr. Eugene Callaghan, Director of the New Mexico Bureau of Mines and Mineral Resources, who aided and sponsored the work in the Capitan area, and to the personnel of the Bureau for their kind help and the use of their facilities. Dr. John Eliot Allen, for the New Mexico Bureau of Mines and Mineral Resources, has read and criticized the manuscript carefully. The writer also wishes to express his gratitude to Dr. Charles H. Behre, Jr., of Columbia University, for his guidance and help in connection with this problem. William Tonking, graduate student at Princeton University, helped with references and spent a day in the field with the writer.

Geography

The maximum relief in the area is about 1,000 feet, but averages less than 400 feet. In the eastern part, the competent sandstone beds of the Mesaverde group and the dikes make the ridges. Both the sandstones and the dikes have a general trend of N. 15° E., which gives the ridges a parallel trend. In the western part, however, the sediments are covered by a mass of volcanic rock, which underlies the high areas as well as the highest point of 7,361 feet. The lowest altitude, 6,340 feet above sea level, is in the Mancos shale, where Magado Creek flows eastward out of the area.

The area is drained chiefly by Salado, Magado, and Oso Creeks, which flow into the Rio Bonito to the east. Magado and Oso Creeks flow constantly; Salado Creek and the tributaries are intermittent.

Vegetation in the valleys between the low ridges and hills consists almost entirely of range grasses. The hills and ridges, on the other hand, generally are covered with dense junipers, piiion, and scrub oak. Cactus, particularly of the staghorn (cholla) variety, is everywhere abundant. The land is used almost exclusively for grazing.

The population of Capitan in the 1950 census was 575.

STRATIGRAPHY

Sedimentary rocks ranging from upper Mancos through Mesaverde are overlain by a series of coarse Tertiary clastics, tentatively correlated with the Baca formation. These are partly covered by Quaternary terrace gravels and recent alluvium.

Upper Cretaceous

The Upper Cretaceous sediments in New Mexico, particularly the Mesaverde group and Mancos shale, commonly show extensive intertonguing due to the repeated withdrawals and transgressions of the Upper Cretaceous seas (Pike, 1947). Beginning in early Benton time and ending well up in Montanan time, these retreating and advancing seas left a series of intertonguing marine shales, beach sandstones, and carbonaceous continental sediments. Attempt will be made to show the correlation of the Upper Cretaceous sediments of the Capitan area with the regional picture set up by Pike (1947).

Mancos Shale

The Mancos shale, named by Cross (1899) near Mancos, Colorado, now includes all of the lower Upper Cretaceous shales of the southwestern United States, and may include rocks as late as middle Montanan age.

Only the upper part of the Mancos shale of the Capitan Valley is exposed within the mapped area. It consists of a gray to black, fissile shale interbedded with thin strata of a gray, dense limestone. Nearing the upper contact with the sands of the Mesaverde, thin beds of buff, quartzose sandstone become intercalated with the shales.

The Mancos shale is a valley-forming unit or is found on the lower slopes of cuestas that are capped with basal Mesaverde. Measuring and describing the Mancos shale is virtually impossible within the area, inasmuch as it is covered everywhere with a veneer of soil or alluvium, except for small exposures in stream beds and at the contact with the Mesaverde. No section was measured, since only the upper part is present in the area. To the east, however, Allen and Jones (1951) measured 389 feet of Mancos shale, whereas Wegemann (1941) measured some 500 feet of "shale, dark gray and bluish. . . " at White Oaks to the north.

One mile to the east of the area, Mancos shale lies conformably on 134 feet of Dakota (?) sandstone (Allen and Jones, 1951). Because of the abnormal thickness of the Dakota (?) sandstone here, Pike (1947) believes that the upper part of the Dakota (?) sandstone is correlative with the Tres Hermanos sandstone member of Graneros age. Fossils collected from the upper Mancos are unidentifiable. Age relations of the lower sandstone member of the Mesaverde group indicate, however, that the Mancos shale cannot be younger here than mid-Carlile. Thus, the Mancos shale was deposited here from Graneros to mid-Carlile time.

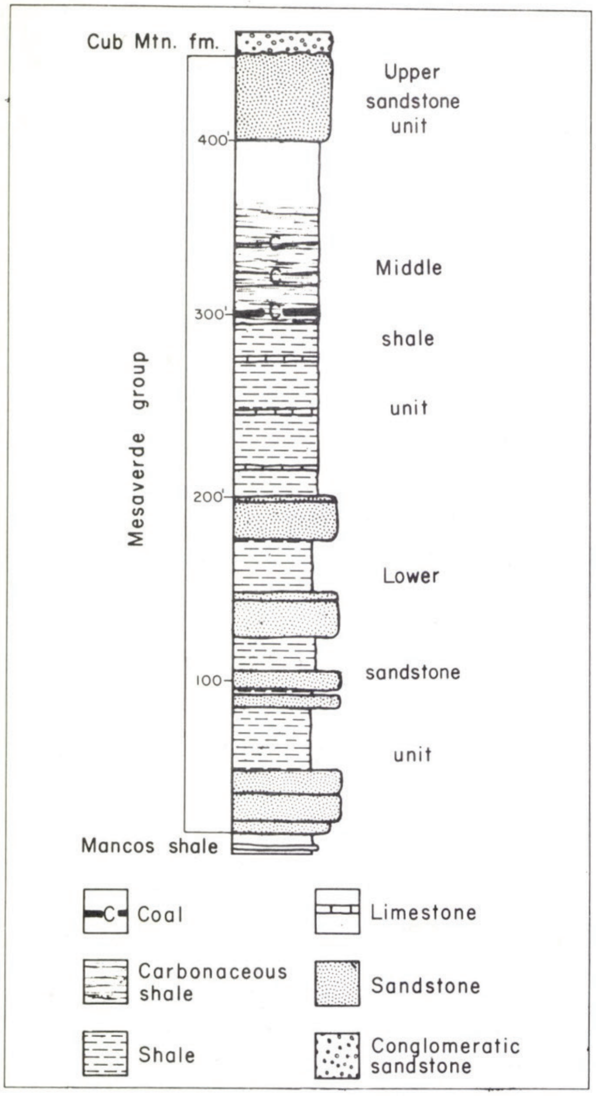
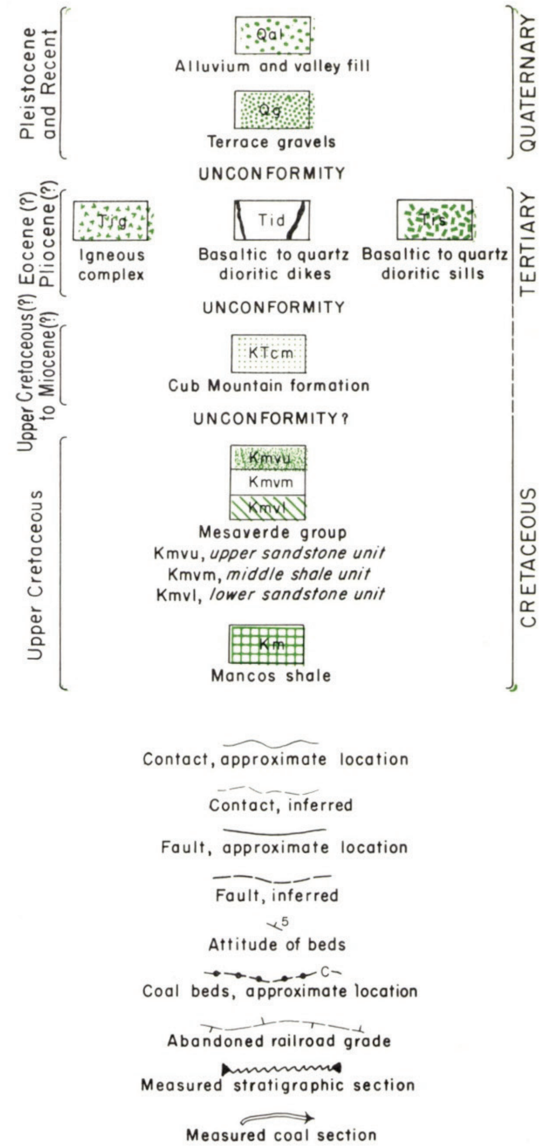


FIGURE 1 Stratigraphic column of the Mesaverde group, Capitan Coal field, New Mexico

EXPLANATION FOR FIGURE 2



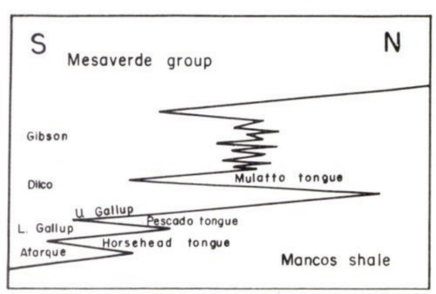
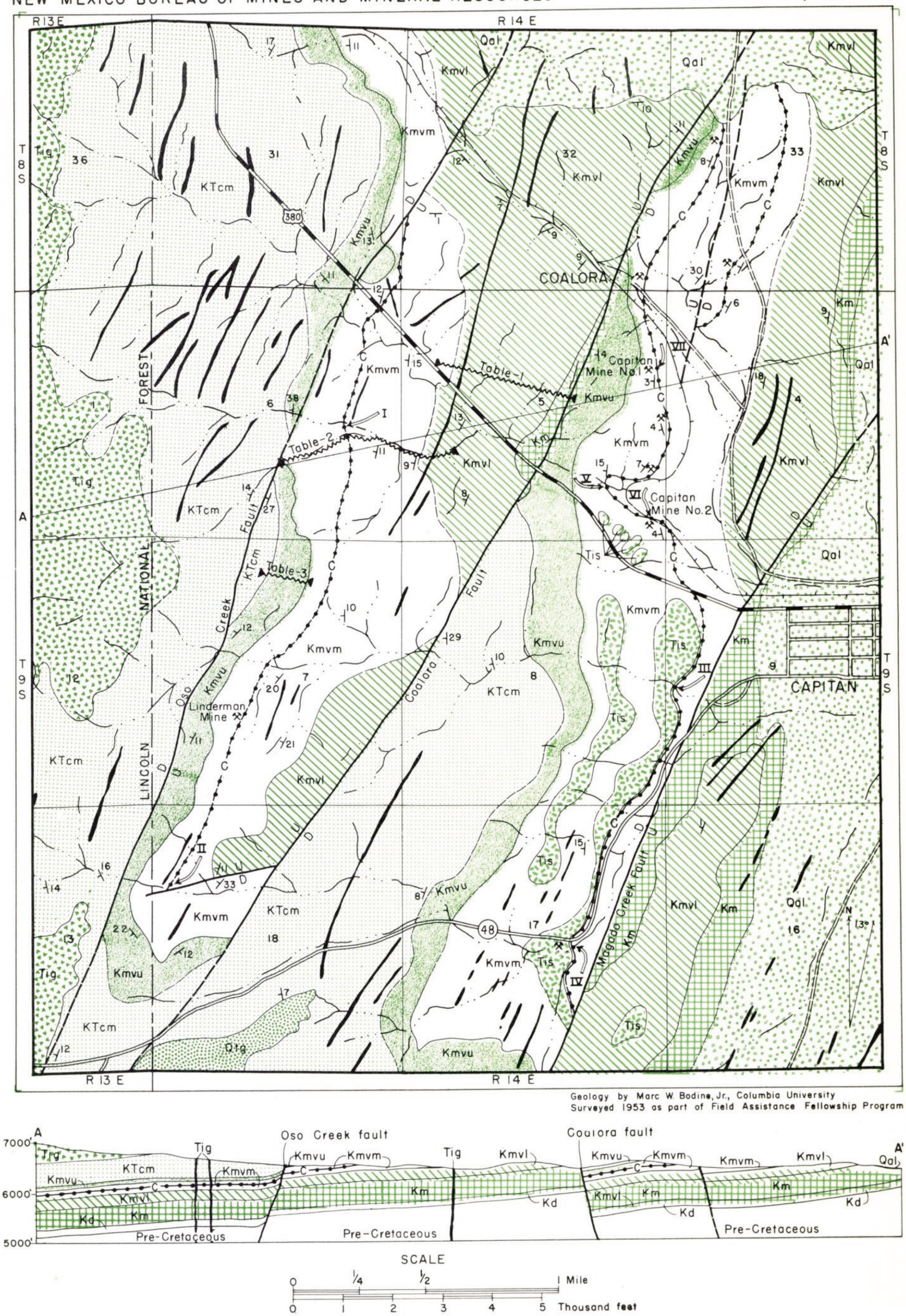


FIGURE 3 Intertonguing relationships between the Mancos shale and Mesaverde group in New Mexico (after Pike, 1947)



Geologic Map and Section of Capitan Coal Field

Mesaverde Group

The term Mesaverde group is applied loosely to the coal-bearing sandstones and shales of the middle Upper Cretaceous. Named from exposures on Mesa Verde, Colorado (Holmes, 1877), it has been considered a group name to the north; in New Mexico also, it has attained this status recently (Allen and Balk, 1954).

In the Capitan area, the Mesaverde group can be divided into three distinct mappable units. These do not follow the nomenclature of Pike (1947) and others, because (1) they cannot be mapped as such, by reason of the amount of cover present, and (2) the correlations are not sufficiently accurate to warrant carrying down the names used to the northwest.

The lower sandstone unit of the Mesaverde group. This crops out as a series of cuestas, each capped by a massive, well-indurated sandstone. The best exposure of the unit is north of U. S. Highway 380, about 1-1/2 miles northwest of Capitan, and west of the Coalora fault.

The base of the lower sandstone consists of a clean, well-rounded, massive, white quartzose sandstone about 13 feet thick, underlain by 3 feet of buff sandstone lying conformably on the shale and sandstone interbeds of the Mancos shale. Above the massive sandstone lies a series of four sandstones, each about 20 feet thick, separated by beds of fissile shale and siltstone of equal thickness (see table 1).

From the information obtained at Carthage (Gardner, 1910) and White Oaks (Wegemann, 1914), Pike (1947) believes this unit to be correlative with the lower Gallup sandstone of the Mesaverde group. In the Capitan area, fossils were collected from the various oyster beds of the lower sandstone member, with Ostrea sp. and Inoceramus sp. being the only identifiable organisms. They may be mid-Carlile in age.

The middle shale unit of the Mesaverde group. Above the uppermost massive sandstone lies a series of marine and terrestrial shales, which for mapping purposes have been combined to form the middle shale unit. It was hoped that it would be possible to separate the lower marine shale from the upper coal-bearing shale, but this was impossible because of the extensive cover of alluvium.

The best section observed was measured along the beds of a south branch of Oso Creek in the E 1/2 sec. 6, T. 9 S., R. 14 E. Approximate thickness of the unit is 275 feet. The basal 95 feet is predominantly a dark-gray, fissile marine shale, with interbeds of thin limestone, whereas the upper 180 feet includes carbonaceous shales, coal, and thin beds of silty, poorly sorted sandstone (see table 2).

Within the upper carbonaceous sequence, there is little evidence for any true cyclothemic deposition. The coal almost always is underlain by a carbonaceous shale, but the lithology of the overlying bed is extremely variable. It may be a clean sandstone, a poorly sorted sandstone containing wood fragments, or another carbonaceous shale. Local disconformities, some of them angular to the extent of 10 degrees, also were observed. The variability of coal thickness, the local disconformities within the unit, and the variable sequence of the beds associated with the coals seem to indicate an irregular surface of deposition.

Several fossil horizons are present within the marine part of the section. The lowest, some 10 feet above the contact with the lower sandstone unit, contains abundant large gastropods, Volutaderma sp., Cardium pauperculum, and Baculites gracilis ?, indicating a Coloradan fauna. About 10 feet above the Baculites zone is a bed containing Inoceramus sagensis.

In the upper carbonaceous sequence, only small unidentifiable fragments of fossil wood were found near the coal beds. Fossil plant remains found in the coal unit were identified by Campbell (1907) as Laramie in age; Wegemann (1914), however, reclassified these as post-Laramie, similar to those of the Denver formation. Pike, on the other hand, is convinced that the Mesaverde group is no younger than Montanan.

The faunas from the lower marine beds are similar to those collected by Wegemann (1914) from White Oaks and appear correlative with Pike's (1947) faunas of the Pescado tongue of the Mancos shale, giving these beds a late Carlile age. The terrestrial sequence above would be equivalent, then, to the Dilco-Gibson or Crevasse Canyon formation of the Mesaverde group, disregarding Wegemann's post-Laramie plant remains.

If the lower shale sequence is correlative with the Pescado tongue of the Mancos shale, and the upper shale sequence is correlative with the Dilco-Gibson (Crevasse Canyon formation of Allen and Balk, 1954) of the Mesaverde group, the upper Gallup sandstone of the Mesaverde group is missing at Capitan. At White Oaks, to the north, Wegemann (1914) described a 15-foot sandstone, which Pike (1947) correlates with the upper Gallup sandstone; below this sandstone, however, there is a thin coal seam with associated carbonaceous sediments overlying the typical marine shales. At Carthage, New Mexico, to the west (Gardner , 1910), a similar sandstone some 20 feet thick is correlated by Pike as upper Gallup sandstone.

At Capitan, there is no sandstone of any consequence between the coal-bearing beds and the marine shales.

The upper sandstone unit of the Mesaverde group. The uppermost mappable unit of the Mesaverde group at Capitan is a thick, massive, buff to white, quartzose sandstone. Like the lower sandstone, it crops out as a ridge-former, giving good, but usually discontinuous, exposures. In places, the unit contains some thin interbeds of fissile shale, but for the most part the sandstone is massive, with some crossbedding toward the top. The unit is extremely variable in thickness. In the southwestern part of the area, it reaches a thickness of 60 feet, whereas to the northeast it is only 30 feet thick.

No estimation of age is possible, since no fossils were found. It is included with the Mesaverde only because of its lithic similarity to the sandstones of the lower member. It is not impossible that this sandstone should be included with the Cub Mountain formation of Upper Cretaceous or Tertiary age.

The history of the Upper Cretaceous of the Capitan coal field may be summarized as follows:

1. Transgression of the early Benton seas accompanied by the deposition of the main Mancos shale body.

2. Retreat of the Benton seas (northwestward, according to Pike, 1947) and deposition of the lower sandstone member of the Mesaverde (lower Gallup sandstone ?) during early Carl ile time.

3. Advancement of the mid-Carl ile sea and deposition of the lower marine rocks of the middle shale member of the Mesaverde group (Pescado tongue of the Mancos ?).

4. Retreat or stillstand of the mid-Carlile sea and deposition of the coal-bearing rocks, with the development of coal basins near shore.

Tertiary (?)

Cub Mountain Formation

A series of rocks of Tertiary or Upper Cretaceous age lies with apparent conformity on the Mesaverde group. The Cub Mountain formation is named for the isolated peak located 7 miles due south of Carrizozo and 18 miles due west of Capitan. The formation is well exposed in the southwest flank of the mountain; a section showing both top and bottom has been measured by Robert H. Weber* in Sanders Creek, southeast of the mountain. It is similar in lithology and stratigraphic position to the Baca formation of western Soc.orro County (Winchester, 1920) and the Carthage district (Wilpolt and Wanek, 1952), but may be correlative with the McRae formation (Bushnell, 1953) at Elephant Butte reservoir.

In no place within or near the area is a complete section of the unit discernable. To the east, the upper part has been faulted out; to the west, the lower part has been downfaulted, and the uppermost part is hidden by igneous material. From I ithologic evidence, however, it is assumed that the two sections should be grouped together as a unit.

To the east, where the section can be studied more carefully, it consists of beds of pale yellow to gray, coarse-grained, quartzose sandstones, with lenses of quartzite and chert-pebble conglomerate. The sandstone, except for the increase in grain size and angularity, is very similar to the underlying upper sandstone unit of the Mesaverde group. As stated above, there appears to be no disconformity between the two units, although regionally there undoubtedly was some erosion of the Mesaverde group before the deposition of the Cub Mountain sediments. This is borne out by the very great thickness of coal-bearing rocks at White Oaks (Wegemann, 1941). There, some 630 feet of sediments was deposited on the marine shale (Pescado tongue of Mancos ?); this is approximately 300 feet more than the amount deposited at Capitan. The upper sandstone unit of the Mesaverde group at Capitan might be equivalent possibly to a 26-foot white sandstone in the middle of the White Oaks section. If this is true, approximately 300 feet of the coal-bearing Mesaverde group was eroded from the Capitan area before the deposition of the Cub Mountain formation.

Above the conglomerates lies a series of poorly indurated sandstones, siltstones, and variegated shales. Color is not at all reliable, as it changes drastically, both vertically and horizontally.

In the western exposures, undoubtedly higher in the section, coarse clastics give way to a preponderance of variegated shales, which assume a more consistent red to red-brown color, with only thin beds of green, purple, and gray shales.

A striking feature of the Cub Mountain formation is the similarity of the conglomeratic phase to the Santa Rosa (?) formation of Triassic age, which is exposed 5 miles to the east. A further coincidence is that above the Santa Rosa (?) lies the Chinle formation, which is very similar to the red shales of the upper Cub Mountain formation. It is not possible, however, that the Cub Mountain formation is of the same stratigraphic position as the Santa Rosa (?) and Chinle formations, for the following reasons:

1. The conglomerate of the Cub Mountain formation is never over 6 feet in thickness and is extremely lenticular. It is made up mostly of quartzite pebbles, with relatively few chert pebbles. The Santa Rosa (?) conglomerate, on the other hand, is thicker (possibly 20 feet or more) and continuous, with the majority of the pebbles consisting of chert.

2. Above the conglomeratic phase of the Cub Mountain formation are many yellow, buff, gray, and white sandstones, siltstones, and shales that are not present above the Santa Rosa.

3. The red shales of the Cub Mountain formation are a darker red and are more fissile than the shales of the Chinle formation.

4. Structurally, it would be virtually impossible to emplace Triassic beds in the position of the Cub Mountain formation. This would have involved considerable thrusting, which is nowhere in evidence.

Regardless of the similarity between the two units, it does not seem feasible, either I ithological ly or structurally, to consider the Cub Mountain formation as an outlier of the Santa Rosa (?) and Chinle formations.

Measuring the Cub Mountain formation proved to be impossible, either in its entirety or in parts, because of its faulted nature and partial cover, which might obscure many additional small faults. However, its thickness must be at least 500 feet.

Apparently, the Cub Mountain formation is another Tertiary intermountain deposit, similar to the Baca formation of Socorro County, the Galisteo formation of north-central New Mexico, and, possibly, the McRae formation of south-central New Mexico. Conglomerates, variegated shales, and poorly indurated and poorly sorted sandstones and silt-stones are typical of these formations.

The sequence above the conglomerate contains many beds which are similar to the underlying Mesaverde group; that is, buff sandstones and gray to yellow siltstones and shales. Where exposures are poor, correlation can be a serious problem; Stearns (1943), however, after working with the Galisteo formation, noted the following criteria:

1. Conglomerates are present in the Galisteo formation, but not in the underlying Mesaverde group.

2. Fine-grained material is often variegated in the Galisteo formation, whereas the shale of the Mesaverde group is generally gray in color.

3. Silicified wood is present in the Galisteo formation and absent in the Mesaverde group.

4. Locally, high-colored sandstones are present in the Galisteo formation, but the sandstones of the Mesaverde group are characteristically buff, yellow, or white.

All these criteria, with the exception of the third (no silicified wood in the Cub Mountain formation), hold true, and make distinction possible.

Source areas suggested by Stearns (1943) are also in keeping with the lithology of the Cub Mountain formation. The quartz is derived presumably from the Mesaverde and older quartz rocks. The quartzite and chert pebbles probably are derived from the Triassic or Permian conglomerates. However, because of the limited material available, some must have been obtained even farther down the stratigraphic column; that is, the chert may have come from the Magdalena limestones (Pennsylvanian).

In the Galisteo area, a distinct unconformity between the Mesaverde and Galisteo is observed (Stearns, 1943), with evidence of channeling and gradual cutting out of the Mesaverde beds, so that, in places, the Galisteo sediments lie directly on Mancos shale.

North of Magdalena, where the Baca is exposed on both flanks of the Bear Mountains, the unconformity is again in evidence. Actual angularity can be measured between the two units; also, as above, there is distinct truncation of the Mesaverde beds.

Although crosscutting of the Mesaverde was not in evidence within the area, undoubtedly it did occur to some extent, and a definite hiatus and probable erosion of the Mesaverde before the deposition of the Baca (?) formation are inferred.

Age relations of the Cub Mountain formation are unknown. Stearns (1943) dates the Galisteo as Eocene, which would be acceptable for the age of the Cub Mountain; however, it would not be surprising if the Cub Mountain were as old as latest Cretaceous or as young as Miocene.

Quaternary

Terrace Gravels

Unconsolidated gravels crop out in only one area, in the 51/2 sec. 18, south of the Linderman mine, where they lie unconformably on the Cub Mountain formation and form a flat-topped ridge at 6,725-6,775 ft elevation. They are made up chiefly of angular to rounded pebbles of igneous rock, with lesser numbers of sandstone pebbles. They are probably a remnant of an ancient river terrace or a pediment.

Alluvium and Valley Fill

Very recent sediments appear in every stream valley; they are mapped only where they reach a thickness of 15 ft or more and cover all the bedrock. They are made up almost entirely of mud and fine silts, but contain some lenses of boulder-size material, composed of many of the various rocks that are present in the vicinity.

IGNEOUS ROCKS

Tertiary

Dikes

Numerous dikes are exposed within the area, usually forming long slender ridges, which generally parallel the ridges of sedimentary rock. In general, the dikes are of dioritic composition (Sidwell, 1946) and of fine- to medium-grained texture. A few are basaltic; others are quartz dioritic, with phenocrysts of quartz. In the area, they range in thickness from 4 to 50 ft, with a linear extent up to 2 miles.

Intruded rocks commonly show a color change and increased induration near the contacts with the dikes. Gray shales are darkened. Within the Cub Mountain formation, red has commonly changed to purple and green. In the sandstones, there was a slight amount of silicification. Both effects are very local, never extending for more than 10 or 15 ft from the dike. Local effects on the coal were not observed. Sidwell (1946) believes that the high rank (bituminous) of the coal should be attributed to the intrusions. He also noted in the laboratory that garnet, magnetite, olivine, epidote, mica, and andalusite were apparently introduced into the altered sediments.

The age of these dikes is probably Tertiary, as they are post-Cub Mountain and later than most of the flows to the west; they are earlier, however, than the terrace gravels.

Sills

The sills have, in general, the same composition as the dikes. Presumably, they are of the same age as the dikes and were associated with their intrusion. One sill, the easternmost, lies a few feet above a coal bed, with no megascopic effects on the coal whatsoever. The east sill varies in thickness within a range of 10-40 ft; the west sill is extremely variable, averaging 50-80 ft in thickness.

Igneous Complex

An undifferentiated series of flows, tuffs, agglomerates, and scoria lies unconformably on the Cub Mountain formation in the western part of the area. No attempt at differentiation was made; in general, however, a series of andesitic flows rests on a thick series of acid to intermediate tuffs and agglomerates, which truncate the Cub Mountain formation.

At the base, dikes are prevalent; they are absent, however, higher in the series. It is certain that the dikes were emplaced after much of the extrusive material was laid down. The dikes penetrate all the igneous material, except the upper volcanics in the extreme western part of the area.

STRUCTURE

The Capitan coal field and the coal areas of White Oaks, Tucson Mountain, and Ruidoso have been described by Wegemann (1914) as lying on the east flank of a large synclinorium, with Tertiary sedimentary and igneous rocks making up the core of the structure.

In general, there is a westward dip of from 5 to 15 degrees throughout the Capitan coal field; the Cretaceous sediments disappear under the Tertiary rocks to the west.

Except for minor flexures due to faulting, the only folding of prominence is found in the northeastern corner of the area. Here, very gentle and broad folds with east-west axes are present. The southernmost of the anticlines is seen in the area of the Capitan No. 2 mine, where a westward-plunging anticline causes a reentrant in the outcrop line of the producing coal. To the north, this folding becomes more noticeable, so that the lower sandstone immediately west of the Coalora fault is striking eastwest and dipping to the south. North of the area, these folds become even more prominent (Allen and Jones, 1951).

Faulting within the Capitan coal field is prevalent and was a major cause for abandonment of the coal operations.

Three major faults dominate the structural picture. Each of these trends approximately N. 20° E. and has displacements of several hundred feet. Because of their importance as controls for coal production, the faults are given local names.

The eastern, or Magado Creek, fault brings the coal-bearing member of the Mesaverde on the west down against the upper Mancos to the southwest of Capitan, indicating a displacement of 300 ft or more. North of Capitan, the trend and magnitude of the fault is obscured by the soil mantle overlying the valley in Mancos shale; however, displacement presumably lessens to the north, and the fault dies out in the Mancos. To the south, on the other hand, the fault extends for a considerable distance. At the southern boundary of the area, the upper sandstone of the Mesaverde group is in juxtaposition with the lower sandstone, showing a displacement of 300 ft. Campbell (1907) believes that the fault extends at least 7 miles south to Bonito Creek, 2 miles east of Angus, and may be connected possibly with the fault on Carrizo Creek.

The central or Coalora fault parallels the Magado Creek fault - undoubtedly the primary reason for the abandonment of Capitan Nos. 1 and 2 mines. The upthrown side here is on the west, bringing up the lower sandstone of the Mesaverde against the upper sandstone unit or against the Cub Mountain formation, which indicates a displacement in the order of 300-400 ft. To the north, this fault is lost in the large alluviated valley in the northern portion of the area, whereas to the south, the fault appears to die out in the Tertiary sediments.

The western, or Oso Creek, fault parallels the other faults, but has considerably less displacement than either the Magado Creek or the Coalora faults. Maximum displacement of no more than 200 ft brings the middle Mesaverde on the east up against the Tertiary sediments on the west. To the north, the fault is lost in the large alluvial valley, and to the south, it appears to die out in the Tertiary, as is true of the Coalora fault.

Numerous small faults with displacements of from 5 to 10 feet are common within the area. Only two of these were mapped, since they are exposed only along creek beds and cannot be traced for any distance. Many of these small fault planes have been intruded by igneous material, causing the parallel dike-swarms within the area.

The date of the faulting must be post-Cub Mountain, as both major and minor faults have displaced this unit. The dikes in the eastern part show no evidence of being slicken-sided or brecciated by fault movement, but this is not true of the area to the west. It may be that faulting was associated with the extrusive activity in the western part of the area.

GEOLOGY AND HISTORY OF THE COAL

Within the middle shale unit of the Mesaverde group is one coal bed which is of sufficient thickness to have been mined profitably. This bed varies greatly in thickness from place to place. Exposures of coal are very poor, and were observed only in stream beds and at locations of the now abandoned mines. Several sections and a description of the lithologies above and below the coal are given in Table 3. In general, the seam averages about 20 inches in thickness.

The coal is of good bituminous rank, with cleating well developed, As stated above, the intrusions seem to have no visible megascopic effect on the coal. Sidwell (1946), on the other hand, maintains that the high rank of the coal is due to the intrusions, because
in nearby areas where intrusions are absent, the coal is not as high in rank.

In most places, the coal appears to be fairly clean, with no visible shale partings. Although no analyses have been made of the coal from the Capitan area, Wegemann (1914) reports two from the White Oaks district. Approximate analysis, after drying, gave the following results:

Moisture	1.6 %
Volatile matter	38.2 %
Fixed carbon	45.4 %
Ash	15.07%
	100.27%
Calories	6,875
British thermal units	12,380
Sulfur	0.8%

These results cannot be applied to the Capitan coal with any assurance, as the analysis is of coal from 20 miles to the north and probably not from the same bed. At Capitan, it was impossible to collect a sample for analysis, only surface coal being available. All the mines, with the exception of the Linderman mine, have collapsed or have been filled in. Furthermore, it was not possible to enter the Linderman mine without the aid of ladders, sufficient gas-detecting equipment, and additional men.

The coal would seem to be of good transportation quality, since the coal on the dumps, exposed for at least 30 years, is still solid, without any apparent slacking or crumbling.

Coal mining and prospecting have surrounded the synclinorium and were particularly active at Capitan, White Oaks, Oscuro, and Willow Hill. Other places, such as Ruidoso, Tucson Mountain, and Three Rivers, also were prospected. On the west side of the synclinorium, there has been little production, but on the east side, the Capitan and White Oaks production enabled Lincoln County, in 1901, to rank third among the counties of New Mexico in coal production.

Wegemann (1914) outlined the history of the coal-producing areas of Sierra Blanca. Corresponding activity at Capitan may be summarized as follows:

The exact date for the discovery of coal in the Capitan area is not known. About 1885, however, some coal from the locality of the Linderman and Gray mines was being used by the personnel of Fort Stanton.

In 1899, the New Mexico Fuel Company opened up several mines in and near Coalora, under the name of Akers and Ayers mines. In 1900, the Akers No. 1, later known as the Capitan No. 1, produced 41,260 tons of coal then valued at $82,520. In the same year, the Akers No. 4, later named the Capitan No. 2, produced 29,327 tons valued at $58,654, and the Ayers mines Nos. 2, 7, and 8, located on the east side of the small fault, produced 13,227 tons valued at $26,454. At that time, the two coal seams were believed to be different beds. The one on the west was named the Akers coal, the term Ayers coal being applied to the eastern seam. The mines were named accordingly.

Peak production was attained the following year, with the mining of 169,440 tons at a price of $2.00 per ton, at the mine. During the same year, the Linderman mine was opened about 3 miles west of Capitan (SW1/2 sec. 7, T. 9 S., R. 14 E.) at the site of the early mine operated by Fort Stanton personnel. However, after a 450-foot incline had been driven, it was realized that the multiplicity of faults, dikes, and the lenticular habit of the coal prevented production.

In 1902, Capitan No. 1, with an incline 1,200 ft long, and Capitan No. 2 having an incline some 1,500 ft in length, produced a total of 115,395 tons of coal. Capitan No. 7, produced another 4,116 tons. All the other mines were abandoned.

By 1905, production had decreased to 42,250 tons, with Capitan No. 2 closing on April 27 and Capitan No. 1 on June 3. For some time, however, coal continued to be mined in small amounts for local use. Aggregating less than 2,000 tons per year, such coal was taken principally from Capitan No. 1 mine.

The final activity came hi 1910, when the Gray mine was opened near the old Linderman workings; like its predecessor, however, the operation failed after producing 250 tons.

In estimating reserves, it should be understood that the results are not conclusive. Assuming that the average thickness of the coal seam is 30 inches and that the coal is minable to at least a depth of 500 feet, and neglecting to consider the coal that must be left underground as pillars, the total amount of coal in the Linderman mine area is estimated as 1,275,000 tons, and in the Capitan mines area as 2,250,000 tons. Well over 600,000 tons has been removed already from the two areas, leaving total reserves of less than 2,925,000 tons.

CONCLUSIONS

Coal of sufficiently high grade and rank for commercial production is present in the Capitan area; however, it would seem inadvisable to reopen the area, for the following reasons:

1. Only one bed of commercial thickness is present, and it is extremely variable in thickness.

2. Major faults, such as the Coalora and the Oso Creek faults, limit the extent of the mines. The Coalora fault probably was responsible for the closing down of the Capitan mines, and the Oso Creek fault would have made extensive production from the Linderman and Gray mines very difficult.

3. Minor faults and associated dikes would be troublesome, particularly in the Linderman mine area.

4. Reserves within the area mapped are not sufficiently high to merit undertaking an extensive exploration program in order to overcome the difficulties cited.

REFERENCES

Allen, J. E., and Jones, S. M. (1951) Preliminary map of Capitan quadrangle, New Mexico, Roswell Geol. Soc. Guidebook, Fifth Field Conference.

Allen, J. E., and Balk, R. (1954) Mineral resources of Fort Defiance and Tohatchi quadrangles, Arizona and New Mexico, N. Mex. Inst. Mining and Tech., State Bur. Mines and Min. Res., Bull. 36, 192 pp.

Bushnell, H. P. (1953) Geology of the McRae Canyon area, Sierra County, New Mexico, New Mex. Univ., unpublished M.S. thesis, 106 pp.

Campbell, M. R. (1907) Coal in the vicinity of Fort Stanton reservation, Lincoln County, New Mexico, U. S. Geol. Survey Bull. 316, 431-434.

Cross, Whitman (1899) Telluride folio, U. S. Geol. Survey Geol. Atlas 57.

Gardner, J. H. (1910) The Carthage coal field, New Mexico, U. S. Geol. Survey Bull. 381, 452-460.

Holmes, W. H. (1877) Report on the San Juan district, U. S. Geol. and Geog. Survey Terr. (Hayden), 9th Ann. Rept., 175-239.

Pike, W. S., Jr. (1947) Intertonguing marine and nonmarine Upper Cretaceous deposits of New Mexico, Arizona, and southwestern Colorado, Geol. Soc. America Memoir 24.

Shimer, H. W., and Shrock, R. R. (1944) Index fossils of North America, Cambridge, Mass., John Wiley and Sons, Inc., 837 pp.

Sidwell, Raymond (1946) Effects of dikes and displacements on sediments in Capitan quadrangle, New Mexico, Amer. Mineralogist, v 31, 65-70.

Stearns, C. E. (1943) The Galisteo formation of north-central New Mexico, Jour. Geology, v 51, 301-319.

Wegemann, C. H. (1914) Geology and coal resources of the Sierra Blanca coal field, Lincoln and Otero Counties, New Mexico, U. S. Geol. Survey Bull. 541, 419-542.

Wilpolt, R. H., and Wanek, A. A. (1952) Geology of the region from Socorro and San Antonio east to Chupadera Mesa, Socorro County, New Mexico, U. S. Geol. Survey, Oil and Gas Inv., Map OM 121.

Winchester, D. E. (1920) Geology of Alamosa Creek Valley, Socorro County, New Mexico, with special reference to the occurrence of oil and gas, U. S. Geol. Survey Bull. 716.

TABLE 1

Section of the lower sandstone unit of the Mesaverde group from north of U. S. •Highway 380, 1-1/2 miles west of Capitan, New Mexico.

	Thickness in feet of unit	Thickness in feet from base
Fissile, black marine shale		
Base of middle shale unit of the Mesaverde group		
Top of lower sandstone unit of the Mesaverde group		
16. Poorly exposed buff, massive quartzose sandstone, fossiliferous at top	25	165
15. Unexposed, probably shales and siltstones	30	160
14. Very fossiliferous, buff quartzose sandstone	4	130
13. Coarse-grained, massive, buff sandstone	20	126
12. Fissile, dark-gray shale with silty interbeds	20	106
11. Medium- to fine-grained, buff, massive, fossiliferous, quartzose sandstone	1	86
10. Medium-grained, buff, massive, quartzose sandstone	5	85
9. Fissile, dark-gray shale with silty interbeds	3	80
8. Thin-bedded, buff, quartzose sandstone	4	77
7. Medium- to fine-grained, buff, massive, quartzose sandstone	3	73
6. Very poorly exposed interbedded shale and siltstone	35	70
5. Massive, crossbedded, white, quartzose, well-rounded, well-sorted, medium-grained sandstone	13	35

TABLE 1 (continued)

4. Buff, thin-bedded, quartzose sandstone	15	22
3. Fine-grained, thin-bedded, tan-brown sandstone	1	7
2. Buff, thin-bedded, quartzose sandstone	3	6
1. Tan-brown, medium-grained, well-rounded, massive, quartzose sandstone	3	3

Base of lower sandstone unit of the Mesaverde group Top of

Mancos shale

Interbedded shales, siltstones, and thin sandstones

TABLE 2

Section of the middle shale unit of the Mesaverde group from 1 mile south of U. S. Highway 380, 2 miles west of Capitan, New Mexico.

unit		Thickness in feet and inches of	from base
	Coarse, white to buff, quartzose sandstone with lenses of quartzite and chert pebble conglomerate		
Base of Cub Mountain formation			
? Disconformity			
Top of upper sandstone unit of the Mesaverde group			
39.	Medium- to coarse-grained, subangular to rounded, buff to white, massive, cross-bedded at top, quartzose sandstone	60' +	60' +
Base of upper sandstone unit of the Mesaverde group			
Top of middle shale unit of the Mesaverde group			
38.	Poorly exposed carbonaceous shales	60' +	201' +
37.	Buff, medium-grained, massive sandstone containing wood fragments.	4' 0"	141' 8"
36.	Coal	0' 4"	137' 8"
35.	Fissile, dark-gray to black, carbonaceous shale	5' 0"	137' 4"
34.	Gray, carbonaceous sandstone containing wood fragments	1' 6"	132' 4"
33.	Fissile, gray, somewhat carbonaceous shale	3' 0"	130' 10"
32.	Gray, carbonaceous sandstone containing wood fragments	0' 6"	127' 10"

TABLE 2 (continued)

31. Coal	1' 2"	127' 4"
30. Fissile, black, carbonaceous shale	6' 0"	126' 2"
29. Coal	0' 4"	120' 2"
28. Fissile, dark-gray, carbonaceous shale	3' 0"	119' 10"
27. Medium-grained, dark-gray, thin-bedded quartzose sandstone	1' 0"	116' 10"
26. Dark-gray, slightly carbonaceous shale containing rich concretions from 1" to 24" in diameter	12' 0"	115' 10"
25. Thin-bedded, light-gray, sandy shale and si I tstone	1' 0"	103' 10"
24. Thin-bedded, carbonaceous sandstone containing wood fragments	2' 0"	102' 10"
23. Coal (producing seam)	3' 2"	100' 10"
22. Fissile, black, carbonaceous shale	0' 6"	97' 8"
21. Fissile, dark-gray, carbonaceous shale containing wood fragments	2' 6"	97' 2"
20. Coal	0' 6"	94' 8"
19. Fissile, black, carbonaceous shale	0' 5"	94' 2"
18. Fissile, light-gray, calcareous shale, probably to beds of marine sequence	6' 0"	93' 9"
17. Dark-gray, weathering to yellow brown, dense limestone	0' 4"	87' 9"
16. Fissile, light-gray shale	1' 0"	87' 5"
15. Dark-gray, weathering to yellow brown, dense limestone	0' 5"	86' 5"
14. Light-gray, fissile shale	2' 0"	86' 0"

TABLE 2 (continued)

13.	Dense limestone, weathering to yellow brown	0' 4"	84' 0"
12.	Fissile, light-gray, calcareous shale	3' 4"	83' 8"
11.	Dark-gray, weathering to yellow brown, dense limestone	2' 0"	80' 4"
10.	Fissile, light-gray shale	4' 0"	78' 4"
9.	Dark-gray, weathering to yellow brown, dense limestone	0' 6"	74' 4"
8.	Fissile, dark-gray shale, fossiliferous at the base	48' 0"	73' 10"
7.	Fissile, buff weathering, light-gray shale	5' 6"	25' 10"
6	Well-cemented, dark-gray, weathering to red-brown, thick- to thin-bedded sandstone	1' 0"	20' 4"
5.	Buff weathering, light-gray, fissile shale, fossiliferous at base	14' 0"	19' 4"
4.	Dark-gray, weathering to yellow brown, dense limestone, containing shell fragments	0' 4"	5' 4"
3.	Fissile, light- to dark-gray shale	2' 0"	5' 0"
2.	Dark-gray, weathering to yellow brown, dense, fossiliferous limestone	1' 0"	3' 0"
1.	Fissile, light-gray shale containing limestone at base	2' 0"	2' 0"

Base of middle shale unit of the Mesaverde group

Top of lower sandstone unit of the Mesaverde group Buff,

fossiliferous, quartzose sandstone

TABLE 3

Thickness and associated lithologies of the coal seam of the middle shale member of the Mesaverde group, Capitan coal field, Lincoln County, New Mexico.

	Thickness of unit in feet and inches
I. In stream bed, where middle shale unit of the Mesaverde group was measured, one-half mile south of U. S. Highway 380, 2 miles west of Capitan, and about 1 mile north of the old Linderman mine.	
Thin-bedded, carbonaceous sandstone containing wood fragments	2'
Coal	3' 2"
Black, fissile, carbonaceous shale	6"
Fissile, dark-gray, carbonaceous shale containing wood fragments	2'
II. In stream bed, about three-fourths of a mile south of the Linderman mine, near the small fault.	
Thin-bedded, carbonaceous sandstone containing wood fragments	1' 6"
Coal	4' 6"
Fissile, black, carbonaceous shale	6"
Coal	4"
Fissile, black, carbonaceous shale	1' 4"
III. In stream bed, one-quarter mile southwest of Capitan High School, in northernmost reentrant of the east sill.	
Sill	10'
Carbonaceous shale, black and fissile	9' 6"

TABLE 3 (continued)

Fine-grained, carbonaceous sandstone containing wood fragments	1' 9"
Coal	1' 6"
Black, fissile, carbonaceous shale	4' +

IV. In stream bed, about 100 feet south of where State Highway 48 crosses the east sill.

Sill	20' +
Black, fissile, carbonaceous shale	2' 6"
Coal	2' 4"
Black and fissile carbonaceous shale	6' +

V. In stream bed, about 800 feet northwest of Capitan No. 2 mine.

Sill	10'
Carbonaceous, shaley sandstone	5'
Coal	1' 7"
Black, fissile, carbonaceous shale	2' 6"
Gray, very slightly carbonaceous shale	6'

VI. In Capitan No. 2 mine (Campbell, 1907)

Sandstone roof	
Coal	1' 9"
Shale	4"
Coal	3' 6"

TABLE 3 (continued)

VII. In Capitan No. 1 mine (Wegemann, 1914)

Sandstone, white	
Shale, carbonaceous	2"
Coal	10"
Sandstone, white	3"
Coal	9"
Sandstone	3/8"
Coal	1' 9"