CIRCULAR 100

The Tierra Amarilla Coal Field
Rio Arriba County, New Mexico

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U. S. Geological Survey

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Abstract

The Tierra Amarilla coal field comprises a small block of coal-bearing rocks of the Mesaverde Group that lies on the east flank of the Chama basin about 12 miles east of the nearest outcrops of the Mesaverde on the northeast flank of the San Juan Basin. At the west end of the field, as many as nine coal beds are present but most are very thin and all are lenticular. The coal beds near the base of the coal-bearing sequence are thicker and more persistent and are locally as much as 49 inches thick. The coal, of subbituminous A rank, has been mined for local domestic use at several places in the western part of the field. A progressive eastward change in lithology reduces the amount of carbonaceous and clayey material in the Mesaverde to a very small amount and greatly increases the amount of sandstone in the unit. The Mesaverde also seems to thin to the east and northeast— the seaward direction at the time of deposition of the Upper Cretaceous rocks of the area.

Introduction

During geologic mapping of the Tierra Amarilla 15-minute quadrangle (Landis and Dane, 1967), the western part of an isolated block of coal-bearing rocks of the Mesaverde Group was examined and mapped in detail, and sections of the coal beds and the coal-bearing sequence were measured. Subsequently, the authors examined the eastern part of the coal field, measured sections, and did reconnaissance mapping of the rock units. The information presented herein contributes to the knowledge of the fuel resources of the northeastern part of the San Juan Basin and the stratigraphy of the Mesaverde Group.

The coal field covers an area of about 21 square miles in the Tierra Amarillo Land Grant, southeast of the town of Tierra Amarilla, the county seat of Rio Arriba County, New Mexico (fig. 1). The area lies in the easternmost part of the Navajo section of the Colorado Plateau's physiographic province and adjoins the western boundary of the Southern Rocky Mountains province (Fenneman, 1946).

PREVIOUS INVESTIGATIONS

Though coal was known to be present in the Mesaverde Group in the Monero coal field, about 22 miles northwest of the town of Tierra Amarilla, and in the extension of the Mesaverde Group southward from Monero, the coal-bearing rocks of the Tierra Amarilla field were unknown to or unreported by most earlier workers. Newberry (1876, p. 73) passed near Tierra Amarilla in 1859 and discussed the Cretaceous rocks in and near the Monero field. He mentioned "...Tierra Maria [sic] , a charming spot at the forks of the Chama, where the Mexicans had formerly a settlement, now abandoned on account of the depredations of the Indians," but the report contains no mention of the coal-bearing rocks nearby. In 1874, Cope (1875, p. 79) traversed the area and observed the Mesaverde Group "To the south and east of this town [Tierra Amarillo] , high hills of yellowish sandstone present escarpments to the north, which are apparently Cretaceous No. 3, and contain numerous Inocerami," but did not record seeing any coal.

Storrs (1902) did not mention the Tierra Amarilla field in his report on the coal fields of the Rocky Mountains, and Campbell (1908, 1917) did not show it on his maps of the coal fields of the United States. Other workers in the area confmed their reports about the coal-bearing rocks to the Monero field and to the outcrops that extend from the Monero field near the Colorado state line to near Cuba, New Mexico, about 70 miles south (Schrader, 1906; Gardner, 1909a,b). The Tierra Amarilla field is not shown on Darton's (1928) geologic map of New Mexico but is shown, as a small, somewhat arbitrarily drawn area, on Averitt's (1942) map of the coal fields of the United States; Carle H. Dane orally reported the presence of coal workings east of the highway south of Tierra Amarilla (probably at loc. 1) to Averitt. The presence of coal-bearing-rocks was subsequently shown by Read et al. (1950), and the general delineation of the areal extent of the Mesaverde rocks was shown by Dane and Bachman (1957), Smith and Muehlberger (1960), Trumbull (1959), Dane and Bachman (1965), and Doney (1966).

ACKNOWLEDGMENTS

Most of the coal field was mapped and the sections measured during the field season of 1964; the eastern part of the field was examined in reconnaissance for a few days during 1966.

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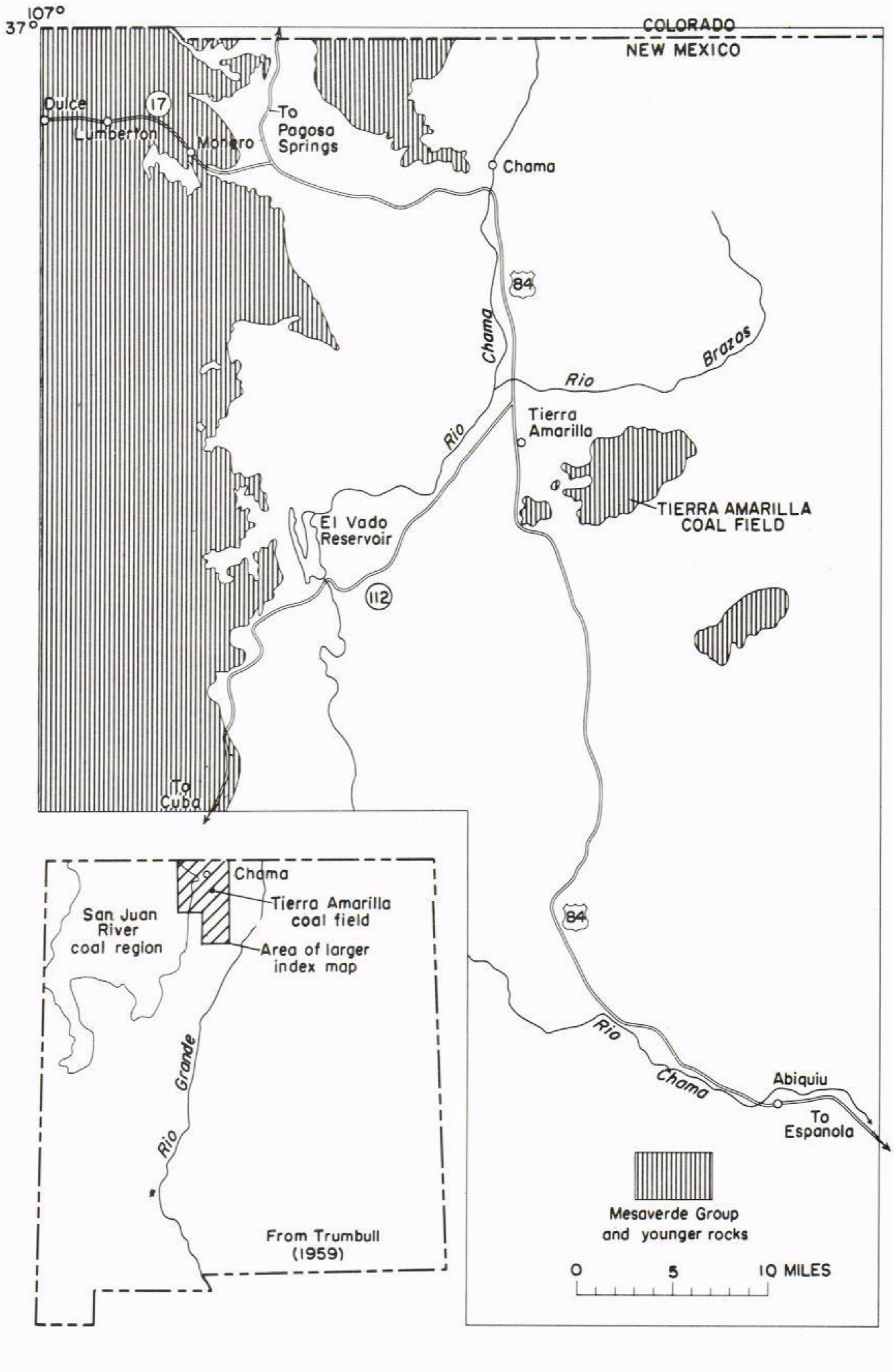

Figure 1

INDEX MAP OF THE TIERRA AMARILLA COAL FIELD
(from Dane and Bachman, 1965)

Geology

The Tierra Amarilla coal field comprises the areas southeast of the town of Tierra Amarilla that are underlain by coal-bearing rocks of the Mesaverde Group of Late Cretaceous age (fig. 2). The field is composed of two segments separated by the valley of Rito de Tierra Amarilla, which has cut through the Mesaverde Group into the underlying Mancos Shale. As thus defined, the field does not include the outcrops of the Mesaverde Group farther south near the town of Canjilon (Dane and Bachman, 1965). This southern block was not examined by us and is not discussed in this report.

The Tierra Amarilla field is on the eastern flank of the structural feature called Chama basin, Chama embayment, or Chama platform (Kelley, 1950; Muehlberger, 1960). Muehlberger (p. 109) considered the basin "essentially a structural terrace between the San Juan Basin to the west and the Brazos uplift to the east." The north-trending Chama syncline marks the lowest part of the basin, and the axis of the syncline passes through the western part of the coal field. The coal-bearing Mesaverde Group crops out in a generally westward-dipping hogback along the boundary between the Chama basin and the San Juan Basin about 15 miles west of Tierra Amarilla, but it has been removed from most of the Chama basin by erosion that started during Tertiary time and continues to the present. The rocks exposed in and around the edges of the Chama basin range in age from Pennsylvanian to Quaternary, but the surface rocks in most of the basin are of Late Cretaceous age.

ROCKS OF LATE CRETACEOUS AGE

MANCOS SHALE

The oldest rocks shown on the geologic map (fig. 2) are assigned to the upper shale unit of the Mancos Shale, as mapped by Landis and Dane in the Tierra Amarilla quadrangle. El Vado Sandstone Member of the Mancos Shale, as defined by Landis and Dane, may be present in the northernmost part of the area shown as Mancos on the map (fig. 2).

The upper shale unit of the Mancos is about 1200 feet thick (Landis and Dane). The lower half of the unit is mostly calcareous brownish-gray and olive-gray fissile shale that commonly weathers light gray to white. *Inoceramus platinus* fragments encrusted with *Ostrea congesta* are found throughout the lower half and indicate that it is of late Niobrara age. The upper half of the upper shale unit is composed largely of medium-gray shale slightly calcareous to noncalcareous. Near the base of the upper half are gray limestone concretions as much as 3 feet long that weather yellowish orange. *Staphites hippocrepis* and *Stantonoceras* sp., which are diagnostic of early Montana age, have been collected from the concretions.

The upper few hundred feet of the upper shale unit of the Mancos contain sandstone beds that increase in number and thickness upward and, in the uppermost part, predominate over interbedded shale in a zone transitional into the Point Lookout Sandstone, the basal formation of the overlying Mesaverde Group.

MESAVERDE GROUP

The Mesaverde Group in the northeastern part of the San Juan Basin comprises three widely recognized units—the Point Lookout Sandstone, the overlying Menefee Formation, and La Ventana Tongue of the Cliff House Sandstone, which overlies the Menefee Formation. In the Tierra Amarilla coal field, however, only the Point Lookout and the Menefee have been recognized. Strata equivalent to La Ventana may be present in the uppermost part of the Menefee as mapped (fig. 2) but were not recognized. The Menefee and the Point Lookout were not separately identified in the eastern part of the coal field because the lithology changes laterally to the east and the beds are poorly exposed.

In the western part of the Tierra Amarilla coal field and in exposures on the eastern flank of the San Juan Basin, the regressive nearshore marine sandstone that comprises most of the Point Lookout Sandstone is overlain by the lenticular sandstones, clay shales, carbonaceous shales, and coal beds of lagoonal, swamp, bay, and terrestrial origin that make up the Menefee Formation. In the eastern part of the coal field the Mesaverde Group is composed largely of sandstone. Figure 3 is a graphical presentation of twelve sections measured in the field. If the lateral relation of the rocks exposed at section 12 with those exposed at the other eleven measured sections is as shown in Figure 3, then the M enefee Formation (and the possible included lateral correlatives of La Ventana Tongue of the Cliff House Sandstone) at the eastern extremity of the coal field is made up mostly of sandstone.

The Mesaverde Group is as much as 180 feet thick in the western part of the Tierra Amarilla coal field but may thin to 120 feet at the eastern end of the field.

No fossils *were* found in the Mesaverde of the Tierra Amarilla coal field but, as mentioned earlier, fossils of early Montana age are present near the middle of the upper shale unit of the Mancos, about 600 feet below the base of the Mesaverde. The oldest fossils the authors collected from the Lewis Shale, which overlies the Mesaverde, in the Tierra Amarilla field come from the ammonite range zone of *Baculites mclearni.* As thus bracketed, the Mesaverde in the Tierra Amarilla coal field is of early Montana age and may all lie within the early Campanian.

Geography

TOPOGRAPHY AND DRAINAGE

The town of Tierra Amarilla lies at an elevation of 7520 feet and the coal-bearing rocks occur at elevations that range from less than 7800 feet to more than 10,000 feet. The Point Lookout Sandstone at the base of the Mesaverde Group is a resistant cliff-forming unit that caps steep shale slopes of the Mancos Shale in the west-facing exposures in the western part of the coal field. Throughout most of the rest of the coal field, the Mancos and Mesaverde rocks are concealed by vegetation, colluvium, talus, and landslide debris, but the Point Lookout-Mancos contact is often manifested by an upward change in slope from steep to steeper. The upper part (or Menefee Formation) of the Mesaverde Group and the overlying Lewis Shale are both soft, weakly resistant units that underlie vegetation-covered slopes; in the higher, eastern part of the coal field, these units are the source of most of the colluvium and landslide debris.

The southern and western parts of the field are drained by Rito de Tierra Amarilla. Rito de Tierra Amarilla heads in the Brazos uplift (Tusas Mountains), the southern extension of the San Juan Mountains of southern Colorado, and flows westward along the southern margin of the coal field until it turns northwest, cuts through the coal-bearing sequence, and joins the Rio Chama a few miles west of the town of Tierra Amarilla. The Rio Brazos drains the northern part of the coal field; it flows from the Brazos uplift to join the Rio Chama a few miles north of Tierra Amarilla.

CLIMATE AND VEGETATION

During 1965, the average temperature at the Tierra Amarilla recording station was 43.6° F and average monthly temperatures ranged from 22.2° F in January to 66.4° F in July (U.S. Weather Bureau, 1966). Extremes were 89° F in July and —20° F in February; consecutive days of the summer growing season in which the minimum temperature exceeded 32° F totaled 101. Total precipitation was 21.86 inches, which was 6.06 inches above the long-term average. Precipitation in 1965 ranged from 0.67 inch in February to 3.35 inches in July; on a long-term basis, however, August is usually the wettest month. The coal field is covered mainly by ponderosa pine and aspen forest; at the lower elevations, however, it is covered by open pinon-juniper forest. Outcrops of coal are largely confined to steep slopes at the lower elevations. Though some crops are grown on the lower, irrigated parts of the area near the streams, most of the region is grazing land. Some timber is cut in the higher, eastern part of the coal field.

SETTLEMENT AND TRANSPORTATION

Rio Arriba County, an area of 5877 square miles, had a population of 24,193 in 1960 (U.S. Bureau of the Census, 1960). Of this total, 3422 people lived in the Tierra Amarilla census county division, which includes most of the populated areas along the course of the upper part of the Rio Chama and the populated area along the west side of the Brazos uplift. The town of Tierra Amarilla itself had a population of less than 1000.

Hard-surfaced U.S'. 84 connects Tierra Amarilla with Espanola and with Santa Fe, about 90 miles southeast; with Pagosa Springs, Colorado, about 65 miles northwest; and, about 4 miles east of Monero, with hard-surfaced N. Mex. 17, which leads to Farmington, about 105 miles west of Monero. N. Mex. 112 is hard-surfaced from Tierra Amarilla to El Vado, about 15 miles, and then is graded to its junction with N. Mex. 96, about 115 miles from Albuquerque by way of Cuba and Bernalillo. Unimproved roads and trails provide access to most parts of the coal field.

POINT LOOKOUT SANDSTONE

The Point Lookout Sandstone is a littoral marine sandstone deposited as the Cretaceous sea regressed—or the next to last time—to the east and north across the San Juan Basin. The sandstone is light gray and fine- to very fine-grained, weathers yellowish gray to grayish yellow, and tends to form bold cliffs or steep slopes above the softer Mancos Shale.

In the western part of the Tierra Amarilla coal field, the upper part of the Point Lookout tends to be silty, carbonaceous, and poorly cemented, and it forms recessive slopes above the main mass of the unit. In the eastern part of the field, the equivalent part of the exposed rocks is similar to the sandstone below, though it tends to be less well cemented.

The vertical and horizontal transitional relationship between the Point Lookout and the underlying Mancos Shale is well exposed in the cliffs at the western end of the coal field.

The contact between the two units is drawn at the base of the cliff-forming massive sandstone that crops out as one bed, because the small-scale intertonguing relationships of the units cannot readily be mapped. As thus drawn, the upper part of the Mancos contains sandstone beds, some of which are tongues of the Point Lookout extending into the dark shales of the Mancos. Accretion of sandstone beds to the base of the Point Lookout causes thickness variations in the western part of the coal field. In the easternmost part of the field, the base of the Point Lookout is not exposed. The Point Lookout Sandstone ranges in thickness from less than 40 feet to 67 feet at the thickest section measured.

MENEFEE FORMATION

The Menefee Formation is a complex interlayered sequence of lagoonal, swamp, bay, and terrestrial sedimentary rocks that conformably overlies the Point Lookout Sandstone and forms the middle part of the Mesaverde Group in much of the eastern San Juan Basin. The upper part of the Mesaverde Group in nearby areas, La Ventana Tongue of the Cliff House Sandstone, is not recognized in the Tierra Amarilla coal field, and the Menefee as mapped (fig. 2) and as discussed in this report may include units representative of La Ventana.

The Menefee is composed of fine- to very fine-grained, well-bedded to massive sandstone, fissile clay shale, lumpy bedded claystone, and coal, most of which are carbonaceous and silty to some degree. Individual rock units tend to be lenticular, but lithologies representing some particular environments persist far enough laterally to allow correlation of measured sections. For example, the lower part of the Menefee is persistently carbonaceous and coaly throughout the Tierra Amarilla coal field, though individual rock units are not. In the same way, the middle part of the Menefee is persistently sandy throughout the field and the rocks above the sandy middle part are persistently carbonaceous wherever exposed. The uppermost part of the Menefee is covered or very poorly exposed at all places where it was examined, but it seems to be largely soft silty claystone and medium-gray clay shale with some interbedded, soft, fine- to very fine-grained, generally silty, poorly bedded, yellow-weathering sandstone. The contact with the overlying Lewis Shale is at best tentative in all exposures but lithologic criteria from nearby areas suggest placement as indicated in Figure 3; that is, most of the yellow-weathering, soft, silty, medium-gray, clay shale and limestone concretions is in the lower part of the Lewis, whereas the ironstone laminae and concretions and most of the soft yellow-weathering sandstone are included with the Mesaverde Group.

Between the western part of the field, where most of the sections were measured, and the eastern part, where the rocks are poorly and incompletely exposed, the Menefee Formation seems to thin, and it becomes much sandier. As correlated in Figure 3, the Menefee ranges in thickness from as much as 120 feet in the western part of the field to 99 feet, or less, at the easternmost measured section. The most striking change, however, is in the relative amounts of sandstone in the Mesaverde in the two areas.

LEWIS SHALE

The Lewis Shale, which conformably overlies the Mesaverde Group, is at least 1000 feet thick in the Tierra Amarilla coal field. A more accurate determination cannot be made because only small parts of the Lewis are exposed at any place in the field because of a thick forest cover and very extensive slumping and landsliding.

The Lewis is largely medium-gray, yellow-weathering, soft, partly silty, clay shale that contains a few interbedded silty sandstone and sandy siltstone beds. Yellow-weathering calcareous concretions as much as 6 feet in maximum dimension are present in the lower part of the exposed Lewis, and calcareous concretions of various sizes, some fossiliferous, are sparsely present throughout the Lewis.

Two collections of fossils obtained from the Lewis in the Tierra Amarilla coal field (fig. 2) were identified by W. A. Cobban as USGS collection D5317: *Inoceramus aff. I. proximus* Tuomey; USGS collection D5318: *Inoceramus* sp. and *Baculites mclearni* Landes.

Collection USGS D5317, from about 0.6 mile east of the Dandee mine, is possibly from the ammonite range zone of *Baculites gregoryensis* (W. A. Cobban, written communication, 1966), which extends through a large part of the Red Bird Silty Member of the Pierre Shale of Wyoming (Gill and Cobban, 1966) and which is found in the lower part of the Hygiene Sandstone Member of the Pierre Shale near Denver (Scott and Cobban, 1965).

Collection USGS D5318 is from the lower part of the Lewis in the southwestern part of the coal field and is from the ammonite range zone of *Baculites mclearni* (W. A. Cobban, written communication, 1966). The *Baculites mclearni* zone extends through the upper part of the Sharon Springs Member of the Pierre Shale into the lowest part of the overlying Mitten Black Shale in eastern Wyoming (Gill and Cobban) and is in the lower shale unit of the Pierre near Denver (Scott and Cobban).

ROCKS OF TERTIARY AGE

A sequence of rocks of Tertiary age about 300 feet thick unconformably overlie the Lewis Shale at the eastern end of the Tierra Amarilla coal field. The lower part of this sequence forms bold cliffs of well-cemented pebble-toboulder conglomerate and sandstone above the Lewis at the western end of the area mapped as Tertiary rocks, undifferentiated (fig. 2). However, the upper half, or more, of the rocks present appears to be softer and is very poorly exposed because of a thick forest cover. None of the rocks above the Lewis was given other than a cursory examination by the authors.

Smith and Muehlberger assigned the lower part of the Tertiary sequence to the Blanco Basin Formation and the upper part to the Potosi Volcanic Series. Dane and Bachman (1965) showed the sequence as Blanco Basin Formation and El Rito Formation of Smith (1938). Muehlberger (1967, p. 45) stated that the Blanco Basin Formation and El Rito Formation of Smith appear to interfinger north of Cannes Box, which is about 10 miles north of the Tierra Amarilla coal field. In the absence of definitive information, it is assumed in this report that the bulk of the Tertiary sequence preserved at the eastern end of the coal field should probably be assigned to the Blanco Basin Formation or El Rito Formation of Smith, which is the basal Tertiary unit of the southern part of the Brazos uplift;Some of the soft, very poorly exposed, rocks at the top of the sequence might belong to the lowest part of the Potosi Volcanic Series of Miocene age as mapped by Muehlberger (1967).

The Blanco Basin Formation has been accepted as being of early Eocene age in the southern part of the San Juan Mountains of Colorado (Steven, Mehnert, and Obradovich, 1967) because of correlation on lithology and stratigraphic position with the San Jose Formation of early Eocene age in the San Juan Basin. In New Mexico, petrographic data reported by Muehlberger (1967, p. 43) "—suggest that the Blanco Basin and (at least) the lower Wasatch [as mapped by Dane (1948) and subsequently mapped as San Jose Formation by Baltz (1967)] are lithologically identical and thus probable correlatives...." Regional stratigraphic and structural considerations discussed by Baltz (p. 57) indicate that "The Blanco Basin and El Rito Formations are probably equivalent to the youngest rocks of the San Jose Formation, or possibly to slightly younger rocks that were part of the same depositional sequence but are not preserved in the San Juan Basin."

ROCKS OF QUATERNARY AGE

Four rock units of Quaternary age were mapped in the Tierra Amarilla coal field, largely as extensions of units mapped in the Tierra Amarilla quadrangle (Landis and Dane). No attempt was made to map the extensive landslide deposits that are made up mostly of the Lewis Shale and largely conceal the Lewis and the Mesaverde Group in the central and eastern parts of the coal field.

GRAVEL DEPOSITS

Unconsolidated gravel deposits as much as 50 feet thick that are largely remnants of older pediment and terrace deposits overlie the Cretaceous rocks in the southwestern part of the mapped area (fig. 2). These gravel deposits are obviously related to early stages in the development of the present drainage system. Some of them, particularly those on the sides of hills, are largely colluvium derived from gravel at higher elevations.

The gravel is composed mostly of rounded to subangular pebble-to-small-boulder clasts of resistant quartzite derived primarily from Precambrian rocks. Clay- and sand-sized constituents form a large part of the deposits in some areas. The original source of the gravel was the Brazos uplift east of the Tierra Amarilla coal field.

BASALT FLOW

A body of soda-rich olivine basalt occupies a former valley of the Brazos River in the northern part of the mapped area (fig. 2). Muehlberger (1967, p. 51) attributed to Hugh H. Doney the information that the basalt flow came from volcanic cones farther up the Brazos River. The flow appears to be 50 feet thick or more near its western end (Landis and Dane), but it may be considerably thinner along its southeastern edge where it has lapped onto the pre-existing valley margin.

TERRACE DEPOSITS

The terrace deposits mapped in the area (fig. 2) lie above flood-plain deposits of the Rio *de* Tierra Amarilla and the Rio Brazos. The deposits are commonly 3 to 10 feet thick but may be 40 feet thick in some places. Clay- and silt-sized material may locally form most of the deposits, but in general sand- to cobble-sized material predominates. The terrace deposits are similar to the older gravel deposits because they are in part derived from them, but they commonly. have more fine-grained material and contain more locally derived resistant rock, such as pieces of Dakota Sandstone, the Greenhorn Limestone Member of the Mancos Shale, and sandstone from the Mesaverde Group.

ALLUVIUM

Alluvial deposits, which may be as much as 25 feet thick in a few places although generally much thinner, are present along the Rio Brazos and the Rito de Tierra Amarilla. Clay-, silt-, sand-, and pebble-to-cobble-sized materials make up the deposits.

STRUCTURE

The Tierra Amarilla coal field lies in the eastern part of the Chama basin (Kelly, p. 101), a structural feature described as essentially a structural terrace separating the San Juan Basin on the west from the Tusas Mountains on the east (Muehlberger, 1967, p. 53). The axis of the Chama syncline, the deepest part of the Chama basin, passes through the western part of the Tierra Amarilla coal field, but most of the field lies on the eastern flank of the basin, west of the faulted margin of the Tusas Mountains (Brazos uplift, Muehlberger, 1960, p. 109). The east-west cross section through the coal field (fig. 2) illustrates diagrammatically the structural attitude of the coal-bearing and adjoining rock units.

Coal

GEOLOGY

All or part of the Menefee Formation was examined at twelve localities in the coal field (fig. 3). Coal beds are present at as many as nine separate stratigraphic positions that can be placed in two roughly designated groups of beds—the upper group, exposed at localities 2, 3, 4, and 12 (figs. 2, 3), and the lower group, examined at all the localities except locality 3 (figs. 2, 3). Three of the nine coal beds fall in neither the upper nor the lower group but are included in the dominantly sandstone unit that separates the upper coal bed group from the lower group. These three beds are very thin—the observed maximum is 5 inches—and nonpersistent.

The upper group of coal beds is exposed only in the western part of the coal field, where three of the four beds appear to be laterally persistent for about 0.7 mile or more (locs. 2, 3, 4). At locality 8, the correlative stratigraphic sequence is covered and coal may be present; no coal smut, however, was observed in the covered slope. At locality 12, the correlative stratigraphic sequence is only partly exposed, but though carbonaceous in part, it does not seem to contain any coal. The maximum observed coal thickness in the upper group was 20 inches.

The lower coal group comprises the lowest 10 to 15 feet of the Menefee Formation—to the base of the persistently sandy stratigraphic sequence that separates the upper and lower coal groups and the top of the Point Lookout Sandstone. Two persistent coal beds are present in the lower group, one near the base and one at the top. The lower bed attains an observed maximum thickness of 31 inches at locality 5 but is generally considerably less.

The upper bed of the lower coal group is the thickest, most persistent, and most mined and prospected bed in the coal field. It is present at nine of the eleven localities *where* the lower coal group was examined; the bed is not present at the southernmost locality, 11, and the whole lower coal group is very poorly represented at the easternmost locality, 12. The bed is 49 inches thick at locality 1 and it contains more than 2 feet of coal at localities 5, 8, 9, and 10.

The lenticular character of the coal beds in the field is well illustrated at localities 1, 2, and 3. At locality 1, the upper bed of the lowei group is more than 4 feet thick but at locality'2, less than 0.2 mile away, it is only 1 foot thick. Locality 3 is less than 200 feet from locality 2, but the lowest bed of the upper coal group decreases in thickness from 10 inches at locality 2 to 7 inches at locality 3, and the next higher bed decreases in thickness from 18 inches at locality 2 to 6 inches at locality 3.

ANALYSES

The Tierra Amarilla field contains normal banded coal of the humic series (Tomkeieff, 1954), which comprises most of the coal world—particularly those of economic importance. American coals are commonly further subdivided according to rank, a classification dependent on the degree of metamorphism within the progressive series that starts with the accumulation of plant matter to form peat deposits that can, through application of moderate amounts of heat and pressure over a period of time, be transformed to coals of various physical and chemical properties. The standard specifications for the classification of coals by rank, as established by the American Society for Testing and Materials (1967), are shown in Table 1.

Analyses (table 2) of two tipple samples collected in 1944 from the Dandee mine (loc. 9, figs. 2, 3) indicated that on the basis of heating value, the rank of the coal could be either high-volatile C bituminous or subbituminous A. No information about agglomerating characteristics is available, but the coal has been grouped as subbituminous A (Walker and Hartner, 1966, p. 22), probably because of its moisture content, which is higher than that of most bituminous coals.

The total sulfur content of U.S. coals, and the form in which the sulfur is present, have become of national concern because of air pollution problems. The coal from the Dandee mine contains from 1.0 to 1.1 per cent sulfur, which places the coal at about the boundary of the low-and medium-sulfur content categories of DeCarlo, Sheridan, and Murphy (1966, p. 3). Walker and Hartner (p. 22) presented analytical data on the form of the sulfur in sample C30859 that indicated that 0.02 per cent is present as sulfate sulfur, 0.59 per cent as pyritic sulfur, and 0.44 per cent as organic sulfur. Removal of organic sulfur by conventional coal-cleaning processes is not generally possible, but considerable reduction of pyritic sulfur can often be made, the amount depending on the size and distribution of the pyritic minerals in the coal.

MINING

The coal in the Tierra Amarilla field has been opened in at least four different localities (1, 5, 9, and 10; figs. 2, 3). At locality 5, coal was removed from the lower bed of the lower coal group through at least two entries, now caved. At the other three localities, the upper bed of the lower coal group was opened and indeterminate amounts of coal

TABLE I.—CLASSIFICATION OF COALS BY RANK.[a]

Class	Group	Fixed Carbon Limits, per cent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, per cent (Dry, Mineral-Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist,[b] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracitic	1. Meta-anthracite	98	...	...	2	...	...	...
	2. Anthracite	92	98	2	8	...	...	...
	3. Semianthracite	86	92	8	14	...	...	Nonagglomerating[c]
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[e]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	Commonly agglomerating[e]
	3. High volatile *A* bituminous coal	...	69	31	...	14 000[d]	...	Commonly agglomerating[e]
	4. High volatile *B* bituminous coal	...	...	...	...	13 000[d]	14 000	Commonly agglomerating[e]
	5. High volatile *C* bituminous coal	...	...	...	...	11 500 10 500	13 000 11 500	Commonly agglomerating[e] Agglomerating
III. Subbituminous	1. Subbituminous *A* coal	...	...	...	...	10 500	11 500	Nonagglomerating
	2. Subbituminous *B* coal	...	...	...	...	9 500	10 500	...
	3. Subbituminous *C* coal	...	...	...	...	8 300	9 500	...
IV. Lignitic	1. Lignite *A*	...	...	...	...	6 300	8 300	...
	2. Lignite *B*	...	...	...	...	...	6 300	...

[a] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[b] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[c] If agglomerating, classify in low-volatile group of the bituminous class.

[d] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[e] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile *C* bituminous group.

TABLE 2 ANALYSES OF TIPPLE SAMPLES FROM THE DANDEE MINE
(Analyses by U.S. Bureau of Mines)

SAMPLE/ CONDITION	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS						CALORIFIC VALUE (Btu)	ASH-SOFTENING TEMP. (°F)
	MOISTURE	VOLATILE MATTER*	FIXED C	ASH	H	C	N	O	S	ASH		
No. C–30859, 8 tons 1–inch lump:												2260
As received	17.9	33.1	41.3	7.7	6.1	57.2	1.3	26.7	1.0	7.7	10,110	
Air dried	7.6	37.3	46.4	8.7	5.4	64.4	1.5	18.8	1.2	8.7	11,380	
Moisture free		40.3	50.3	9.4	5.0	69.7	1.6	13.0	1.3	9.4	12,310	
Moisture and ash free		44.5	55.5		5.5	77.0	1.8	14.3	1.4		13,600	
No. C–30860, 2 tons 1–inch slack:												2200
As received	19.5	32.1	39.1	9.3					1.1		9,640	
Air dried	7.5	37.0	44.8	10.7					1.3		11,080	
Moisture free		39.9	48.6	11.5					1.4		11,980	
Moisture and ash free		45.1	54.9						1.6		13,540	

Samples collected by Herbert Fowler, Coal Sampling and Inspection Section, U.S. Bur. Mines, Nov. 30, 1944.

*Determined by modified method.

were removed. Locality 10 seems to have been a prospect or house mine, but fairly large slack piles near locality 1 indicate a fair-sized operation at one time.

According to A. J. Pais (written communication, 1966), deputy to William H. Hays, the State Inspector of Mines, the Dandee mine (loc. 9) was first operated by a Mr. Herron and was taken over in 1949 by Mr. Rafael Flores of Tierra Amarilla, who operated it until 1954. Mr. Flores stated that a 600-foot entry had been run into thy coal bed by Mr. Herron and that he, Flores, had run another opening in to the limit of natural ventilation before ceasing operations because of shortage of help; "The coal bed consisted of 2 feet of coal on the bottom, then 1-foot of rock, and then another foot of coal...." and "The roof was of a good sand rock material, requiring only single stick timber for support." (A. J. Pais, written communication, 1966).

RESOURCES

The coal resources of the Tierra Amarilla coal field cannot be quantitatively evaluated in much of the field because of a lack of information. However, data collected in the western part of the field are sufficient to allow some general conclusions about the thickness, persistence, and distribution of some individual coal beds and to allow some very conjectural resource estimates.

In the western part of the field, the stratigraphic sequence that contains the lower bed of the lower coal group was examined at seven different localities, but the coal is either absent from or very thin at all but three. In the dissected southwestern part of the field, the coal bed is about 28 to 31 inches thick over an area of about 15 acres and may be 14 to 28 inches thick in an additional area of about 270 acres.

The upper bed of the lower coal group seems to be very lenticular in the part of the coal field west of Rito de Tierra Amarilla and is more than 14 inches thick in only two small areas. The bed is more persistent, however, in the area surrounding the Dandee mine (loc. 9) and is from 28 to 36 inches thick over an area of about 205 acres. The bed is probably from 14 to 28 inches thick over an additional contiguous area of about 855 acres.

If these assumptions are true, the lower bed might have originally contained as much as 60,000 tons of coal where it is more than 28 inches thick and as much as 835,000 tons where it is 14 to 28 inches thick; the upper bed might have originally contained as much as 945,000 tons of coal where it is 28 to 36 inches thick and as much as 2,650,000 tons where it is 14 to 28 inches thick. Because of a lack of data on past production in the field, no allowances have been made for coal that has been mined or rendered unrecoverable by past mining activities. It must be emphasized that because of the sparseness of measured-thickness information and the demonstrated extreme lenticularity of the coal beds, the foregoing resource estimates are very conjectural and should certainly be categorized as "inferred resources" (Averitt, 1961, p. 22).

The resource potential of the eastern part of the field is largely unknown, but the existing information indicates that the Mesaverde Group probably contains little or no coal in that area.

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