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COAL-BEARING FORMATIONS IN THE WESTERN PART OF THE SAN JUAN BASIN OF NEW MEXICO

By

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INTRODUCTION

This article is intended as a general guide to the coal deposits in the western part of the San Juan Basin in New Mexico. There is no implication of total, complete, and equal coverage of the subject in all parts of the region or for all of the formations. The deposits described in the New Mexico portion of the Basin extend without interruption into Colorado, and coal mining has been an active enterprise through many decades in the vicinity of Durango. The potential for development on the Colorado side of the Basin is equal in many respects to that in New Mexico.

The coal occurs through nearly the entire vertical range of Upper Cretaceous rocks, a sequence of marine and nonmarine sediments several thousand feet in thickness. Owing to the lateral changes resulting from shifting shorelines during the Late Cretaceous, coal is not distributed equally through this range throughout the area of interest. Coal occurs in the lagoonal facies associated with both transgressive and regressive movements of the sea. During Cretaceous time the shorelines were shifting nearly constantly either in a transgressive direction towards the south (landward) or northeasterly (seaward) in regressive movements. The lagoonal facies are closely associated with beach and near-shore sand deposits on the one side and fluviatile noncoal-bearing continental deposits on the other side. Occurrences of coal are noted in the lowermost transgressive deposits which comprise a portion of the Dakota Sandstone, and as the Late Cretaceous epoch drew to a close, coal is found in abundance in the final regressive lagoonal deposits which constitute the Fruitland Formation. Inasmuch as the southern part of the San Juan Basin contains a relatively greater abundance of nonmarinc strata as compared with the Upper Cretaceous sequence in the northern part of the San Juan Basin, the southern San Juan Basin contains a larger number of coal-bearing units in proportion to the total thickness of the preserved rocks. However, greater erosion in the southern part of the San Juan Basin has preserved only the earlier Late Cretaceous rocks in that area, and with but one exception all of the commercial coal deposits in the southern San Juan Basin are older than the coal-bearing units in the San Juan River area. In the following paragraphs the various coal-bearing formations in the western San Juan Basin are described and considered briefly in varying detail. The areal distribution of these units is shown in the accompanying map (fig. 1), and the stratigraphic relationships are presented diagrammatically in figure 2.

COAL-BEARING UNITS

DAKOTA SANDSTONE

The Dakota Sandstone is relatively unimportant as a potential coal-producing formation in the area covered by this report. However, coal does occur in thin stringers and lenses in varying degrees of concentration throughout the San Juan Basin. Coal has been mined from the Dakota on a very limited scale in several localities in the area of interest, but mainly it has been used by the Navajo Indians for minor domestic purposes. Generally the coal occurs in a nonmarine, carbonaceous sequence in the medial part of the formation. At several localities coal has been observed in the uppermost part of the Dakota in approximate contact with the overlying Mancos Shale.

GALLUP SANDSTONE

The Gallup Sandstone, the lowermost formation in the Mesaverde Group, has its maximum development in the vicinity of Gallup, or in the southern part of the San Juan Basin, but it can be traced with interruption northward to the vicinity of the San Juan Basin where, in the outcrop, it become difficult to distinguish from the enclosing Mancos Shale. From the San Juan Basin southward to the Chuska Mountains the Gallup Sandstone contains minor lenses of coal. The writer has observed local developments with thicknesses of three to four feet. South of the obscured area beneath the Chuska Mountains the Gallup Sandstone contains increasing amounts of coal in the upper part which are related to the overlying coal-bearing Dilco Coal Member of the Crevasse Canyon Formation. In the vicinity of Gallup, actually a few miles to the west, coal beds which have been commercially exploited were shown by Sears (1925, p. 17) to occur stratigraphically below the top of the Gallup Sandstone as defined by Sears at Gallup.

DILCO COAL MEMBER OF THE CREVASSE CANYON FORMATION

The Gallup Sandstone is transitional with the overlying Dilco Coal Member of the Crevasse Canyon Formation, a sequence which essentially represents the regressive lagoonal deposits associated with the Gallup regression. The coal in the Dilco is culminated in what have been excellent coal deposits in the vicinity of Gallup. The coal sequence thins rapidly in a northerly direction and is present in less imposing quantities along the outcrops flanking the north side of the Zuni Mountains. Mined beds in the Dilco in the Gallup area range in thickness from two and one-half

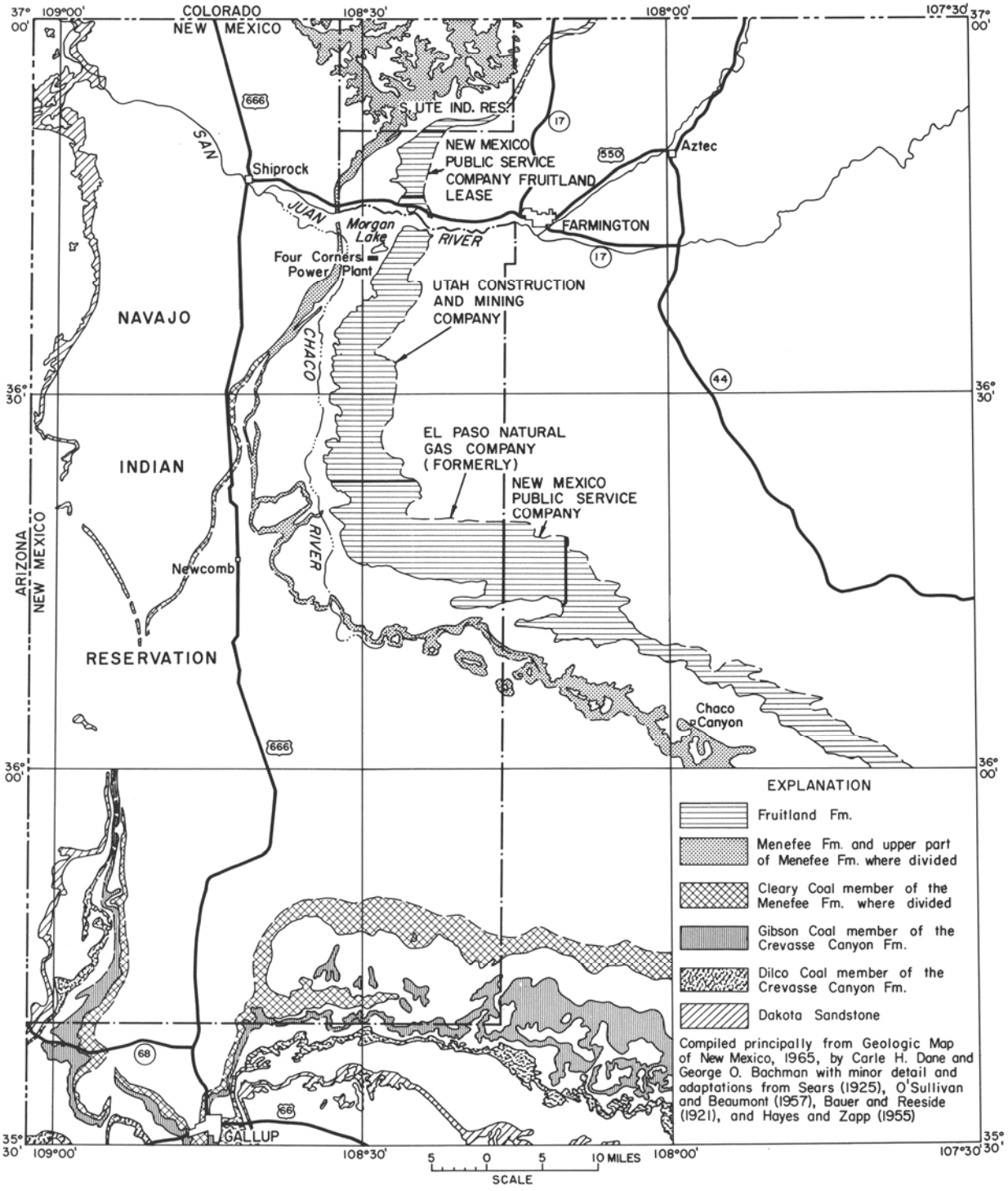


FIGURE 1.
Outcrop of coal-bearing units in the western part of the New Mexico portion of the San Juan Basin.

to seven feet. The name was derived from the small mining town located near Gallup operated by the Direct Line Coal Company. Fortuitously the optimum development of Dilco coal occurs very close to the town of Gallup, thus close to the railroad, and this unit was probably the first to be exploited in the southern San Juan Basin. On the western flank of the San Juan Basin, west and northwest of Gallup, the Dilco occurs in a much thinner sequence than the 240-300 foot thickness that it attains in the Gallup vicinity, and the writer is not aware of the presence of any coal beds which may be considered to have potential commercial value. North of the Chuska Mountains the Dilco may be present to a very minor degree in association with the "stray sandstone" (fig. 2).

GIBSON COAL MEMBER OF THE CREVASSE CANYON FORMATION

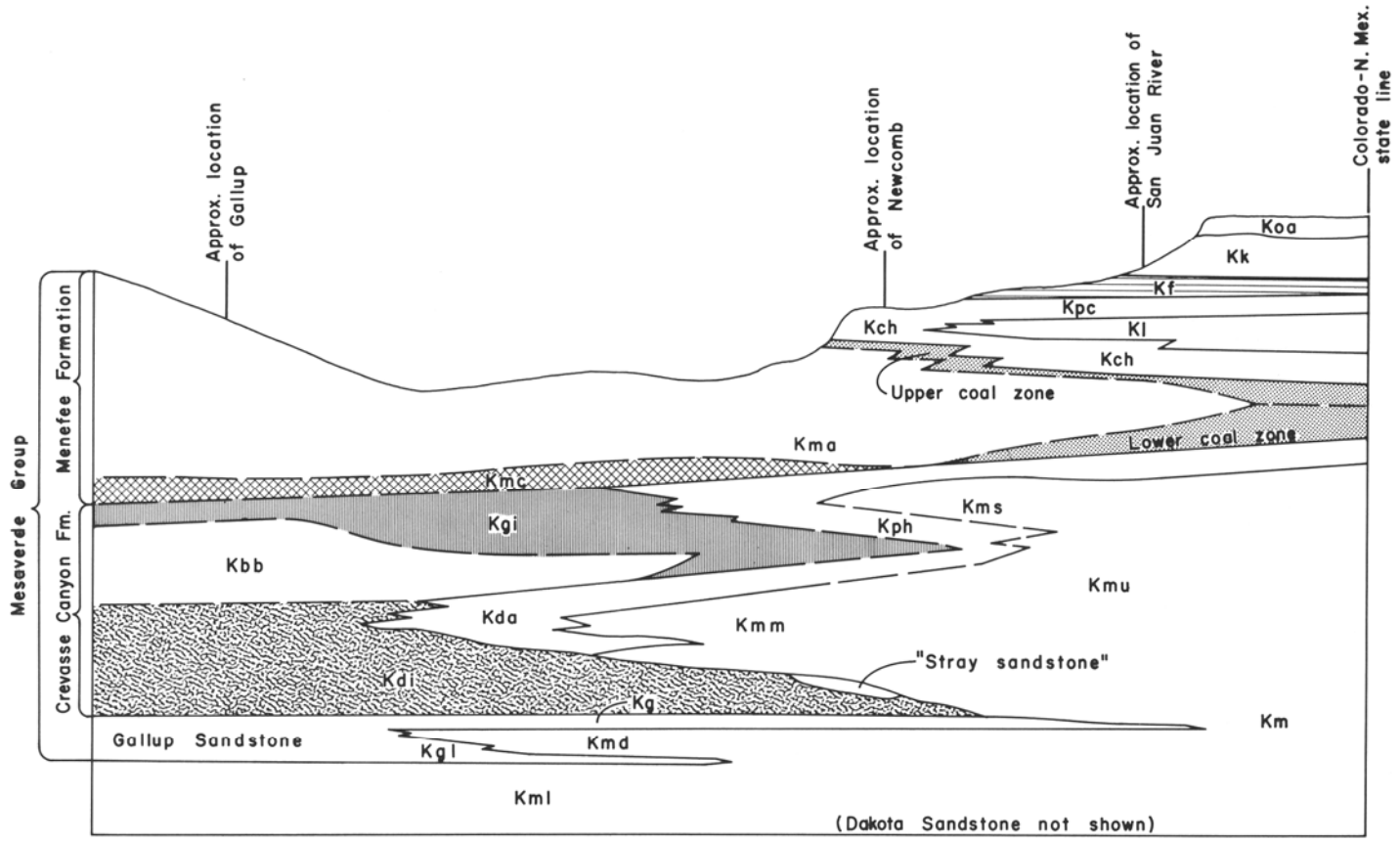
The Dilco Member is overlain by a barren interval known as the Bartlett Member of the Crevasse Canyon Formation which, in turn, is overlain by the coaliferous deposits comprising the Gibson Coal Member of the Crevasse Canyon Formation. The unit is mainly a transgressive deposit, but the lower part to the north and northeast of Gallup is thought to be of regressive origin. The regressive lagoonal facies that would be expected to be associated with the Dalton Sandstone is missing for the most part, but it may be that the uppermost Dilco beds and the lowermost Gibson strata represent this facies in parts of the Basin.

This unit was named for the small mining town of Gibson a few miles north of Gallup, and as the definitive work on this coal sequence was initially undertaken in the vicinity of Gallup, the nomenclature first used was sufficient to explain the relationships in the vicinity of Gallup but was insufficient to relate this and subsequent units to the northern Mesaverde Group. Thus, some minor changes and adaptations of the southern Mesaverde nomenclature are incorporated in a paper by this writer and others (Beaumont et al, 1956) that resulted in some nomenclatural difficulties in the immediate vicinity of Gallup. Working northward and eastward from Gallup, Sears (1925 and 1934) recognized that the Gibson coal-bearing sequence, which comprised a single unit in the vicinity of Gallup, was split by a massive sandstone unit which was in turn split by a marine shale unit. Thus the Gibson was divided by Sears into upper and lower parts. The lower Gibson of Sears has been retained as the Gibson Coal Member of the Crevasse Canyon Formation and the upper Gibson of Sears, that part which lies above the Point Lookout Sandstone both to the northeast and northwest of Gallup, has been renamed the Cleary Coal Member of the Menefee Formation. In the vicinity of Gallup, beyond the southernmost occurrence of the Point Lookout Sandstone, this treatment of this sequence has resulted locally in the artificial interjection of a formational boundary within a continuous coal-bearing sequence (figs. 1 and 2). The separation between the Gibson Coal Member of the Crevasse Canyon Formation below and the Cleary Coal Member of the Menefee Formation above cannot be traced beyond the southward pinchout of the Point Lookout Sandstone, and it would not be reasonable or practical to attempt to separate the two units. The division is illustrated in the map (fig. 1) and diagram (fig. 2) solely to emphasize the relationship that is implied. Elsewhere in the San Juan Basin the intervening formations eliminate the nomenclatural difficulties that are found in the vicinity of Gallup. Thus, from a practical standpoint, the Gibson-Clearly coal sequence cannot be divided in the vicinity of Gallup and at the McKinley Mine of the Pittsburg & Midway Coal Company located a few miles to the northwest of the town of Gallup. Mining operations can quite properly be said to be occurring in the combined Clearly-Gibson Coal Members of two formations in question.

The McKinley Mine was opened in January of 1962. Coal, bituminous in rank, is strip-mined from a sequence of six coal beds varying considerably in thickness and distribution. One bed, the Blue Seam, which ranges in thickness from four to fifteen feet, provides most of the mine's output. The coal is removed by railroad to Joseph City, Arizona where it is converted to electrical power in the Cholla plant belonging to Arizona Public Service Company. The McKinley Mine operates considerably below its one million ton per annum capacity, and in 1965 the mine produced about 369,000 tons of coal.

CLEARY COAL MEMBER OF THE MENEFEE FORMATION

As previously discussed, in the southernmost part of the San Juan Basin it is impractical to attempt to distinguish between the underlying Gibson Coal Member of the Crevasse Canyon Formation and the overlying Cleary Coal Member of the Menefee Formation. A few miles to the northwest and to the northeast of Gallup, the coal sequence is interrupted by a northward- and northeastward-thickening sand wedge, the upper part of which becomes the Point Lookout Sandstone Formation, the lowermost unit of the Mesaverde Group in the northern part of the San Juan Basin in both New Mexico and Colorado. In the vicinity of the San Juan River, the Menefee Formation is involved structurally in the Hogback monocline and the total thickness of the formation is about 1,000 feet. Coal occurs through much of this 1,000-foot sequence but is more abundant in the upper and lower parts. Immediately north of the San Juan River several small coal mines have been operating in coal beds near the base of the Menefee Formation for a number of years. South of the San Juan River coal beds of minor consequence are recognized in the lower several hundred feet of the Menefee Formation. As the outcrop of the lower part of the Menefee Formation approaches the covered area of the Chuska Mountains the thickness of coal in this sequence diminishes essentially to zero. The decreasing abundance of coal is associated, this writer believes quite significantly, with local thinning of the underlying Point Lookout Sandstone. South of the Chuska Mountains and also to the southeast in the Zuni Mountains outcrop belt, coal beds in the lowermost Menefee Formation increase in abundance and culminate to economic advantage in the combined Cleary-Gibson coal-bearing sequence in the vicinity of Gallup. Southward from Gallup, in the Gallup structural sag, coal in this sequence decreases in abundance and importance.



		SYMBOL	NAME	NOTES
		Tc	Chuska Sandstone	
		Koa	Ojo Alamo Sandstone	
		Kk	Kirtland Shale	
		Kf	Fruitland Formation	
		Kpc	Pictured Cliffs Sandstone	
		Kl	Lewis Shale	
		Kch	Cliff House Sandstone	Cliff House Sandstone replaces Chacra Sandstone throughout the former extent of that unit—the older and stratigraphically lower sandstone present at the top of the Mesaverde on the eastern side of the San Juan Basin is now considered the La Ventana tongue of the Cliff House Sandstone.
		Kt	Tohatchi Formation of Allen and Balk	Uppermost formation of Mesaverde group in the southern part of the Chuska Mountains. U.S.G.S. retains original spelling of Tohachi.
		Kkf	Kirtland and Fruitland Formations undivided	This unit was mapped by Zieglar in the vicinity of Toadlena.
Mesaverde Group	Menefee Formation	Kma	Allison Member	Formerly Allison Barren Member.
		Kmc	Cleary Coal Member	Formerly upper Gibson Coal Member.
		Kpl	Point Lookout Sandstone	Formerly Hosta and upper Hosta Sandstone of the southern part of the San Juan Basin.
		Kph	Hosta tongue of the Point Lookout Sandstone	Formerly lower Hosta Sandstone. Includes lower Gibson Coal Member of Previous usage.
	Crevasse Canyon Formation	Kgi	Gibson Coal Member	
		Kbb	Bartlett Barren Member	
		Kda	Dalton Sandstone Member	
		Kdi	Dilco Coal Member	
	Gallup Sandstone	Kg	Gallego Sandstone Member	
		Kgl	Lower Gallup Sandstone	
		Km	Mancos Shale	
		Kml	Lower part of Mancos Shale	
		Kmu	Upper part of Mancos Shale	
		Kmd	D-cross tongue of Mancos Shale	
		Kmm	Mulatto tongue of Mancos Shale	
		Kms	Satan tongue of Mancos Shale	

FIGURE 2.

Diagram showing stratigraphic relations and distribution of coal in the Mesaverde Group, Mancos Shale and related formations in the western and southern parts of the San Juan Basin, New Mexico. From Road Log, Second Day, by R. B. O'Sullivan, E. C. Beaumont, and L. M. Knapp; Four Corners Geological Society, Second Field Conference, "Geology of Southwestern San Juan Basin," 1957, p. 187.

Coal in the underlying Gibson Member represents transgressive deposition and the corresponding regressive facies is represented by the Cleary.

The organic matter, and consequently the amount of coal, contained in these strata was, in this writer's opinion, in large part controlled by the rate of transgressive or regressive movement of the shorelines. The writer feels that the abundance of coal in the combined transgressive and regressive sequence in the vicinity of Gallup represents a period of relative stability that occurred near the end of a major transgressive phase and just prior to and in the early stages of the major regressive phase associated with the Point Lookout regression. The writer feels that during this period the shorelines remained relatively constant, oscillating perhaps locally but with no major movements, so that environments favorable to floral abundance and organic accumulation remained relatively stable and localized. As the regression gained momentum and the shorelines retreated seaward, it would appear that the rate of regression increased to a maximum in the vicinity of Newcomb where the Point Lookout sandstone, representing the near shore and beach sand deposits, was deposited in a thickness of only a few tens of feet compared with thicknesses of over two hundred feet both to the south and to the north of this locality.

The associated lagoonal deposits are correspondingly thin. The writer is saying that, in effect, there was insufficient time for the accumulation of organic material that would result in the formation of coal at a given locality. As the regressive shorelines approached the vicinity of the San Juan River in southernmost Colorado, the rate of regression began to diminish and the major regressive phase is marked by several minor transgressive interruptions represented by minor intertongues between the Point Lookout Sandstone and the Menefee Formation to the north of the San Juan River. Thus, in the vicinity of the San Juan River and northward into Colorado, economically important coal beds occur in the lowermost portion of the Menefee Formation. At what point the Cleary Member ceases to be defined and at what point it becomes appropriate to refer to the coal beds in the lower part of the Menefee Formation simply as such, or as the "lower coal zone," this writer does not care to define; but it is apparent from the work that has been done that the Cleary Coal Member of the Menefee Formation in the southern and eastern San Juan Basin is equivalent to, but somewhat older than, the coal beds in the lower part of the Menefee Formation in the vicinity of the San Juan River and Mesa Verde National Park.

UPPER PART OF THE MENEFEE FORMATION

The regression associated with the deposition of the Point Lookout Sandstone in the lower part of the Menefee Formation was followed by a major transgression which resulted in deposition of the upper part of the Menefee Formation and the overlying Cliff House Sandstone, the uppermost formation in the Mesaverde Group in northernmost New Mexico and southern Colorado. This major transgression resulted in a movement of the shoreline from the vicinity of Pagosa Springs, Colorado to a position somewhere intermediate between Shiprock and Gallup. This major transgression resulted in the deposition of the upper part of the Menefee Formation, the nonmarine facies of the regression and the shoreline and nearshore sand deposits of the Cliff House Sandstone. Closely associated with the Cliff House Sandstone are the underlying coal measures of the upper part of the Menefee Formation. At the San Juan River there is essentially no coal, or perhaps it might be more accurate to describe it as scattered lenses and stringers of coal in this portion of the section. Southward from the river along the face of Hogback Mountain this situation persists and the only coal of any possible consequence in the Menefee Formation is in the lower part as previously described. Near the south end of Hogback Mountain, several miles south of the San Juan River, the lowermost massive sandstone of the Cliff House Sandstone pinches out and a sizable intertongue of Cliff House and Menefee can be noted. Coal beds occur in abundance in the Menefee tongue and its projected interval to the south, and in the process the Menefee gains in thickness on the order of 300 feet. The coal beds associated with this tongue decrease in abundance southward but a series of similar tongues between the Menefee and the Cliff House can be observed for the next 25 to 30 miles. In each instance there is an abundance of coal associated with these tongues. Also, the thickness of the Menefee Formation more than doubles in this distance.

As can be seen by the map (fig. 1), the outcrop of the upper part of the Menefee Formation diverges greatly from that of the lower part of the Formation. The actual thickness of Menefee rocks that might have been attained in the west-central portion of the San Juan Basin is difficult to determine due to lack of preservation and lack of ability to reconstruct the sedimentary situation in that area. The coal beds in the upper part of the Menefee Formation are discontinuous, and they are lenticular almost to the point of being stubby. The writer has observed bits of nearly pure coal on the order of 15 to 20 feet in thickness that terminate very abruptly in a north-south direction, and it is quite obvious that these thick developments of coal are very closely related to the intertongues between the Menefee and the Cliff House. As the major transgressive phase was interrupted from time to time by minor regressive sub-phases, the rate of movement of the shoreline was (by this writer's interpretation) reduced to nearly a standstill both as the reversal from transgression to regression was made and again as the reversal from regression to transgression was put into effect. These decreases in the rate of movement resulted in more nearly static conditions which resulted in thickened local accumulations of organic debris and thus, coal. The stratigraphic position of the coal beds in the upper part of the Menefee Formation rises considerably from north to south as the overall thickness of the Menefee Formation increases, and there are no equivalent coal beds to those in this unit in the southern part of the San Juan Basin. Although it cannot be proved, it is very likely that at one time the coal beds associated with the upper part of the Menefee, the transgressive phase, were continuous and coalesced with the regressive phase that formed the deposits of the Fruitland Forma-

tion. The rocks in the interval in which this phenomenom probably occurred have been removed by erosion but the likelihood of this occurrence can be projected on the basis that the Cliff House Sandstone is observed to merge with the regressive Pictured Cliffs Sandstone in the western part of the San Juan Basin. By analogy with the observable situation in the vicinity of Gallup, it can be speculated that an optimum development of coal probably occurred in the interval in which the two coal-bearing units merged; in other words, landward beyond the projection of the coalesced Cliff House and Pictured Cliff sandstones.

It should be observed that, unfortunately, the coal in the upper part of the Menefee Formation is nearly everywhere structurally involved in the Hogback Monocline to the extent that clips of 20 to 30 degrees are common. As the Hogback Monocline decreases in intensity southward, the coal in the upper part of the Menefee likewise decreases in prominence and economic potential. The maximum development of coal in this interval in New Mexico occurs between the San Juan River and the Burnham Road a few miles to the northeast of Newcomb, New Mexico. The coal is quite commonly burned on the outcrop and in a few places where burned coal has been observed, an abundance of pyrite has been noted. The writer attributes the propensity for burning to the pyrite content of this coal. It might be noted that in the vicinity of Newcomb, in the Captain Tom Wash Area, coal in the upper part of the Menefee Formation is much less abundant than would be indicated by the abundance of coal burned that can be observed. A bit of scratching behind the burns reveals that the clinkered shale is principally the results of oxidation of highly carbonaceous shale rich in pyrite and containing a minor amount of coal.

FRUITLAND FORMATION

In the final regression of the Late Cretaceous sea there was deposited along the western margin of the San Juan Basin and on into southern Colorado a sequence of coal beds closely associated with the regressive sand deposit, the Pictured Cliffs Sandstone. The coal-bearing sequence is known as the Fruitland Formation, and without doubt the Fruitland contains the most economically significant coal in the region. The coal in the Fruitland Formation is relatively low in BTU content—having an average of somewhat less than 9,000 BTU's per pound over much of its extent, but it has the definite advantage over all the other coal-bearing formations of being readily available to strip-mining techniques. Near the northern boundary of New Mexico the Fruitland Formation is caught up in the Hogback Monocline. To the south of this area dips in the Fruitland range from less than 1 degree to 2 degrees for many miles (see map). The Fruitland Formation is overlain by and grades into the non-coal-bearing Kirtland Formation, and the principal difference between these two is the presence or absence of coal. However, the Fruitland definitely is more nearly a lagoonal phase as opposed to the fluviatile and lacustrine environment represented by the overlying Kirtland.

As a regressive deposit, the base of the Fruitland Formation can be presumed to rise stratigraphically toward the north along the line of outcrop. Thus the coal beds in the Fruitland can be likewise presumed to become progressively younger from south to north, and it is reasonable to suppose that the lowermost or basal coal in the Fruitland Formation in the vicinity of the Colorado line is equivalent in age to one of the uppermost beds in the Fruitland in the southern area of the Formation's presence on the Navajo Reservation.

In the southeastern portion of the map area the Fruitland contains only minor coal in several thin beds. Observations on the outcrop by Bauer and Reeside (1921) reveal the presence of one or two beds having thicknesses of 3 to 4 feet, but at most points of observation the coal is considerably diluted by shale partings. It might be added that in general the coal in the Fruitland Formation is dirty, at least by comparison with coal beds in the earlier formations of the Cretaceous period. Northwesterly toward the Navajo Reservation, the Fruitland increases in coal content and thus in economic potential. In the New Mexico Public Service Company Bisti Block, immediately adjacent to the Navajo Reservation, there are four coal beds with definite economic potential. As elsewhere, these beds tend to be more or less dirty, i.e., either with thin shale partings or dispersed clay and silt, and the BTU value of this coal is much as it is elsewhere south of the San Juan River. The lowermost bed in the Bisti Block has the maximum areal extent and is the most accessible to strip-mining. This bed contains gross thicknesses in excess of 16 feet locally and the average thickness would be on the order of 10 feet. As the formation passes westerly onto the Navajo Reservation, into the area formerly leased to El Paso Natural Gas Company, there are a total of six coal beds having economic importance. Again, the lowest bed in the formation would appear to have the greatest potential in terms of tonnage, but the succeeding four beds also contribute extensively to the stripping potential of this block. In the Utah Construction & Mining Company lease block which extends for about 25 miles northward from the foregoing area to the San Juan River, there are 8 minable coal beds. The writer is not aware of the details of distribution of the various beds in this block, but it is presumed that all are not equally minable throughout the lateral extent of this lease. Considerable variation in had quality is encountered in the mining in this lease. It is necessary to blend the coal to maintain quality control for feed to the Arizona Public Service Company power plant. North of the San Juan River and south of the Southern Ute Indian Reservation, Arizona Public Service Company controls nearly all of the Fruitland coal in their Fruitland lease. In this area the commercially potential coal is essentially restricted to the basal coal bed which throughout most of the area is divided into two lesser units by an intervening split of shale. Distribution of this coal is not uniform throughout the six mile stretch of this lease, and it is recognized that one or more higher beds do possess some economic potential in the area. In contrast to the coal south of the San Juan River, the coal on the Public Service Company Fruitland lease is somewhat cleaner in nature and consequently has a somewhat higher BTU value. A short distance north of the Public Service

Company lease in the southernmost part of the Southern Ute Indian Reservation, the Fruitland coal beds are caught up in the pronounced fold of the Hogback monodine. Were it not for this involvement in the local structural steepening, the Fruitland coal in this area would have a great potential, for the lowermost bed contains thicknesses in excess of anything observed farther to the south. Hayes and Zapp (1955) observed gross thicknesses for this bed in excess of 35 feet a few miles south of the Colorado line. Of this total thickness a considerable portion is waste in the form of shale partings, but nevertheless there are several intervals from 7 to nearly 10 feet of nearly pure coal intervening. The dominance of this lower coal in the Fruitland carries into Colorado, and in the vicinity of Durango, Zapp (1949) indicates graphically a thickness of the carboneral bed (as it is called in this region) in excess of 200 feet. In this area the coal is quite shaly and impure, but nevertheless this thickness of coal represents a considerable reserve in southern Colorado.

On the basis of exploration and development drilling that has been done by various companies, it is possible to summarize the stripable coal reserves of the Fruitland Formation in the area of consideration. In the area covered by figure 1 it is possible to project a tonnage of stripable coal that by present day economic standards amounts to nearly 1.8 billion tons. These figures are derived as follows:

	MM Tons
(1) To southern boundary of Southern Ute Indian Reservation	10 (Est.)
(2) Fruitland lease of the New Mexico Public Service Company	50+
(3) Utah Construction & Mining Company Navajo lease	1,100
(4) Former El Paso Natural Gas Company Navajo lease	450+
(5) Public Service Company of New Mexico Bisti lease	130
(6) Remaining area to southwest edge of map	30+
	1,770

With the exception of the Utah Construction figures, these reserves take into account only that coal which can be won at depths of 120 feet or less. The Utah Construction figures presume that stripping can take place to a maximum depth of 180 feet for successive beds below the upper bed. If this same scheme were to be applied to the other areas under consideration, it would seem quite likely that the stripable reserves for the Fruitland Formation in the area of consideration could be extended to 2 billion tons.

As coal deposits go, the coal in the Fruitland is not of a particularly impressive quantity, nor for that matter is the quality anything to become excited about. However, from an economic standpoint and strictly on the basis of BTU content, the coal in the Fruitland Formation is readily available and quite inexpensive to mine. I have no figures on the actual cost of mining this coal, but it is generally known that the coal supplied to Arizona Public Service Company has a price tag of about $2.50 per ton. Also it is acknowledged that coal which will be supplied to the new generating facilities at the plant will be priced somewhere closer to the $2.00 level.

DEVELOPMENT ACTIVITIES

Aside from the Pittsburg & Midway Coal Company activities at the McKinley Mine in the vicinity of Gallup, all of the interest seems to be focused on the Fruitland Formation. Utah Mining and Construction Company pioneered this activity when it first became interested in the area in 1953. Early exploration activity resulted in the company obtaining a lease which has grown to somewhat over 31,000 acres, extending from the San Juan River southward for about 25 miles (fig. 1). At the present time this mining activity is supplying coal for power generation at the rate of about 2½ million tons per year, but when the power generating facilities have been expanded to the projected maximum of 2,085,000 kilowatts, the mine will be producing at the rate of 8,500,000 tons per year which will make it the largest coal mine in the United States in terms of production. Even at this fantastic rate of 8,500,000 tons per year, a reserve of over a billion tons means adequate coal for considerably more than 100 years. And, of course, it must be realized that additional productive capacity for this mine may develop as additional uses for this coal come to light.

The tremendous energy resource represented by even one small unit of coal in but a portion of the San Juan Basin is staggering. In recent months a vast new petroleum resource is reported to be taking form in the Northern Slope of Alaska. This giant field is estimated to contain possibly ten billion barrels of recoverable reserves, and it is acknowledged to be one of the largest fields (if not the largest) ever found in North America, and to rank among the giants of the world. This is truly a great thing for our national economy, but the small area of near-surface coal in the Fruitland Formation within the area covered by this paper represents, in equivalent terms, possibly seven billion barrels of liquid hydrocarbon.

There does not seem to be much question in the minds of the leaders of the petroleum industry that our natural petroleum resources are being sharply reduced. There would seem to be every indication that within five years coal-derived hydrocarbons will be not only necessary but economically competitive. It might be added that natural gas, required to hydrogenate the coal for conversion, is in plentiful supply in the San Juan Basin.

In order to be competitive with natural sources, it is necessary to convert coal at a rate of at least 50,000 barrels of production per day, and 100,000 barrels per day is considered a likely objective; the investment and operating costs involved in a plant of this magnitude deter hasty action. It has been estimated that the initial investment will be on the order of $300 to $400 million. No concern would plunge into this new field without exhaustive research and extensive experimental work—all of which takes time. Should the critical factors eventually become favorable, however, a coal conversion project may result in a

doubling of the present anticipated maximum production from the Fruitland Formation.

There arc strong indications that within the next decade uses other than for power generation will become dominant for the coal in this region. Research in the field of conversion of coal to liquid hydrocarbon, undertaken principally through the Office of Coal Research, have led to several interesting prospects which would seem to make this energy form an imminent reality. This type of utilization was visualized by El Paso Natural Gas Company with respect to its Navajo lease in the Fruitland Formation, although it is this writer's understanding that at least in the early stages the emphasis was on gasification. It may be significant that El Paso was joined in this venture by Consolidation Coal Company (now a division of Conoco), the leader in coal conversion technology and research. Consolidation is, to the writer's knowledge, the only company that is operating a major coal conversion pilot plant, this one located at Cresap, \Vest Virginia. At present the Cresap plant is experimenting with Eastern coals, but it is recognized that Western coals, principally those in Wyoming but also the Fruitland beds of the San Juan Basin, have a direct potential for this use. It is generally acknowledged that coal can be converted to liquid hydrocarbons to produce a yield somewhere between three and four barrels per short ton. In this instance the somewhat lower BTU value of the coal is less significant than it is when the coal is used directly for steam generation. The included volatile constituents of the coal become important with respect to liquefaction. Looking down the road, it would seem quite logical to anticipate that coal converted to other forms, namely gasoline and associated by-products, might be the future for this area. The key to competitive production of high quality liquid hydrocarbons is not only in advancing technology but also in the net cost of coal for this use.

REFERENCES CITED

Bauer, C. M., and Reeside, J. B., 1921, Coal in the middle and eastern parts of San Juan County, New Mexico: U.S. Geol. Survey Bull. 716, p. 155-237.

Beaumont, E. C., Dane, C.H., and Sears, J. D., 1956, Revised nomenclature of Mesaverde group in San Juan Basin, New Mexico: Amer. Assoc. Petrol. Geol. Bull., v. 40, no. 9, p. 2149-2162.

Dane, C. II., and Bachman, G. 0., 1965, Geologic map of New Mexico: U.S. Geol. Survey.

Hayes, P. T., and Zapp, A. D., 1955, Geology and fuel resources of the Upper Cretaceous rocks of the Barker Dome-Fruitland area, San Juan County, New Mexico: U.S. Geol. Survey Oil and Gas Prelim. Inv. Map OM-144.

O'Sullivan, R. B., and Beaumont, E. C., 1957, Preliminary geologic map of western San Juan Basin, San Juan and McKinley Counties, New Mexico: U.S. Geol. Survey Oil and Gas Prelim. Inv. Map OM-190.

Sears, J. D., 1925, Geology and coal resources of the Gallup-Zuni Basin, New Mexico: U.S. Geol. Survey Bull. 767, 53 p.

, 1934, Geology and fuel resources of the southern part of the San Juan Basin, N. Mex.; part 1, the coal field from Gallup eastward toward Mount Taylor, with a measured section of pre-Dakota (?) rocks near Navajo Church: U.S. Geol. Survey Bull. 860-A, 29 p.

Zapp, A. D., 1949, Geology and coal resources of the Durango area, La Plata and Montezuma Counties, Colorado: U.S. Geol. Survey Oil and Gas Prelim. Inv. Map OM-109.