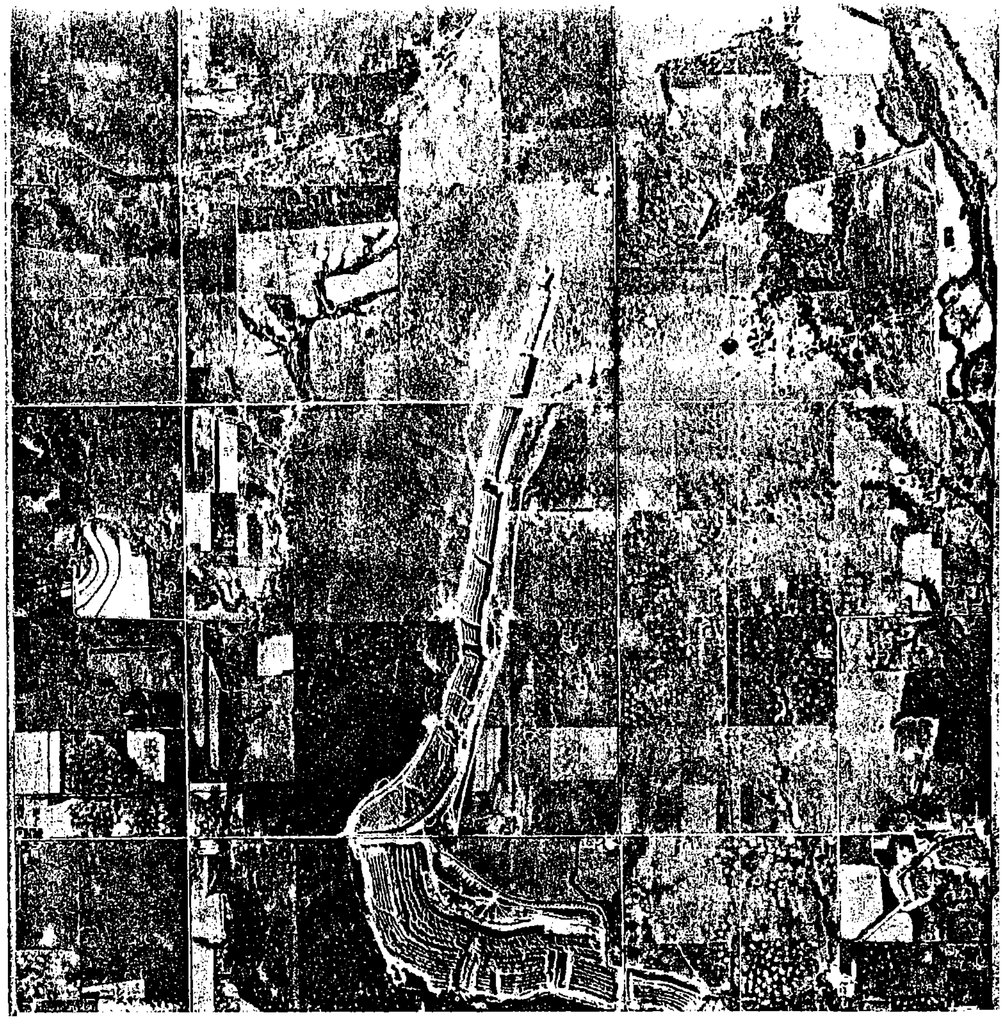


Strip-mined area in Sequoyah County showing fresh spoil and stripping operations contemporary with date of the photograph.
(Aerial photograph, U. S. Dept. Agriculture, 1952.)

OKLAHOMA GEOLOGICAL SURVEY
CARL C. BRANSON, *Director*

CIRCULAR 54

COAL MINING AND LANDSCAPE MODIFICATION IN OKLAHOMA

by

ARTHUR H. DOERR

The University of Oklahoma
Norman
March 1961

FOREWORD

Coal Beds of Oklahoma

Coal is widespread at and near the surface in eastern and northeastern Oklahoma, scarce elsewhere in the State. A few wagon mines were opened to produce coal for local consumption in a 10-inch seam of lignite in the Dakota sandstone of Cimarron County. A coal seam in and near Ralston in Pawnee County has been dug at a few places. The bed is below the Brownville limestone near the top of the Virgil series. A thin Cretaceous coal was once dug in Bryan County. Some coal has been mined near Ardmore in Carter County.

Northeastern District

The youngest coal of commercial value is the Dawson coal of the Seminole formation, once mined in Tulsa and stripped there and in and near Collinsville, and dug in a few long-abandoned pits in southern Nowata County. In Collinsville the coal has a dense concretionary limestone caprock, but the limestone weathers too slowly to affect the soil significantly.

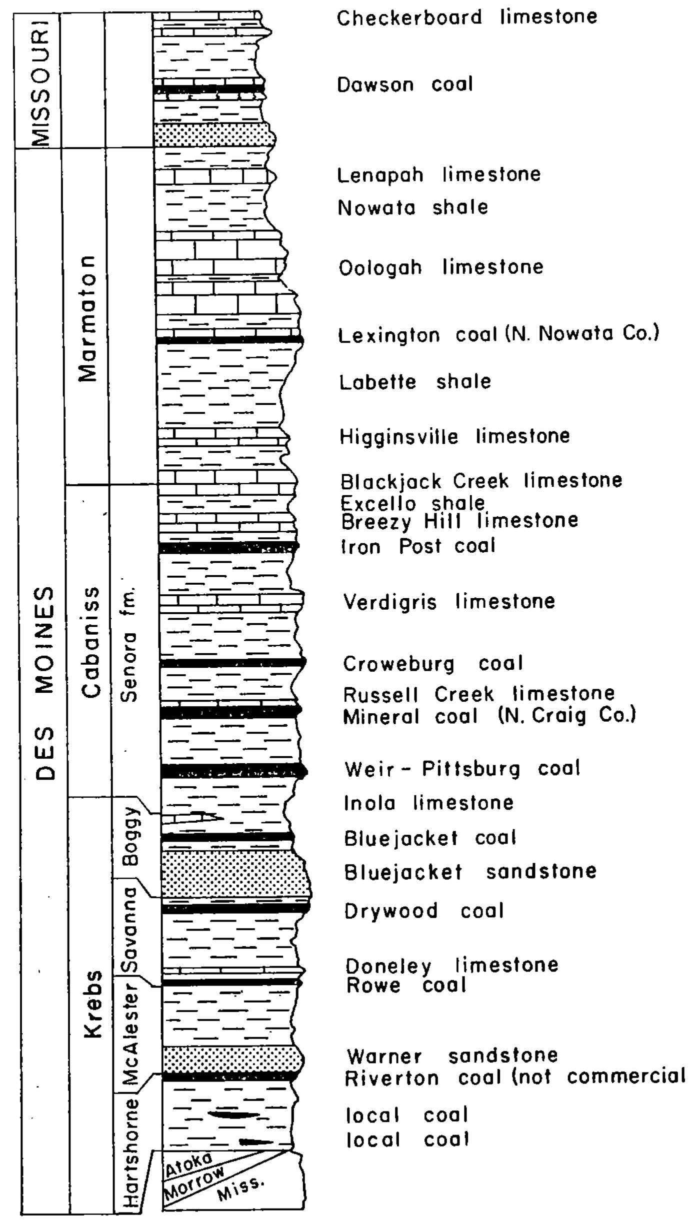
The Iron Post coal seam lies from two to five feet below the Breezy Hill limestone. The limestone is five to eleven feet thick, and operators have dug the coal only on escarpments where the limestone can be moved readily. Pits in the Iron Post coal are narrow, shallow, and parallel the edges of escarpments. The limestone and phosphate in the overlying Excello shale provide soil chemicals which aid in early revegetation, but the rock piles leave a permanent topographic irregularity.

The Croweburg coal is the most widely produced seam in the district. It has been stripped at many places from the Kansas state line across Craig County, Rogers County, and in Wagoner County (under the name of Broken Arrow coal). It has been produced by stripping and by underground mining near Okmulgee and in and near Henryetta (where it is called Henryetta coal). Ten to 40 feet above the coal is the Verdigris limestone, and the limestone is underlain by a few feet of phosphatic black shale. These rocks provide some plant nutriment in the spoil banks.

The "Sequoyah" coal lies about 40 feet below the Croweburg. The coal has been stripped at a few places in Rogers County. It lies in a shale sequence.

The Mineral coal has been strip-mined only in northern Craig County and the coal bed is not recognized farther south. Its cap rock is the Russell Creek limestone, a two-foot ferruginous impure limestone which adds carbonate and iron to the waste heaps.

The Weir-Pittsburg seam is the most important seam in southeastern Kansas. In Oklahoma it has been strip-mined in Craig County, extreme northwestern Mayes County, Rogers County, and central Wagoner County. The coal is pyritic and is overlain by black shale.



The Bluejacket coal has been mined at a few places, by drift near Bluejacket and by stripping near Estella in Craig County.

The Drywood coal has been produced in drift mines and in a shaft mine on Timbered Hill in Craig County.

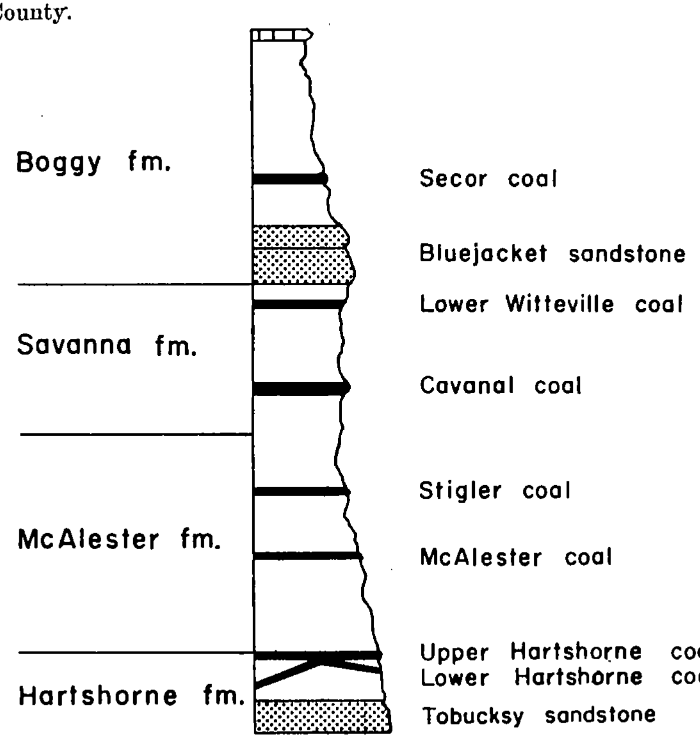
The Rowe coal has been dug in many small pits and wagon mines in Craig, Mayes, Wagoner, and Muskogee Counties. The cap rock is impure limestone which provides carbonate in the spoil banks.

Arkoma District

The Arkoma basin is the area of the thickest and best coals of Oklahoma. The youngest commercial coal of the area is the Croweburg coal, continuous from the Northeastern District, and locally called Henryetta coal. In the basin the coal is mined by shaft and by stripping as far south as Henryetta.

The Morris coal is produced by strip mining only in the vicinity of Morris in Okmulgee County. The coal may be equivalent to the "Sequoyah" coal of Rogers County.

The Eram coal was dug locally near Eram in Okmulgee County. The bed may be equivalent to the Mineral coal of northern Craig County.



FOREWORD

The Secor coal has been produced by stripping and by shaft in Muskogee and Pittsburg Counties. Locally it has an algal limestone cap rock. The Upper Witteville coal of the Poteau area may be correlative.

The Lower Witteville coal bed has been mined near Poteau. It has the stratigraphic position of the Drywood coal of the platform sediments.

The Cavanal coal seam was produced near Poteau and locally near McAlester. It lies in the Savanna formation, which contains other locally workable coal beds.

In the McAlester formation there are two commercial coal beds, the lower, the McAlester coal, mined near McAlester and under the name of Lehigh coal in the Lehigh area, and the Stigler coal mined at many places in Haskell, Le Flore, Sequoyah, and Muskogee Counties, and locally in Pittsburg County.

The Hartshorne formation contains two widely developed coal beds. The Upper Hartshorne coal is the uppermost bed of the formation, and it has been mined in Sequoyah, Le Flore, Haskell, Pittsburg, and Coal Counties. The Lower Hartshorne coal has been mined by slope, by shaft, and by stripping in Le Flore, Haskell, Latimer, Pittsburg, and Coal Counties. Near Wilburton the Upper and Lower Hartshorne seams coalesce and the united bed is ten feet thick. Mining has been by shaft, by slope, and by stripping.

—Carl C. Branson

CONTENTS

ILLUSTRATIONS

COAL MINING AND LANDSCAPE MODIFICATION IN OKLAHOMA

ARTHUR H. DOERR*

ABSTRACT

Coal mining has been carried on in Oklahoma since the middle 1800's but did not become significant until 1872, reaching peak production of 4,849,388 tons in 1920, and declining to an average of 2,000,000 tons per year in recent times.

This activity has led to the development of hundreds of underground and strip mines over an area of 14,550 square miles in the northeastern and east-central parts of the State.

Underground mining creates topographic changes through the development of waste heaps and local subsidence. Generally the waste heaps are barren of vegetation because of the toxic character of the waste.

Strip mining has led to the stripping of an estimated 12 to 18 thousand acres of land and, at the present rate, an estimated 400 acres is stripped each year. Topographic modification by strip mining depends on the characteristics of the deposits and the method of mining. Generally the resultant forms are series of parallel ridges of spoil with moderate relief; in many places lakes are formed in the last excavation made.

Revegetation of stripped areas generally proceeds at a slow rate because of toxic constituents of the spoil and because of its low organic content. Replanting with suitable plants may accelerate the revegetation process but replanting is not practiced widely in Oklahoma.

The effects of coal mining on the cultural landscape in most cases are of the boom-and-bust type where early development leads to rapid growth and prosperity of towns, followed by decline and decay as the coal resource is exhausted or loses its value for other reasons. Only those towns which can shift to another economic base can avoid the eventual decline.

INTRODUCTION

Geologists, botanists, soils scientists, geographers, and others have long been aware that man is a significant modifier of landforms, of animal and plant life, and of soils. The effects of coal mining upon the physical and cultural environment are particularly significant. Flat plains may be furrowed with strip-mine ridges; piles of waste coal or rock dot the countryside at many places in coal mining regions like miniature cinder cones; bed rock and mature soils are often overturned, reversing, in a few months

* Associate professor of geography, The University of Oklahoma.

or years, the soil-forming processes of centuries; normal ecological succession may be altered; lakes are formed; drainage patterns are disturbed, temporarily or permanently; geologic weathering can be retarded or accelerated; subsidence occasionally produces local tremors and slumps. These, and many other influences upon the physical landscape may be attributed directly, or indirectly, to the cultural act of mining coal. Some of these physical modifications are dramatic, others subtle in their impact. Many changes are transitory, whereas a few are enduring. Some influences are harmful, whereas others are useful.

The normal cultural changes in the landscape, which can be directly attributed to coal mining, must not be neglected. Coal-mining communities are born, grow, and die. Transportation facilities are constructed, utilized, and abandoned. Land-use changes are forced by edaphic and biologic alterations in the environment. Strip lakes provide recreational opportunities not previously present. Waste-coal piles supply county commissioners with new road-surfacing material. Abandoned surface or underground mines are ready-made sites for garbage or trash disposal for local residents. These sequence-occupance changes in the former pattern directly affect people and become part of history. The measurement of physical or cultural change, which may be attributed to coal mining, is a difficult thing. Most physical changes may be measured quantitatively, but only within the framework of an instant. Cultural changes must be assessed qualitatively, and such an evaluation calls for a precision which is not attainable.

The purpose of this study is to investigate in what way, and to how great an extent, coal mining has modified the landscape of Oklahoma. To this end it is necessary to describe briefly coal mining, past and present, to inventory the mining regions from an areal standpoint, and to measure and describe landform, soil, vegetation, and drainage modifications, and to assess the cultural impact upon the State. The accomplishment of these objectives has necessitated a comprehensive search of relevant literature and has entailed more than a month's detailed field work. This field work included more than 5,000 miles of driving, several miles of walking, hundreds of slope, pH, and other measurements, exhaustive examination of several score aerial photographs, numerous interviews, field mapping of mining areas, analysis of several soil samples, identification of plant species, analysis of the plant cover, and, in some areas, correlation of structural relationships. Generalizations drawn from an evaluation of the above sources of information are believed to have validity, but it must be emphasized that obvious similarities of the effect of coal mining upon the landscape from place to place may mask significant differences.

The author wishes to express his gratitude for the encouragement and assistance of Dr. Carl C. Branson, Director of the Oklahoma Geological Survey, prior to field work, and during the writing of this report. Further, the author is indebted to both the Oklahoma Geological Survey and The University of Oklahoma Faculty Research Fund for financial assistance, which enabled the author to work in the field, purchase materials, and hire necessary help. Without the assistance of the previously mentioned agencies and of persons associated with them it would have been impractical to have prepared this report. In addition, Mr. Stephen Sutherland assisted in some botanical problems.

COAL MINING — PAST AND PRESENT

It is difficult to ascertain exactly when coal mining began in Oklahoma, but in the interval from 1829-1840 some coal was stripped from exposed seams in the extreme eastern part of the State. Commercial coal mining was not significant, however, until the coming of the railroads in 1872. In that year J. J. McAlester began the mining of a four-foot bed of coal in the Choctaw Nation. As railroad facilities expanded and demand for coal increased, production rose. By 1880 coal mining had become a significant occupation. Coal production rose steadily to the all-time production peak of 4,849,388 tons in 1920 (Trumbull, 1957, p. 361-362). Over the past decade coal production has averaged approximately 2,000,000 tons per year (Malloy, 1958, p. 18-19). Since mining began in Oklahoma, more than 179,000,000 tons of coal has been mined. Of that amount, more than 36,000,000 tons has been mined by strip-mining methods. Stripping has increased rapidly since World War II, and in more recent years stripping has accounted for between two-thirds and three-fourths of the total production. This contrasts with a national average of approximately 25 percent of the coal mined by stripping. The trend toward stripping continues to be more pronounced in Oklahoma than in the nation as a whole. In spite of the recent increase in the proportion of strip mining, more than four-fifths of the cumulative production of Oklahoma coals has been mined from underground (Trumbull, 1957, p. 362-363).

All types of underground mines are, or have been, represented in Oklahoma coal mining. In the early history of Oklahoma vertical-shaft mines were more numerous, perhaps reflecting a national tendency at that time as well as the fact that the area in which most coal mining was done could not be mined practically by other means. Slope and drift mines followed, although the word drift is rarely used in Oklahoma coal-mining circles. Underground, the room and pillar system has been most widely used; however, the panel and longwall systems have also been employed.

THE OKLAHOMA COAL FIELD

The main coal region of Oklahoma is a part of the Western Interior Coal Province, and is located in the northeastern and east-central parts of the State. Coal underlies an area which has a north-south extent of about 185 miles and a maximum east-west extent of about 110 miles. This is an area of about 14,550 square miles, or slightly more than one-fifth the total area of the State. Small deposits of coal in Carter County and of lignite in Cimarron County are known to be present, but they are not commercially exploited. The main body of the Oklahoma coal field can logically be divided into northern and southeastern portions by the Canadian River and that part of the Arkansas River below their junction.

The northern part of the Oklahoma coal field lies in the Osage section of the Central Lowland physiographic province. This region is characterized by undulating to gently rolling plains country interrupted by eastward-facing cuestas of sandstone or limestone, that are more resistant than the shales, which predominate in the geologic section. Local relief of less than 50 feet is typical of most of the area, although in some places the relief along cuestas may be more than 200 feet. The southern edge of this region is somewhat hillier because of the larger amount of sandstone in the section.

The southern part of the Oklahoma coal field is essentially coincident with the Arkansas Valley portion of the Ouachita physiographic province. This region is characterized by a series of eastward- and northeastward-trending folds. Sandstones are more re-

sistant than shales, and most hills are erosional remnants guarded by sandstone beds. Higher elevations are normally found in synclines where almost flat-lying sandstone beds near the axis of the fold are more resistant to erosion. Anticlines, on the other hand, normally have little topographic expression within the region; and are cut into by streams.

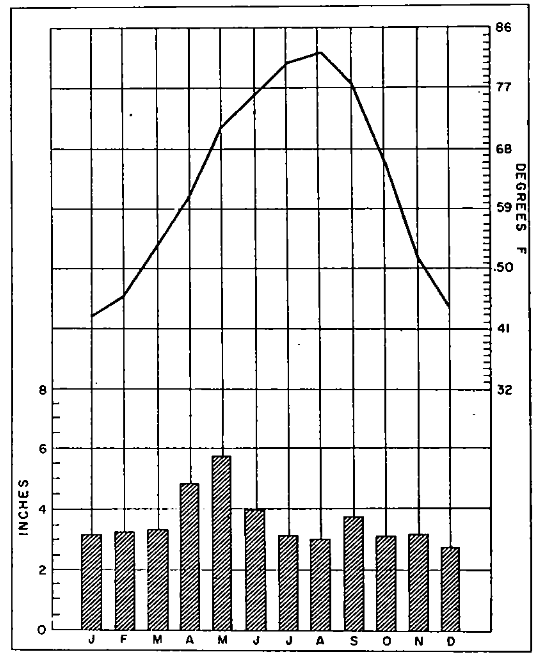


FIGURE 1. Climograph for Poteau, Oklahoma. Latitude 35°04'N., longitude 94°36'W. Elevation: 483 feet. Average annual temperature: 62°F. Average annual precipitation: 44 inches. Length of record: 36 years. All data processed with IBM cards. Reliability is higher than that of data previously published in normal outlets. (IBM cards supplied by U. S. Weather Bureau)

Most of the Oklahoma coal field has drainage to the east through the Arkansas River system, except in the far south where drainage is south to the Red River. Most streams of the area meander in broad valleys mantled with sand and silt. Smaller streams are typically intermittent (Trumbull, 1957, p. 327-329).

The climate of the Oklahoma coal field is generally classed as humid subtropical (Cfa according to the Koeppen system). Normally summers are hot and winters cool. Average annual temperatures are generally lower in the north than in the south, and precipitation decreases from southeast to northwest. January average temperatures range from about 35°F in the north to 41°F in the south, whereas July temperatures average almost 81°F for the region as a whole. Annual precipitation ranges from almost 44 inches

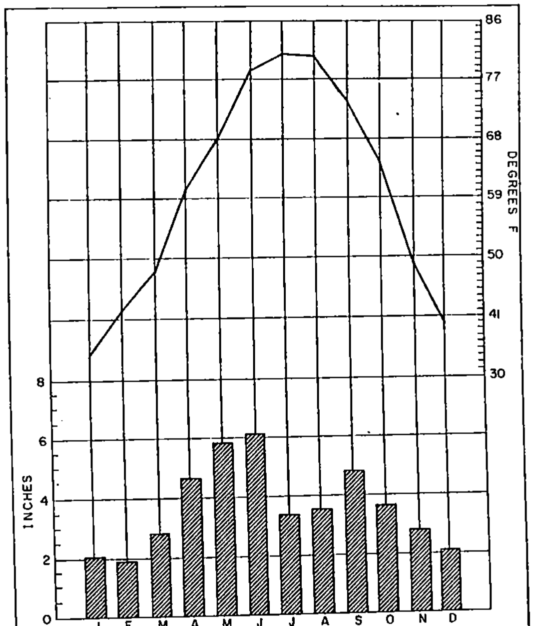


FIGURE 2. Climograph for Vinita, Oklahoma. Latitude 36°37′N., longitude 95°08′W. Elevation: 702 feet. Average annual temperature: 60°F. Average annual precipitation: 44 inches. Length of record: 36 years. All data processed with IBM cards. Reliability is higher than that of data previously published in normal outlets.
(IBM cards supplied by U. S. Weather Bureau)

near the southern margin of the region to approximately 39 inches near the northern and western boundaries of the coal field. Approximately 60 percent of the annual precipitation falls during the period from April to September (U. S. Dept. Agriculture, 1941, p. 1065-1074). Climographs of three representative stations illustrate variations extant within the coal-producing districts (figs. 1, 2, 3).*

* Averages calculated from a 36-year span from U.S. Weather Bureau IBM records. Computation by J. R. Castelli and Kenneth Morris.

Extremes characterize the climate of this portion of Oklahoma, and departures from the means may be dramatic and frequent. One-hundred-degree temperatures are common in the summer, and severe cold snaps may be anticipated in most winters. Precipitation may vary drastically from the norms, and droughts are not uncommon.

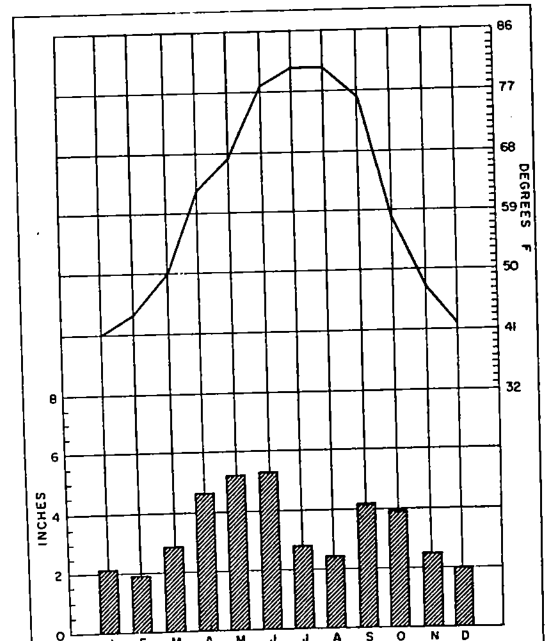


FIGURE 3. Climograph for Okmulgee, Oklahoma. Latitude 35°36′N., longitude 98°58′W. Elevation: 670 feet. Average annual temperature: 60°F. Average annual precipitation: 40 inches. Length of record: 36 years. All data processed with IBM cards. Reliability is higher than that of data previously published in normal outlets.
(IBM cards supplied by U. S. Weather Bureau)

Soils which have evolved in partial response to this climatic framework are dominantly of the planosolic, alluvial, and red and yellow podzolic great soil groups. With the exception of the alluvial soils most soils are mediocre to poor in quality.* Soils have been

* Details are available in the following U. S. Department of Agrichlture soil surveys: A. C. Anderson, A. W. Goke, O. H. Brensing, R. E. Penn, and C. B. Boatright, 1931, Soil Survey of Craig County, Oklahoma, 41 p., and plate; E. W. Knobel and O. H. Brensing, 1938, Soil Survey of McIntosh County, Oklahoma, 45 p., and plate; M. H. Layton, 1937, Soil Survey of Pittsburg County, Oklahoma, 28 p., and plate; E. W. Knobel and O. H. Brensing, 1942, Soil Survey of Tulsa County, Oklahoma, 68 p., and plates; and E. W. Knobel, C. B. Boatright, and W. C. Boatright, 1931, Soil Survey of Le Flore County, Oklahoma, 38 p., and plate.

abused for long periods, and the greater number of them are nitrogen deficient and below average in content of organic matter.

Natural vegetation which has made essential ecological adjustments to the physical environment varies from open prairie to dense forest. The northern and western parts of the Oklahoma coal field are characterized by prairie grasses such as: big bluestem (*Andropogon gerardi*), little bluestem (*Andropogon scoparius*), broomsedge (*Andropogon virginicus*), and three awn grasses (*Aristida* spp.). Bottom lands in, and adjacent to, these prairie areas are forested with white oak (*Quercus alba*), red oak (*Quercus borealis*), blackjack oak (*Quercus marilandica*), sycamore (*Platanus occidentalis*), elm (*Ulmus* spp.), pecan (*Carya illinoensis*), dogwood (*Cornus florida*), and black walnut (*Juglans nigra*). To the south and east forests become dominant, with oak, hickory (*Carya* spp.), elm, hackberry (*Celtis* spp.), pine (*Pinus echinata*), dogwood, redbud (*Cercis canadensis*), and walnut as significant species.

Economic activities of the region largely revolve about agriculture and grazing, except locally, where forestry or mineral industries may be significant. Agricultural yields are greater and farming success more assured in bottom lands on soils of the Yahola series. Man's modification of the landscape through land clearing and agricultural pursuits have long been recognized and are chronicled in various histories, geological bulletins, soil surveys, and similar sources. Landscape modifications affected by coal mining have largely been neglected previously.

UNDERGROUND MINING AND LANDSCAPE MODIFICATION

Whereas far more coal has been removed by underground mining in Oklahoma than by surface means the landscape modifications of underground mining are less dramatic. Typically the more noticeable effects are the mounds of "slack" (waste coal), "gob" (shale and other rock), and occasionally "clinkers" (cinders). These hillocks vary considerably in size. Some are small mounds 8 to 10 feet in diameter and 3 to 4 feet high, whereas large ones reach almost 100 feet in height and cover as much as an acre (fig. 4). These hills may be symmetrical, in which case they resemble small parasitic volcanic cones, or they may be oriented along asymmetrical axes.

FIGURE 4. Large waste pile from underground mine near Calhoun in NE¼ sec. 11, T. 7 N., R. 24 E.

In Oklahoma the asymmetrical waste coal ridge is by far the more common of the two. Sides of the ridges are quickly gullied and weathering of the exposed coal or rock material is generally rapid. Radial drainage patterns evolve on the conical hills, heightening the impression that these hillocks resemble cinder cones. (Indeed, in reality, not infrequently they may become cinder cones as fires purposely set or spontaneously generated produce clinkery material, physically very much like volcanic cinders.) Water debouching at the bases of steep slopes, which average almost 30° in Oklahoma, produces a series of miniature alluvial fans. Sizes are reduced and shapes altered as man removes quantities of the rocky or clinkery material for road surfacing.

Poisonous wastes present in these spoil heaps preclude the development of any significant high-order vegetation for long periods of time. Most of these hillrocks are devoid of vegetation for 20 years or more. Vegetative barrens which have been poisoned by noxious wastes carried by runoff waters persist in adjacent areas.

As plants finally invade these waste piles, more frequently they are acid-tolerant weeds and/or bushes, since in all areas tested soils and associated waters carried low pH readings.

These hillocks, particularly where sizeable, stand out as significant landscape features. They are especially noticeable from the air, because they are normally bare in areas which are heavily mantled with vegetation. Because of the nature of Oklahoma road rights-of-way these hillocks may be hidden from ground view behind a screen of fence-row brush or trees.

At least one such hillock in Oklahoma is currently burning. This hillock, left at an abandoned mine near Henryetta, is smoldering, and smoke and steam issuing from a small fissure gives a fumarole-like appearance. Sulphurous fumes condense at the surface of the hole to produce delicate crystals of pure sulphur.

Removal of coal from beneath the surface causes eventual subsidence and man-induced faulting. "Squeezes" resulting from the collapse of subterranean pillars may cause earthquake-like tremors. Such minor tremors are frequently felt in areas, such as McAlester, Hartshorne, Haileyville, and Henryetta, where underground mining has been significant. The effects of squeezes are both immediate and persistent. After a squeeze, cracks may appear at the surface, small hills may disappear, swamps may appear and drainage may be temporarily or permanently deranged. In short, man-induced faulting may produce many of the features typically associated with natural faulting. As mine pillars continue to break down additional subsidence may alter surface features radically to human detriment in populus areas.

In Oklahoma, because of the succession of potentially minable beds one above the other, the accumulation of water in abandoned workings is of considerable economic, as well as geomorphic significance. The development of a layer or pool of water of meteoric and/or connate origin in abandoned mines is usual, if not the universal circumstance, in Oklahoma. The presence of such a pool of water tends to accelerate weathering and erosion of remaining pillars and may therefore speed up and accentuate the effects of subsidence. Obviously, lower beds would be difficult, perhaps hazardous, to mine under the threat of an invasion of water under considerable hydrostatic pressure. Further, the presence of these subsurface pools necessitates leaving behind wide coal barriers between operating and

abandoned mines. Obviously, then, accumulation of water in abandoned mines lowers recovery rates or inhibits mining operations in nearby areas.

The features described above are most prevalent in regions where underground coal mining has been most significant. In short, Coal, Latimer, Le Flore, Haskell, Pittsburg, Muskogee and Okmulgee Counties show the greatest physical landscape modification attributable to underground mining, although practically all other coal-mining counties, past and present, are locally so modified.

STRIP MINING AND LANDSCAPE MODIFICATION

Some coal has been stripped from the earliest days of Oklahoma coal mining, but significant tonnages have been mined by stripping methods only since 1920 (Trumbull, 1957, p. 362). Crude equipment, removal of minimal amounts of overburden, and nature have all but obliterated the landscape modifications of early strip mining within the state. Expansion of strip mining, the use of more sophisticated earth-moving equipment, and the removal of increasing quantities of overburden have resulted in greater landscape changes in recent years. The author's crude estimates suggest that at least 12,000 acres or perhaps as many as 18,000 acres have been stripped for coal in Oklahoma. At the present time at least 400 additional acres are stripped per year. Stripping procedures are nearly uniform throughout the United States and apply, with few exceptions, to Oklahoma.

The first cut is made at an outcropping seam in hilly terrain, or at the limit of the leased or purchased property in level terrain. The overburden from the first cut is piled on the ground next to the area to be strip mined. In some cases the dragline or continuous wheel simply digs down to the coal (no continuous wheel is now operating in Oklahoma). In other sections a large shovel and dragline work in parallel-tandem operations. In this latter operation the dragline removes most of the overburden, and the shovel actually exposes the coal seam. This type of operation is most frequently employed in Oklahoma stripping regions. After the coal is drilled and blasted it is hauled by truck to a nearby beneficiation plant where it is washed and/or treated prior to shipment to market.

All the while the dragline operates continuously. At the end of the first cut the direction is reversed, and a new cut is made parallel to the first. The overburden from this new cut is dumped into the cut from which the coal has been removed. This repetitive cut-and-fill sequence continues until the limit of the minable area is reached.

Strip mining typically leaves the surface topography in a series of approximately parallel ridges and valleys. The width, height, and steepness of the ridges vary with the character and thickness of overburden, the character of the unstripped terrain, the equipment used, and the age of the spoil banks. Under comparable original stratigraphic and terrain situations, where the same kinds of mining equipment and techniques are utilized, the resultant landforms are essentially alike. Because of variations in original soil condition and vegetative cover the character of the resultant spoil and the ecological succession thereon may differ considerably from place to place.

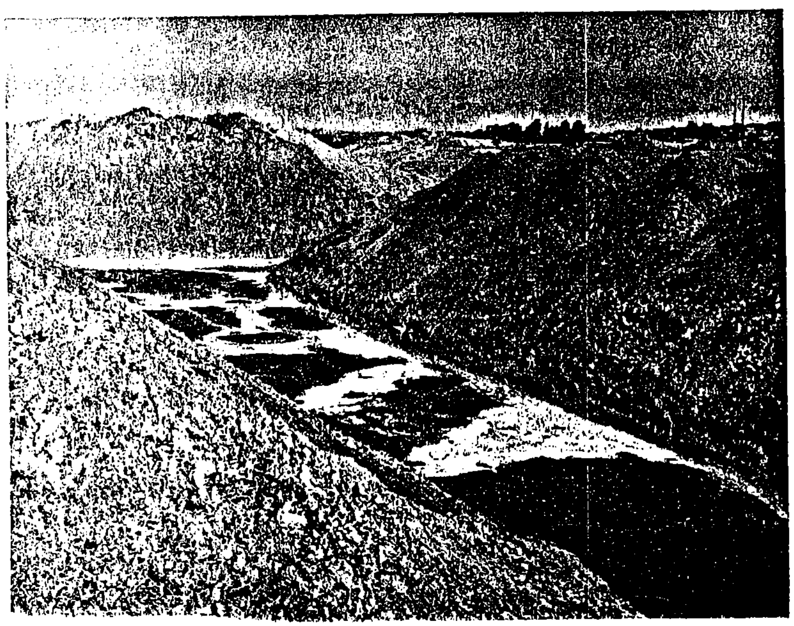


FIGURE 5. Typical relief developed in an area of thin overburden. Ridge crests stand about 25 feet above the exposed seam of Croweburg coal, and relief from ridge crest to adjacent trough is about 7 to 8 feet. Shale, siltstone, and sandstone are exposed in fresh, relatively unweathered spoil. Photograph is of a pit in sec. 34, T. 23 N., R. 16 E.

Where the coal seam is thin and is buried under a thin mantle of overburden the local relief of the stripped terrain is naturally low. The strip mining of shallow coal seams in Oklahoma typically leaves a vertical distance of from 5 to 15 feet between ridge crest and valley bottom, and the relief between the bottom of the last cut and the high wall may be only 20 to 25 feet (fig. 5). At increasing depths, up to a maximum of about 80 feet in Oklahoma, stripping produces greater local relief. Normally, in areas where the coal seam is deeply buried, the height of the last ridge crest above the bottom of the last cut may exceed 125 feet. Angle of repose of the spoil varies considerably from place to place in Oklahoma depending upon the character of the overburden and the age of the spoil. Measured angles of repose in Oklahoma range from less than 15 degrees, in old spoil with little local relief, to more than 45 degrees in fresh spoil with great local relief. The greater number of spoil banks in the state have an angle of repose between 25 degrees and 40 degrees. The most frequently measured angle was 35 degrees. As spoil banks age local relief and angle of repose lessen because of settling, erosion, and deposition. Although it is difficult to generalize, it is safe to say that local relief normally is greater in the southern part of the Oklahoma coal field. This reflects, in part, a normal response to stratigraphy, and, in part, a willingness to remove more overburden to mine the higher rank coals in the south.

Disposal of the overburden alters the terrain more than is at first apparent because the spoil occupies a greater volume than did the original overburden. Spoil actually covers a greater area than the total land area stripped. Whereas symmetry characterizes most stripped regions it should be pointed out that the first spoil is placed on unstripped land, and the first ridge is therefore higher than subsequent ridges. Further, it should be pointed out that the high wall is a vertical cliff above the floor of the last cut.

Mining equipment and methods exert an influence upon the character of the stripped terrain almost as significant as structure and stratigraphy. When draglines or power shovels are used singly a high percentage of the rock strata immediately above the coal is placed on top of the overburden. This in most cases creates sharp serrate ridges or conical banks, which, because of their steep slopes, are quickly eroded (Garner, 1953, p. 205). In Craig and Rogers Counties mining for Iron Post coal below the Fort Scott and

Breezy Hill limestones has produced a jagged rock-strewn surface, which will undoubtedly weather and erode into uncommon forms (fig. 6).

In operations where both the dragline and shovel are used in tandem operations the upper part of the overburden can be placed on top of the lower strata (figs. 7, 8). The spoil thus produced has a higher percentage of soil and is more nearly homogeneous in composition than when the dragline is used alone. This type of spoil settles rapidly, however, and erosion is severe in spite of the fact that slopes and local relief may be minimal. Variations of the fact that slopes and local relief may be minimal. Variations in the outcrop pattern of the coal seam and different sizes and shapes of the properties leased or owned account for the orientation of pits, their length, and width.

Most Oklahoma pits are long and narrow although a few in the undulating plains country of the northern portion of the Oklahoma coal province, particularly in Rogers County (Croweburg coal), and east of Checotah (Secor coal) have considerable width. Maximum

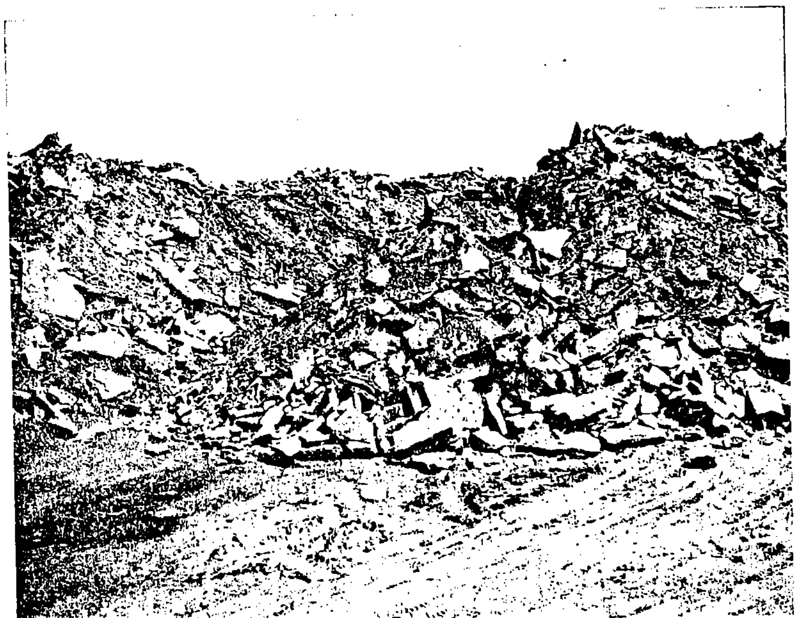


FIGURE 6. Rough surface of culm heap in west-central portion of sec. 34, T. 26 N., R. 18 E. Large broken rock is Breezy Hill limestone, which has been removed along with a total overburden of about 16 feet to mine a 12- to 18-inch seam of Iron Post coal.

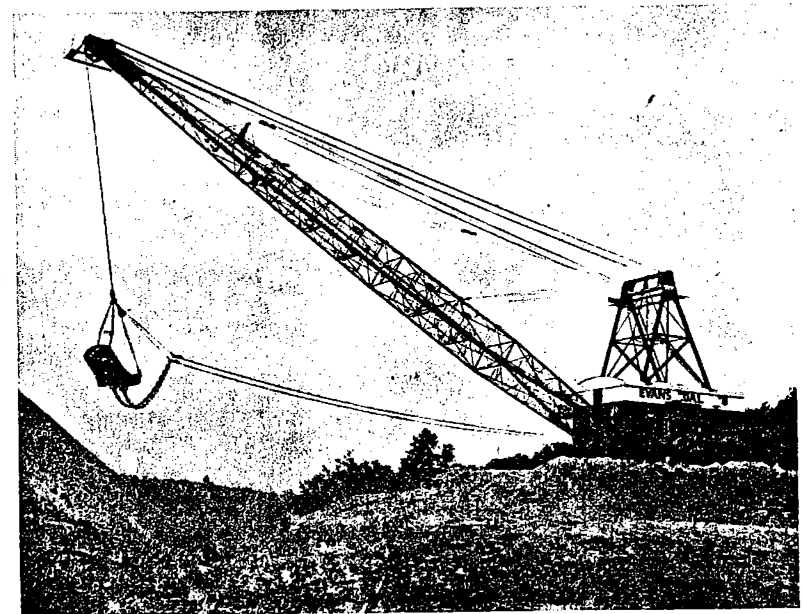


FIGURE 7. Dragline in operation near McCurtain.

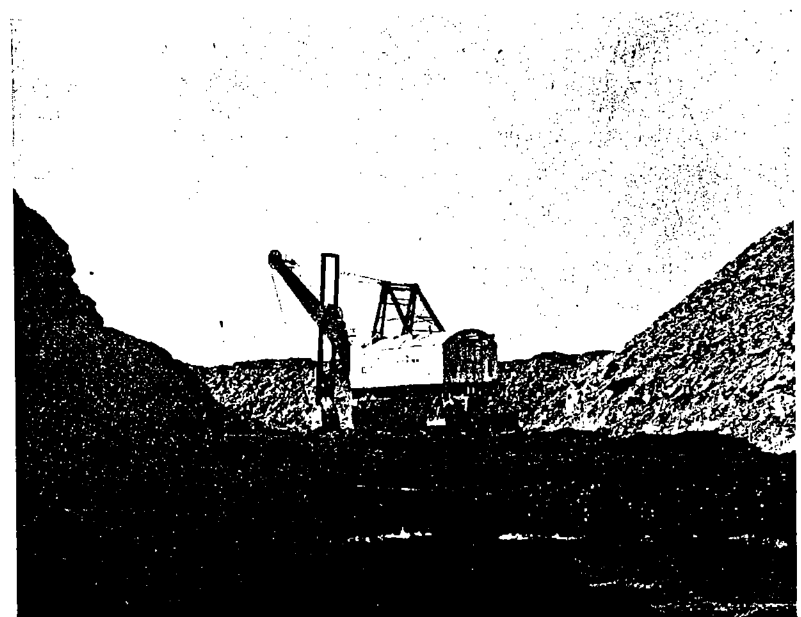


FIGURE 8. Stripping shovel in operation west of Vinita.

width encountered in Oklahoma strip pits is approximately two miles, whereas the average of all pits investigated is 428 feet. Coal strip mines on the contour in steeply dipping seams of the southern part of the Oklahoma coal province may be less than 100 feet in width, and many are less than 200 feet. It is difficult to discuss length of pits, because even in the obviously continuous pits section-line roads generally interrupt stripping, although operations may be continued on the other side of the road. Long, narrow pits along outcrops paralleling the strike are characteristic of Croweburg (Broken Arrow) coal and of Iron Post coal in northeastern Oklahoma. Generally these pits have long north-south (approximately) axes and short east-west axes. Not uncommonly they exceed 5 miles in length. Many are narrow, although one is approximately two miles wide. Most of the stripped areas in southern Oklahoma are more curvilinear in plan, because they follow the outcrop contour in an area. The longest, essentially continuous, pit encountered in the southern part of the coal field is located in central Haskell County. This pit has a continuous length, if section-line road breaks are ignored, of almost 9 miles. Further stripping along the same outcrop breaks up to a mile in width cover a total distance of about 15 miles. This coal (the Stigler seam) has been mined about the marginal outcrop of the pitching Kinta anticline (Oakes and Knechtel, 1948, p. 83-85 and plate).

Several new developments are taking place in the coal stripping industry of Oklahoma. Better earth-moving equipment provides tools necessary for re-working of mines stripped by inferior equipment or those worked by underground means. The Evans Coal Company is currently re-working and expanding a strip along the flank of the Siloam syncline northeast of McCurtain. This pit, which is being extended into LeFlore County from Haskell County, is actually being worked and a new beneficiation plant and rail spur have been constructed to serve it. Field evidence suggests that certain drift mines, long abandoned, have had their near-surface pillars stripped after abandonment. Undoubtedly thicker seams, which have been partly stripped along steeply dipping outcrops, will be worked later by underground means.

In an area where strip mining is significant, strip pits are quite numerous. Figure 9 illustrates their frequency distribution. As stripping becomes relatively more significant in the production of

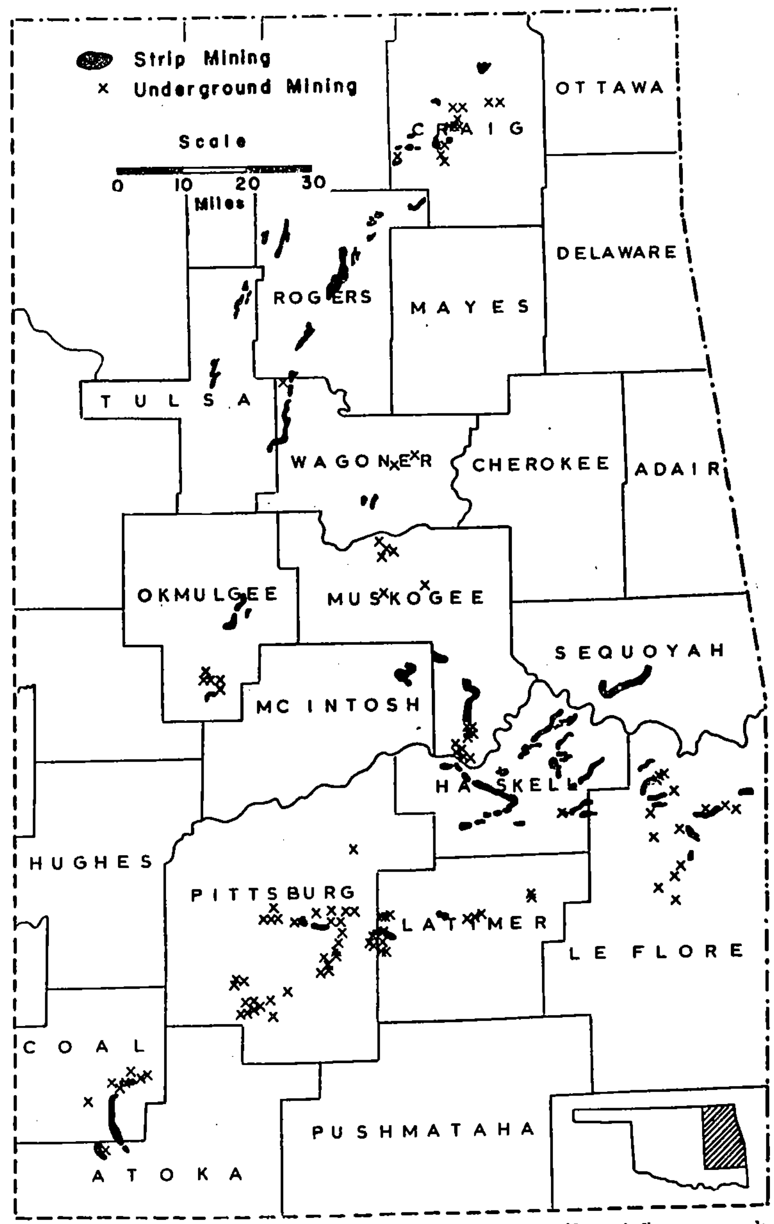


FIGURE 9. Map showing areas which exhibit principal landform influences resulting from coal mining. Stripped areas drawn approximately to scale (some enlarged for clarity).

coal in Oklahoma, the number of strip pits will increase. Number of pits, their configuration, and areal extent results from the interaction of a variety of factors, namely: 1) a local decrease in the thickness of seam; 2) an increase in chemical or mechanical impurities; 3) high cost of mineral rights; 4) unwillingness of landowner to permit stripping (an important factor in Oklahoma); 5) roughness of terrain; 6) faulting or other structural interruptions; 7) economic unfeasibility of disposing of water (Deasy and Griess, 1959, p. 74).

Deasy and Griess (1959, p. 74) suggest that the following questions should be answered in the analysis of a strip-mined landscape.

> First, how numerous are the pits in an area of intensive stripping? Second, what is the areal pattern that the pits assume, i. e. what spatial relationships do they bear to one another? Third, what are their normal and extreme dimensions? Fourth, what typical configurations do they possess? And fifth, what is the pattern of routes associated with the strip pit landscape?

The author suggests that those questions have been answered in the preceding discussion either verbally or graphically. Further, he insists that there is more to an analysis of a strip-mined landscape than the preceding quotation would suggest. A quantitative assessment, where practical, and a qualitative analysis where necessary, should be made of soil changes, ecological adjustments, and human beneficiation of the banks.

A great variety of soil types have been stripped in eastern Oklahoma, and the vast majority of them are poor to moderate in inherent fertility. Undoubtedly in a few localities the upheaval of subsurface soil has exposed a soil material richer in mineral content than the original topsoil, but the organic content is uniformly lower. With few exceptions, soil textures and structures on exposed spoil are inferior to original topsoils from a cultivation standpoint. In areas where soils are heavy or tight, aeration of spoil may yield a soil habitat which is temporarily more suitable for cultivation than the original topsoil. Although compaction is an ultimate result of exposure even graded banks are normally less compact, initially, than the surrounding unmined areas (fig. 10).* Various percentages

* Although the author knows of no definite studies made in Oklahoma to support this contention, presumptive evidence from similar regions elsewhere tends to validate this contention. For example, see Guernsey, J. Lee, 1956?, Reclaiming strip mined lands by grading: Commonwealth of Kentucky, p. 5.

of toxic materials may be present in the spoil, although generally lower pH readings are encountered in the northern part of the Oklahoma coal field. Wherever highly carbonaceous shale is exposed revegetation by natural means is slow, and cultivation and re-planting possibilities are nil until after a long period of weathering. In many areas, soil, as such, is nonexistent, because rocky overburden has buried the previous topsoil. Shale overburden, thus exposed, maintains an angle of repose as great as 80 percent after 25 years or more (Garner, 1953, p. 208). Widely varying soil conditions, both in terms of physical and chemical characteristics, different climates, orientation of spoil ridges, steepness of slopes, presence or absence of toxic substances, and seed sources, all play a part in determining the rate of revegetation and the type of vegetation which succeeds in a given area.

Generally weeds and grasses will appear in fresh spoil almost immediately, although some spoils are so toxic that they frustrate revegetation attempts for as long as five years or more. On the upland surfaces sycamore, cottonwood (*Populus deltoides*) and

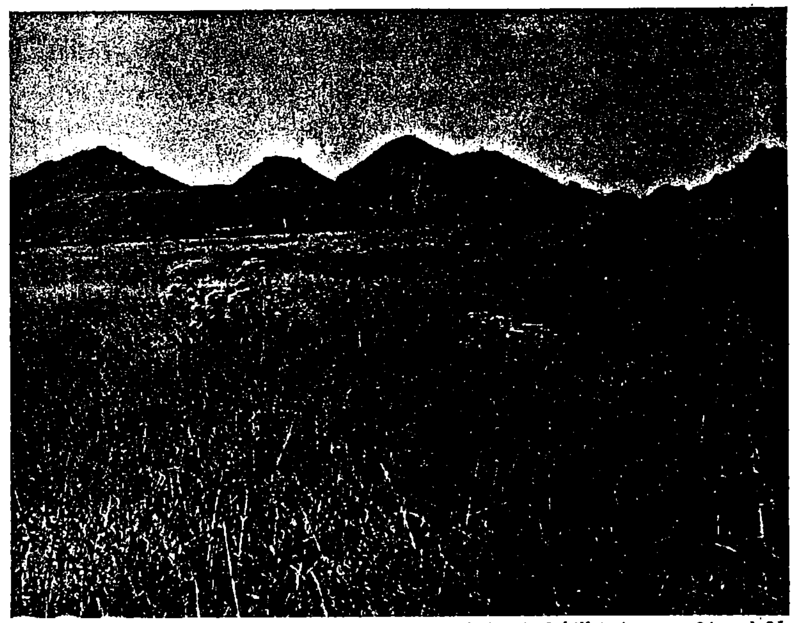


Fig. 10. Graded (flat-topped) and ungraded spoil (conical hills) in secs. 34 and 35. T. 1 N., R. 10 E.

sassafras (*Sassafras albidum*) are the more frequent pioneer trees. In most cases, after 10 years, or even longer, slopes and ridge crests are less than 50 percent covered. Almost without exception pioneer trees cling to the intermediate slopes. Their general absence from ridge crests and swale bottoms, in the beginning, is presumably due to dessicating winds in the former case and accumulation of toxic wastes or the danger of water-logging in the latter. Field investigation in Oklahoma suggests that survival rates are greater on east-ward-facing slopes. Guernsey (1956?, p. 10) noted in Kentucky that survival rates were higher on north- and east-facing slopes. Capricious Oklahoma rainfall and prevailing southwesterly winds provide an environmental austerity that tends to validate qualitative field investigations.

Margins of the inevitable lakes are quickly vegetated by willow (*Salix nigra*) and reeds, such as the cat-tail (*Typha latifolia*). Algal colonies are present in most lake waters, and the author observed an unidentified species growing in water with pH of 2.0.

Given a sufficient length of time, revegetation will proceed rapidly and excellent forests may develop. It is concluded that normally re-planting is the most efficacious method of achieving quick cover and a quality product. Spring planting is normally most successful, and planting of a nurse crop is useful insurance for a high survival rate (Guernsey, 1956?, p. 4-6).

In Oklahoma very little replanting of trees has been undertaken. Black locust (*Robinia pseudoacacia*), honeylocust (*Gleditsia triacanthos*), and shortleaf pine (*Pinus echinata*) were the most abundant tree plantings observed in Oklahoma. Normally tree plantings are undertaken on spoil with a low pH reading. Various authorities have estimated that 15 to 20 years would be required to produce trees large enough for fence posts and mine props.

Oklahomans have planted a far greater percentage of land to forage crops for animals. White sweetclover (*Melilotus alba*), yellow sweetclover (*Melilotus officinalis*), and Bermuda-grass (*Cynodon dactylon*) revegetate some spoil naturally, but in many other areas they are planted. Quick cover and rapid growth are achieved most frequently in neutral or slightly basic soils, although sweetclover is a successful pioneer in many unfavorable environments. One mine operator east of Checotah has planted Thunberg kudzu (*Pueraria thunbergiana*) with considerable success. Whereas some

plantings have been made by mine operators or land owners, the great majority of stripped lands in Oklahoma have been allowed to revegetate naturally. Garner (1953, p. 208-209) has found that, although most Oklahoma spoils contain sufficient quantities of moisture, they may be deficient in available minerals. Guernsey (1956?, p. 2) suggests that really successful revegetation of spoil in the midwest is contingent upon levelling, or at least topping of the ridge peaks. Opponents of grading argue that compaction of the soil would have a deleterious effect upon new plantings. Much accumulated evidence demonstrates, rather effectively, that this latter contention is false except in rare instances and under special circumstances (Guernsey, 1956?, p. 7-8). It is certainly true, however, that levelling is prohibitively expensive if estimated costs in excess of $300 per acre have any validity.

Stripped areas have been put to little economic use in Oklahoma in spite of the fact that the raising of trees for fence posts or mine props, beneficiation of pasture land, orchard planting, and Christmas tree raising all provide opportunity for economic gain. Of these improved pastures through planting of good forage grasses, which has been attempted to some degree in Oklahoma, and the raising of Christmas trees, which has not been attempted at all, promise most immediate and greatest financial returns. The development of commercial game farms, associated with strip lakes, is an additional interesting possibility.

One of the more significant features of strip-mined areas is the presence of lakes in the last cut. These lakes are rarely absent, and they are universally long and narrow. Of 125 strip-mine lakes investigated in Oklahoma the average length was 1,311 feet, maximum length was 5,676 feet, and minimum length was 330 feet. The average width for the same lakes was 108 feet, with a maximum width of 178 feet, and minimum width of 40 feet. Total estimated acreage covered by strip-pit lakes in Oklahoma is greater than 400 acres but less than 500 acres. Depths vary greatly from place to place, but the typical strip-pit lake is steep-sided and deep. Water pH readings vary from place to place, but the greater number of lakes tested had water in the range of pH 7.0 ± 1.0.

The ultimate fate of all strip-pit lakes, even the deep ones, is filling. The normal marsh ecological succession is speeded by slumping and wash from adjacent spoil. The paucity of minerals useful to planktonic organisms restricts their growth and most waters are quite clear. Sunlight penetration to depths soon fosters the growth of bottom-rooted aquatic plants and filling is accelerated. Fishing, which is normally excellent in the first years after stocking, deteriorates rapidly because of lack of food and overstocking.

Occasionally in undulating or rolling terrains spoil will be dumped in such a way as to dam existing drainage. Small ponds or swamps are at places formed in this manner. Smaller pockets of water may form between spoil ridges because of seepage and lateral movements of water after rain. In many cases these waters may be charged with toxic wastes, which inhibit the growth of vegetation.

Acid patches, rapid weathering, and subtle rock and/or soil changes are observable upon close inspection of spoil, but variations, even within the same spoil heap, are almost limitless. Soil particle size and agglomerations of soil particles into soil texture, compaction at various levels, and many other aspects of the spoil itself are major problems meriting special attention within the individual framework of a particular stripped area. Coal mining influences upon the cultural landscape are perhaps more striking and significant than those influences on the physical environment.

The effects of coal mining upon the cultural landscape are well known and will be only briefly recounted here. Oklahoma coal-mining areas have experienced the exultant rise of communities, their placid acceptance of prosperity, and their ultimate and inevitable decline. Only those communities which have been able to shift their primary reason for being to something other than coal, have survived as thriving cities and towns. Communities, such as McAlester, Okmulgee, and Henryetta have been able to make this transition successfully. Others, such as Hartshorne, Haileyville, and Bokoshe are reluctantly dying and decaying. Many, such as Blanco, Savanna, Calhoun, Morris, and Eram have virtually disappeared.

Abandoned mine properties, bleak and gaunt, project abandoned tipples, dumps, wash-houses, and other buildings, above the ground in grotesque fashion. Abandoned ponds used for wash water or steam generation lie abandoned and filling in a normal aquatic vegetation succession cycle. Waste coal left behind in piles, previously described, is frequently used as a source of road surfacing material. Rural roads in and near the coal-mining areas are inevitably surfaced with "gob" or shale, fresh or burned. In general, coal-

mining towns of Oklahoma have a dirty and depressing appearance. Business buildings are abandoned or unkept, pride of ownership has vanished, and the towns are dying.

SUMMARY

The physical and cultural environment of Oklahoma has been modified by coal mining to a considerable degree. Strip mining has produced the most obvious landscape changes. Ridges furrow the landscape and lakes dot the countryside in areas of initial low relief. Belts of spoil lie bare around the margins of stripped hills. Edaphic and biotic communities have been markedly disturbed, and a new ecological succession has been set into motion. The total impact and ultimate duration of these influences is undetermined at present.

Underground mines normally produce less striking landscape modifications, although occasional surface hills of waste coal of considerable local relief are encountered. Subsidence and modifications of local water table relationships are more subtle, but nevertheless significant, products of underground mining.

Cultural changes follow the typical boom-and-bust pattern of mining regions, and most coal-mining communities present a drab appearance. Death and decay is the fate of all such existing communities unless the resource base supporting them is drastically modified.

Minimal efforts have been exerted to bring abandoned mining regions into productive economic use. Attempts at revegetation should probably be assumed by the title holder, although state or federal assistance should probably be employed. The State Planning and Resources Board should consider the possibility of establishing state parks to provide places for recreation and/or further study of a newly created landscape.

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APPENDIX

The following is a formalized set of field notes upon which the preceding generalizations are based. An attempt is made to keep specific points in parallel position, but the quality of notes varies from place to place because of the exigencies of particular situations. Specific facets of the environment may be examined in detail in certain areas, whereas circumstances allowed only a perfunctory examination in others. Similarly not all notes are included, because some have limited relevance for this study. Many areas were mapped which were not examined in detail.

The counties are alphabetized, and the noted areas are located by section, township, and range. Portion of the section is noted in few cases because notes typically apply to a rather large area.

Atoka

Secs. 3, 10, and 11, T. 2 S., R. 10 E.

Spoil ranges from yellow clay to carbonaceous shale, with abundant ironstone nodules present in different portions of the pit. Local relief is about 30 feet and angle of repose is about 30 degrees. Grass is the dominant vegetation, but elm, cottonwood, willow, and sycamore are liberally sprinkled on the surface of the spoil. The north edge of this pit has modified local relief, and it blends into the surrounding countryside very well. Several small underground mines have been in operation nearby, and their tailings are locally noticeable. Water in the strip lake has a pH of 7.0. Lower Hartshorne coal.

Atoka and Coal

Sec. 6, T. 2 S., R. 11 E. and northward

Carbonaceous shale of moderate relief has considerable grass cover—apparently artificially seeded. Willows and cottonwoods are numerous at the water's edge. Lehigh coal.

Coal
(fig. 11)

Secs. 22 and 28, T. 1 N., R. 10 E.

Small stripped area, with slight local relief, is cloaked with weeds, grass, elm, and willow vegetation. Lehigh coal.

Sec. 32, T. 1 N., R. 10 E.

This area was stripped 50 years ago, and the tops have been knocked off the spoil. Local relief is moderate, about 15 feet, and the angle of repose is approximately 30 degrees. Bermuda has been planted, and, although this grass covers much of the spoil surface, some sections are still bare after 30 years. Lehigh coal.

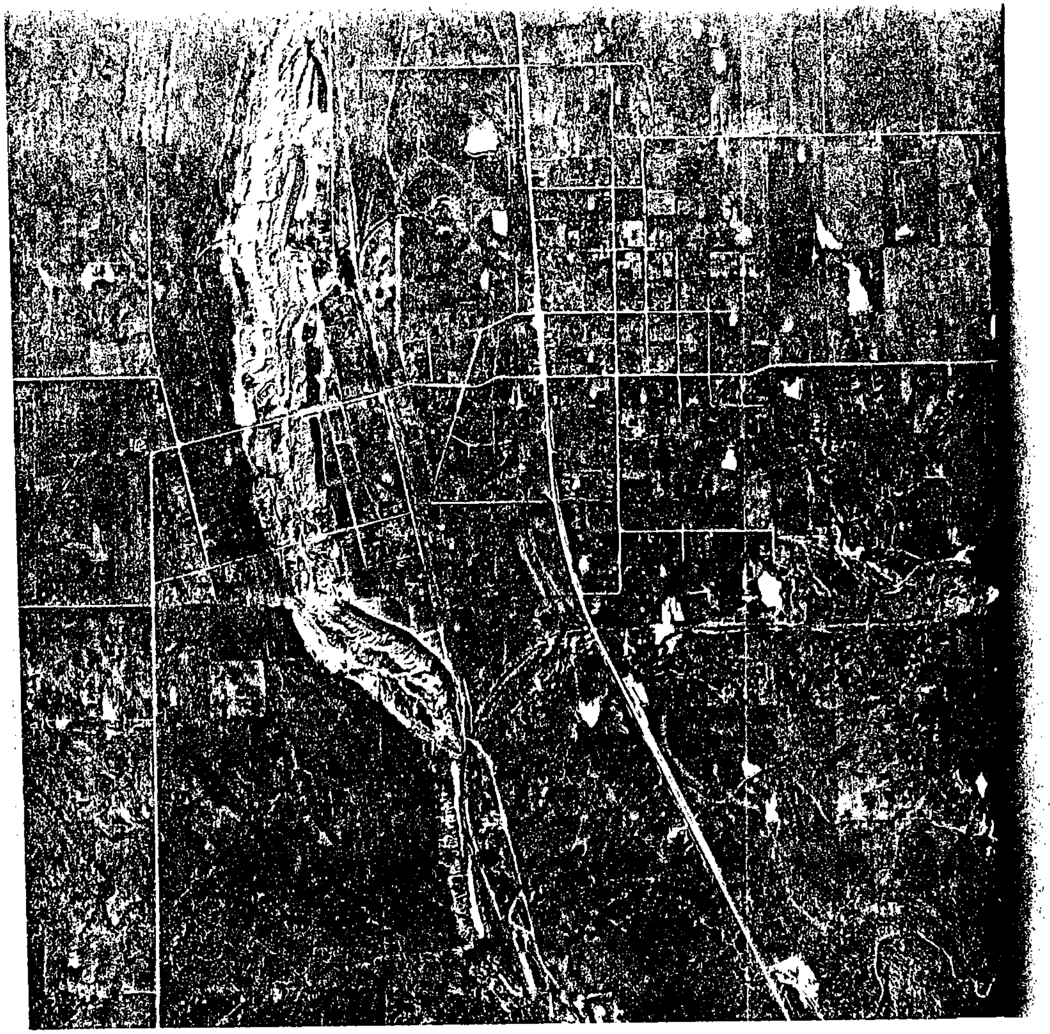

FIGURE 11. Stripped area at Lehigh, Coal County, showing lakes of modest size which locally are used for various recreational pursuits. Since coal mining activities have ceased Lehigh has shown a dramatic decline.
(Aerial photograph made in 1955.)

Secs. 34 and 35, T. 1 N., R. 10 E.

Clay spoil has a local relief averaging more than 30 feet, and some spoil has been graded, whereas other portions remain as they were left after mining (fig. 10). All of the area has been seeded to Bermuda grass, but in a few areas it will not grow. Trees are few, except for local clusters of willow at the water's edge. Lehigh coal.

Secs. 36 and 25, T. 1 S., R. 10 E.

This area is rough and hummocky terrain resulting from stripping and subsequent heavy erosion. Local relief is 50 feet and more. Little vegetation has come in on the spoil. Water in strip pit lake has a pH of 6.8. Lehigh coal.

CRAIG
(fig. 12)

SW$\frac{1}{4}$ sec. 27, T. 28 N., R. 20 E.

Maximum local relief is 20 feet, average 12 to 15 feet, and the angle of repose is between 20 and 30 degrees on different slopes. Overburden consists of blue-gray shale, some siltstone, and silty sandstone, which is brownish in color. Exposed rock is weathering rapidly. The area, which was stripped in 1952, is approximately 25 percent revegetated (by natural means) with black locust, hackberry, wild polk, ragweed (*Ambrosia artemisifolia*), and wheatgrass (*Agropyron* spp.) as the dominant species. Small strip lake present with maximum depth greater than 15 feet. Maximum length of the stripped area about 0.8 of a mile and maximum width approximately 0.2 of a mile. Weir-Pittsburg coal.

SE$\frac{1}{4}$ sec. 28, T. 28 N., R. 20 E.

This area has moderate local relief not exceeding 10 feet in any section and normally less than 6 feet. Angle of repose is low, although it was not measured in the field. Area has been abandoned approximately 20 years and is almost completely covered with cottonwood and willow forest. Most trees average over 25 feet in height, and they are 6 to 8 inches in diameter at waist height. Abundance of leaf litter and other duff covers the abandoned spoil masking its true character, although it appears to be clayey in nature throughout. Mineral (?) coal.

Center sec. 20, T. 28 N., R. 19 E.

Local relief averages 12 to 15 feet, and the angle of repose ranges from 20 to 33 degrees. The overburden is predominantly clay and shale of buff to gray color, weathers rapidly and tests pH 7.2 on intermediate slopes. Coal last worked in the spring of 1959, and vegetation, principally ragweed and sweet clover, covered about two-thirds of the total in August, 1959. Equipment is present for additional stripping. Mineral coal.

Secs. 32 and 29, T. 26 N., R. 19 E.

Massive blocky sandstones, sandy limestone, and shale overburden with a local relief averaging 10 to 12 feet, although at the highwall this may exceed 20 feet. Angle of repose averages about 35 degrees. Coal is quite soft, and the exposed seam is about 18 inches thick. High sulfur content of coal is reflected in strong acid reaction of water in pits—pH 3.5. Only a small percentage of the area is revegetated, mostly with low-order plants.

SW¼ sec. 13 and SE¼ sec. 14, T. 26 N., R. 19 E.

Several small mounds of waste coal left from drifts abandoned 20 or 25 years ago are noted. A 4-foot seam of coal was mined at a depth of 7 to 8 feet. Only evidence remaining is hillocks about 5 feet high and 10 feet in diameter and poisoned areas, devoid of vegetation, perhaps 100 feet in diameter. Drywood (?) coal.

Sec. 27, T. 26 N., R. 19 E.

This spoil has an average local relief of about 15 feet, with angles of repose of approximately 25 to 35 degrees. Sandstone is fairly prevalent in the overburden along with shales. Considerable amount of ferruginous material in the form of ironstone nodules present on the overburden. Mixed herbaceous and tree vegetation taking over. Sweetclover, sycamore, elm (*Ulmus* spp.), and willow are dominant species. No strip lake, but small pool of water at base of spoil tested pH 2.0. Algae of unknown type were growing in this strongly acid water. Bluejacket coal.

Sec. 3, T. 25 N., R. 18 E.

Low local relief and moderate angle of repose characterizes the spoil. Partially revegetated with weeds, grasses, and trees, principally elm.

Sec. 34, T. 26 N., R. 18 E.

Fresh spoil with local relief of 12 to 15 feet (fig 6). Breezy Hill limestone is broken up in massive pieces over shales. Spoil is approximately three years old, and it will probably weather and erode in peculiar fashion because of limestone caprock. Older spoil is being revegetated with sunflowers (*Helianthus annus*). Iron Post coal.

Sec. 4, T. 25 N., R. 18 E.

Spoil, relief, and vegetaton almost duplicate that described in sec. 34, T. 26 N., R. 18 E., except that ragweed is also significant in the vegetation pattern. Bluejacket coal.

Haskell

Sec. 9, T. 10 N., R. 22 E.

Carbonaceous shale with 15 to 20 feet of local relief and a low angle of repose is being trucked away as a road surfacing material. Elm, cottonood, and willow dominate in the vegetation pattern. Lake water has a pH of 8.2. Stigler coal.

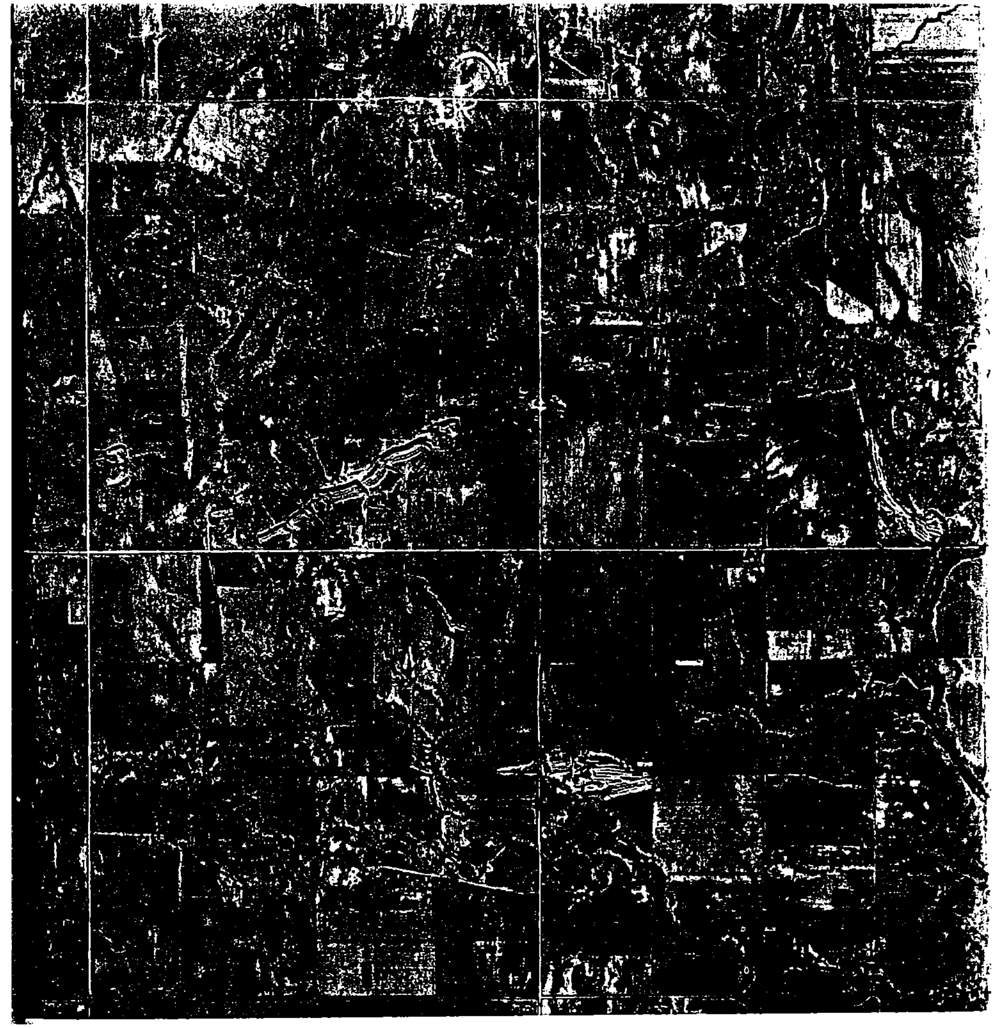

FIGURE 12. Small strip pits in Craig County showing the irregular orientation of stripped areas and a number of small lakes. Various ages of the spoil can be inferred from the differences in vegetative cover. Northeast and southeast parts in Weir-Pittsburgh coal, north-central in Mineral coal, west-central in Croweburg coal.

Secs. 5 and 6, T. 10 N., R. 22 E.

Stripping done along outcrop around a hill. Vegetative cover is rather thick. Elm and sassafras appear to be dominant. Stigler coal.

Sec. 26, T. 9 N., R. 22 E.

Local relief of brown to black shale is about 20 feet with a moderate angle of repose. Strip lake is shallow, and it has a pH of 7.0.

Secs. 34 and 35, T. 9 N., R. 22 E.

This spoil is composed of hummocky debris, which has a considerable amount of black-shale material. Vegetation is spotty with a variety of species represented. Stigler coal.

Sec. 22, T. 8 N., R. 22 E.

This area was stripped at least 20 years ago, but it has minimum vegetative cover. Elm, sumac, and willow appear to be doing well. Lake water has a pH of 7.0. Hartshorne coal.

Secs. 28 and 29, T. 8 N., R. 21 E.

Moderate local relief is encountered in the spoil, and sweet-clover appears to be seeding itself naturally. Stigler coal.

Secs. 7 and 8, T. 8 N., R. 21 E.

The spoil of this pit is primarily carbonaceous shale, but yellowish to brownish clay is also exposed. Willows are present at water's edge, and sumac and sycamore are significant on the slopes. Stigler coal.

Sec. 23, T. 9 N., R. 20 E.

Brownish spoil is exposed in a narrow band around the margin of a hill. Little revegetation has taken place. Stigler coal.

Sec. 30, T. 9 N., R. 20 E.

Carbonaceous shale and clay are exposed in the spoil, and the local relief is 15 to 40 feet. Lake water has a pH of 7.8. Weedy growth is coming in on the spoil. Stigler coal.

Secs. 35 and 36, T. 8 N., R. 19 E. and sec. 31, T. 8 N., R. 20 E.

This area has moderate hummocky relief and an angle of repose less than 20 degrees. Ragweed and cockleburs (*Xanthium orientale*) are common, and willows grow well along the margins of the shallow murky lakes. Lake water has a pH of 7.3. Stigler coal.

Sec. 12, T. 8 N., R. 20 E.

Interesting fact about this area is that the spoil has been topped, and yet vegetation is insignificant. Stigler coal.

Sec. 29, T. 9 N., R. 20 E.

Spoil characterized by a high angle of repose and considerable local relief. Stigler coal.

Sec. 15, T. 9 N., R. 19 E.

Carbonaceous spoil has an average local relief of 15 to 20 feet and an angle of repose of between 20 and 35 degrees. Ragweed, Bermuda, and sycamores are revegetating this spoil. Water in the strip lake has a pH of 8.2. Stigler coal.

Secs. 26 and 27, T. 10 N., R. 21 E.

This area has considerable local relief and minimal amount of vegetation.

Sec. 23, T. 10 N., R. 21 E.

As much as 60 feet of overburden was removed and significant local relief is developed. Carbonaceous shale has difficulty supporting vegetation, but low-order vegetation seems to come into the clay areas quickly. Stigler coal.

Secs. 20, 28, and 29, T. 10 N., R. 22 E.

Approximately 40 feet of overburden was removed along the margin of a hill. Almost no water is encountered in the abandoned cut, and vegetation is scarce, although sycamores are beginning to colonize. Stigler coal.

Sec. 14, T. 9 N., R.. 20 E.

Area has moderate local relief, because it has been bulldozed. Bermuda has been planted and appears to be doing well. Stigler coal.

Secs. 16, 17, and 18, T. 9 N., R. 20 E.

New carbonaceous shale spoil has a local relief of 30 to 70 feet and an angle of repose of about 30 degrees. Top of spoil is being graded. Some weedy types of vegetation are coming into areas freshly stripped. Clay spoil near the western end of this stripped area is being colonized by Bermuda, cottonwoods, and willows. The clay spoil is eroding rapidly, and it is being deposited in considerable amounts on adjacent unstripped regions. Stigler coal.

Sec. 8, T. 9 N., R. 23 E.

Carbonaceous spoil has a local relief in excess of 20 feet. Several of the ridges have been graded, and Bermuda grass has been planted. Strip-pit water has pH of 7.7. Stigler coal.

Le Flore

Sec. 15, T. 9 N., R. 24 E.

This area of carbonaceous shale has a local relief of 15 to 25 feet, and it is characterized by an abundance of ironstone nodules. Natural vegetation is minimal, but Bermuda, locust, and pine are all doing well where planted. Angle of repose averages about 28 degrees, and the lake water has a pH of 8.4. Hartshorne coal.

Sec. 4, T. 8 N., R. 24 E.

Old spoil, primarily clay and shale, has moderate local relief and is rapidly being covered by a variety of plants. Hartshorne coal.

Sec. 11, T. 7 N., R. 24 E.

The principal features here are two large hillocks of waste coal and shale from an abandoned underground mine. The larger hillock (fig. 4) is more than 250 feet long, about 50 feet wide, and 90 feet high. It has an angle of repose in excess of 45 degrees and has been heavily eroded. The smaller hillock is about 15 feet high and about 25 feet in diameter at the base. The hillocks are devoid of vegetation, and a considerable area around them has obviously been poisoned by toxic wastes. Small pond used in washing and steam generation still remains. Secor coal.

Sec. 2, T. 7 N., R. 25 E.

Clay and shale overburden has a local relief of about 20 feet and an angle of repose averaging less than 25 degrees. Slumping is significant, and a number of trees have been killed by this slumping. Vegetative cover is fairly complete with weeds, sweetclover, elm, sycamore, and willow (at water's edge) dominant. Lake water has a pH of 8.0. Cavanal (?) coal.

SW¼ sec. 18, T. 8 N., R. 25 E.

Three small hillocks of waste coal and shale have been left from an abandoned underground operation. The largest hillock is about 15 feet high and the smaller two are 8 to 10 feet high. Bermuda and elm are creeping up the slopes. The waste piles are being used as road surfacing material, however, and they probably will soon disappear.

Sec. 13, T. 8 N., R. 24 E.

About 20 feet of gray-brown and black shale have been removed to mine 18 to 20 inches of coal, which dips steeply to the south. Only one cut has been made, and at the base of the cut drifts have been dug into the exposed seam. The drifts are now abandoned, and although no water occurs in the bottom of the cut the drifts are flooded. Local relief is slight, but the angle of repose is about 33 degrees. Bermuda grass is beginning to cover the spoil. Hartshorne coal.

Sec. 11, T. 8 N., R. 24 E.

Quite new spoil, primarily carbonaceous shale, has a local relief of 30 feet. Sycamore, sumac, wild polk, and ragweed are vegetative colonizers on spoil with an angle of repose of 25 to 33 degrees. Lake water has a pH of 7.0. Hartshorne coal.

Sec. 34, T. 7 N., R. 25 E.

An asymmetrical hill of waste coal, shale, and other waste from an underground mine is the only significant evidence of the mine's existence. The hill is about 50 feet high and has almost no vegetation. Cavanal coal.

Sec. 34, T. 9 N., R. 24 E.

Shale spoil, weathered to clay in most areas, appears to be low in essential plant foods. Maximum local relief is more than 40 feet. Scrubby vegetation, particularly sassafras, grows on the spoil, and willows, cottonwoods, and cat-tails are important near the water's edge. Hartshorne coal.

Sec. 7, T. 8 N., R. 23 E.

An area just being stripped (as of August, 1959) where considerable overburden is being removed. High local relief (more than 40 feet) is characteristic. Angle of repose is 35 degrees or more. Hartshorne coal.

Sec. 20, T. 8 N., R. 26 E.

Carbonaceous shale overburden has considerable local relief and a high angle of repose. A small swamp has been formed because the last ridge of spoil has formed a temporary dam. Vegetation is spotty with sycamore and sassafras dominant. Ironstone guards some interesting pinnacles on the outer margins of the spoil. Water in the strip lake has a pH of 8.0. Hartshorne coal.

McIntosh

Secs. 29, 31, and 32, T. 12 N., R. 18 E.

Clayey spoil stands in great hummocks above the surface of a practically flat field. Local relief is 15 to 20 feet, and the average angle of repose is about 30 degrees. The extension of this mine westward produces greater local relief, where as much as 45 feet of overburden is removed to mine a seam of coal which averages 28 inches in thickness. Kudzu is planted on many of the slopes. In unplanted areas Bermuda, sweetclover, ragweed, and sycamores are colonizers. Ironstone is present in the spoil, and there is an abundance of pyritized fossils. Water in pits varies from pH 3.2 to pH 4.0. Secor coal.

Muskogee

Sec. 13, T. 11 N., R. 19 E., and sec. 18, T. 11 N., R. 19 E.

Spoil is composed mainly of black to yellowish shale. Angle of repose averages about 35 degrees. Low-order vegetation is just coming in. Cultivation comes to the base of the spoil with no apparent deleterious effects. Spoil at a depth of 18 inches has a pH of 7.5 and water in strip lake has a pH of 8.0. Stigler coal.

Okmulgee

Sec. 8, T. 13 N., R. 14 E.

Gray to buff calcareous shale and/or sandstone characterizes most of the surface spoil. Clayey material and ironstone nodules are present, and all exposed material weathers rapidly. Has modest local relief and considerable vegetation. Sweetclover, Bermuda, ragweed, wild polk, and cottonwood are all doing well. Morris coal.

Secs. 11 and 14, T. 13 N., R. 13 E.

Spoil is primarily shale and sandy shale of a gray to buff color. Relief and angle of repose are modest. The swales are being used as a dump ground, and much of the mineral is being used for road resurfacing. Grasses and weeds dominate in the vegetation patterns, but cottonwoods and elms are also doing well. Morris coal.

Sec. 30, T. 12 N., R. 13 E.

Two large piles of waste coal and shale are significant features of the landscape. The largest is about 90 feet high at the higher end and 15 feet high at the lower end. The hillock is about 50 feet in diameter at the base and essentially symmetrical in ground plan. Weeds are beginning to creep up the slope of this hillock. The second small hill, which is more nearly symmetrical, is about 50 feet high and about 50 feet in diameter at the base. Two small piles of waste coal are burning nearby with a pungent sulphurous odor. Henryetta coal (Croweburg).

Sec. 31, T. 12 N., R. 13 E.

An underground mine, which is still being operated, with two small waste piles of coal. Henryetta coal.

Secs. 8 and 9, T. 11 N., R. 13 E.

Spoil has a local relief of about 20 feet and an angle of repose of about 25 degrees. The gray to buff shale has been exposed about the margin of a hill where stripping has occurred. Because of the slope of the hill, the distance from bottom of cut to the top of the highwall is more than 50 feet. Unlike most areas trees appear to be growing mainly on the crest of the spoil; water in pit has a pH of 3.9. Henryetta coal.

Pittsburg and Latimer

Secs. 21 and 22, T. 5 N., R. 17 E.

The spoil exposed is yellowish clay and carbonaceous shale. Local relief on the spoil is about 20 to 30 feet, and the angle of repose is 30 to 35 degrees. There is a large variety of trees, but willows appear to be dominant.

Pittsburg

Sec. 18, T. 5 N., R. 16 E.

Spoil of buff or carbonaceous shale has a pronounced hummocky effect. Local relief is about 20 to 25 feet and the angle of repose is between 25 and 35 degrees. Apparently about 20 feet of overburden has been removed to mine a 10 to 18 inch seam of coal. Bermuda, ragweed, and sweetclover are most significant near the eastern edge, and trees are becoming increasingly significant in the west.

Rogers

Sec. 32, T. 24 N., R. 15 E.

Spoil dominantly of blue-gray shale, much weathered, and the local relief is minimal. Typical angle of repose is somewhat less than 30 degrees. Sunflowers, sweetclover, and an occasional tree dominate the spoil surface, although cottonwoods and willows are coming in near water's edge along the strip lake. Lake water has a pH of 7.8, and it possesses abundant aquatic life. Dawson coal.

Sec. 5, T. 23 N., R. 15 E.

Continuation of stripped area in sec. 32, T. 24 N., R. 15 E. Principal difference is that this spoil is almost completely forest clad, with cottonwood, willow, and locust dominant. Dawson coal.

Secs. 12, 13, 14, and 15, T. 24 N., R. 18 E.

Overburden is predominantly yellowish and blue-gray shale. Shale is weak and is readily weathered and eroded. Local relief approximates 15 feet. Elm, hackberry, wild cherry (*Prunus serotina*) and sumac (*Rhus* spp.) predominate on the intermediate slopes of the spoil, and blackberries (*Rubus* spp.) grow near the base of the spoil. Willows ring the numerous strip-pit lakes. These waters have a pH averaging 7.5. Weir-Pittsburg coal.

Secs. 33 and 34, T. 24 N., R. 17 E.

Shale overburden, with slopes of about 30 degrees, has an average local relief of 20 feet. Some spoil is fresh and lacks vegetative cover, but in older areas ragweed, cottonwood, elm, and sycamore dominate, although only a small percentage of the area is covered. Cat-tails are prevalent along water's edge. Water has a measured pH of 7.2. "Sequoyah" coal.

Sec. 25, T. 24 N., R. 17 E.

Stripping done around margins of a hill. The overburden is shale or sandy shale, and the local relief is as much as 30 feet. Less than 5 percent of the area has been revegetated. Wild polk growing in erosion channels and in miniature alluvial fans along with willow are the only types of vegetation encountered.

Sec. 10, T. 23 N., R. 17 E.

Stripping done around margin of hill similar to that described in sec. 25, T. 24 N., R. 17 E. except that considerable revegetation has occurred. Persimmon (*Diospyros virginiana*), hackberry, and elm are quite important here. Croweburg coal.

Secs. 30 and 31, T. 23 N., R. 17 E.

Fresh spoil, mostly shale, is interspersed with blocks of sandtone from local lenses. Local relief is up to 40 feet, and angle of repose is generally greater than 35 degrees. Approximately 20 to 25 feet of overburden is being removed to mine approximately 18 inches of coal. Mining is currently underway, and practically no vegetation has come onto the spoil Croweburg coal.

Sec. 34, T. 23 N., R. 16 E.

Overburden, consisting mainly of shale, sandstone, and sandy shale (fig. 5), is partly cloaked with sweet clover, ragweed, and a few small trees. Strip-pit water tests pH 7.6. Croweburg coal.

Sec. 25, T. 21 N., R. 15 E.

This new pit has soft gray-brown shale with no vegetation as yet. Croweburg coal.

Sec. 27, T. 20 N., R. 15 E.

Blue-gray to black shale is sporadically covered by massive blocks of limestone. The limestone is fossiliferous. The spoil is apparently being revegetated rapidly, and trees such as wild cherry, elm, and persimmon are more commonly encountered. The angle of repose is about 30 degrees, and water in the strip lakes ranges from pH 7.2 to pH 7.8. Croweburg coal.

SEQUOYAH
(frontispiece)

Sec. 7, T. 11 N., R. 24 E.

Shale, heavily fossiliferous, and sandstone make up most of the exposed overburden. Low angle of repose and rounded profile is quite characteristic. Apparently a 4-foot seam of coal has been mined. Spoil appears to be singularly lacking in essential plant foods. Sycamore is the dominant tree, although willow and cottonwood grow at water's edge. Two plants of prickly pear (*Opuntia* sp.) were observed in the spoil; pH of water in strip pit lake is 7.8. Stigler coal.

Sec. 8, T. 11 N., R. 24 E.

An extension of pit in sec. 4, T. 11 N., R. 24 E., but distinguished from it by high percentage of clay material exposed. Angle of repose is generally more than 40 degrees and in places as much as 50 degrees. Local relief is greater than 50 feet, and the lakes appear to be deep. Aquatic life is apparently quite abundant. Stigler coal.

Secs. 16 and 17, T. 11 N., R. 24 E.

A small pit, which has gray-brown shale spoil and subdued local relief. Bermuda grass and berry bushes are creeping up the slope. Stigler coal.

Sec. 18, T. 11 N., R. 24 E.

Carbonaceous shale is exposed and a local relief of 50 feet or more is modified by grading of the ridges. Locally here, and to the west, relief may exceed 100 feet from the bottom of a cut to the top of the first spoil heap. Forty to eighty feet of overburden is being removed to mine a 15- to 18-inch seam of coal.

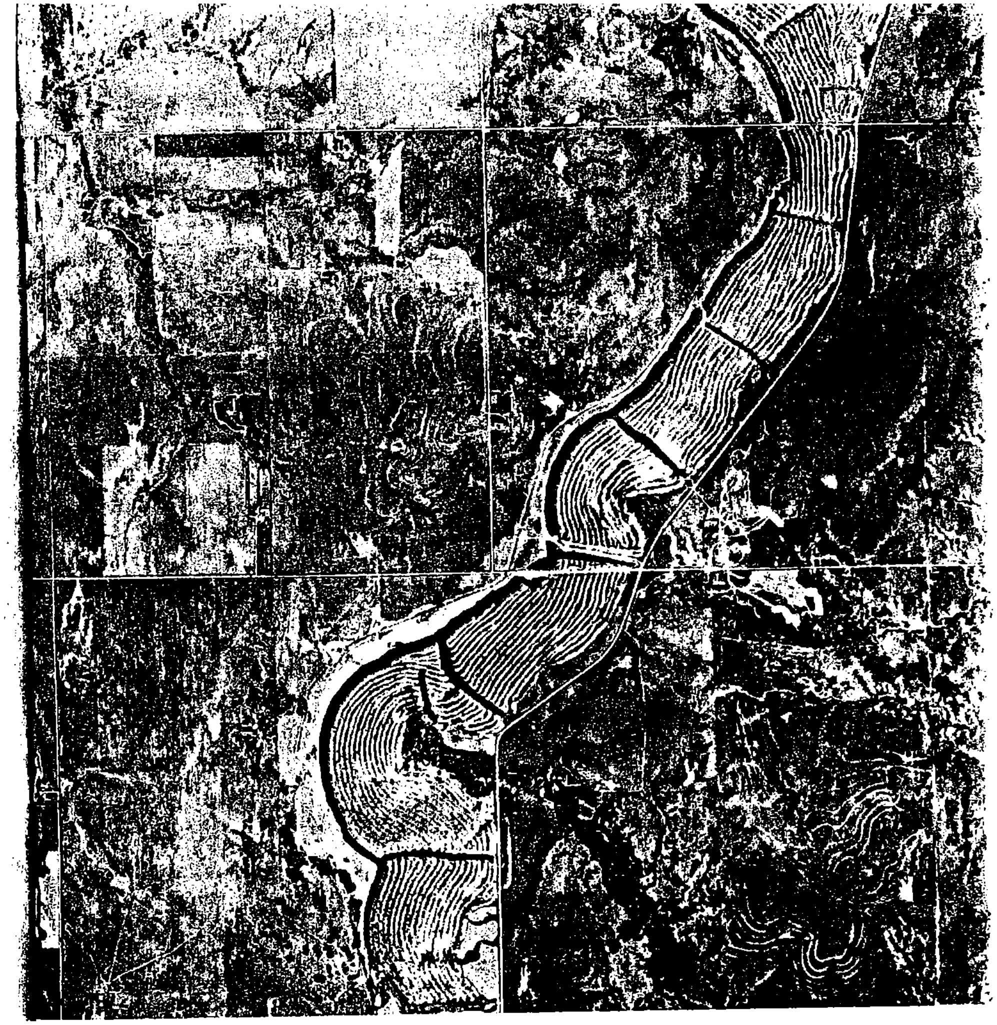

FIGURE 13. Aerial view of coal stripping in Wagoner County showing elongate lakes occupying the last cut and several transverse lakes. The stripped area averages slightly more than 1,000 feet in width.
(Aerial photograph dated 1952.)

Water seeping through the porous spoil is a considerable problem for the mine operator. A strip lake near the western edge of section 18 is being used as a dumping ground for a lime plant at Sallisaw. This has produced water of beautiful azure color. Several tests by independent testing concerns show that water in this region (in strip lakes) is very hard, and that it has an average pH of 7.9, whereas water impounded in a normal surface reservoir has a pH of 6.9. Stigler coal.

Tulsa

Northern Tulsa Within City Limits

This spoil is being used as fill, and cuts and troughs are being filled with garbage and other debris. Subsequent levelling prepares this land for use as housing development plots. Dawson coal.

Wagoner
(fig 13)

Secs 20, 21, 28, 29, 32, and 33, T. 19 N., R. 15 E.

Relatively new spoil, predominantly shale, has a local relief of 15 to 20 feet and an unusually high angle of repose (about 40° on the average). Vegetation includes grasses, sweetclover, cottonwood, elm, and willow. Stripping was apparently terminated near the western edge of this stripped region because the operators encountered a ledge of compact limestone, the Verdigris limestone. Croweburg (Broken Arrow) coal.