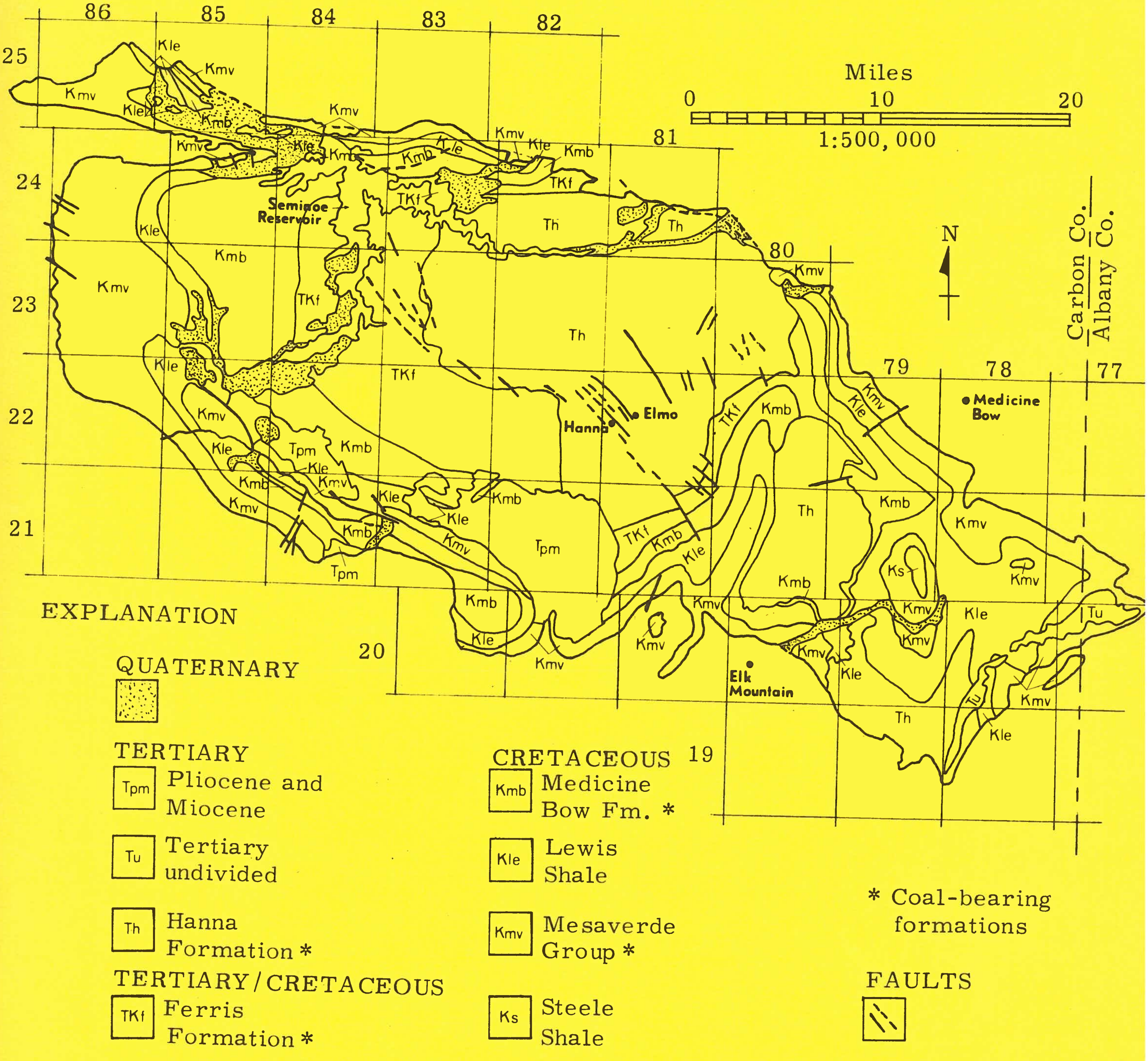
MINING IN THE HANNA COAL FIELD

By

Gary B. Glass
Wyoming Geological Survey



Modified from Love (1955)

ROCKY MOUNTAIN SECTION, GEOLOGICAL SOCIETY OF AMERICA

GUIDEBOOK

MAY 13, 1972

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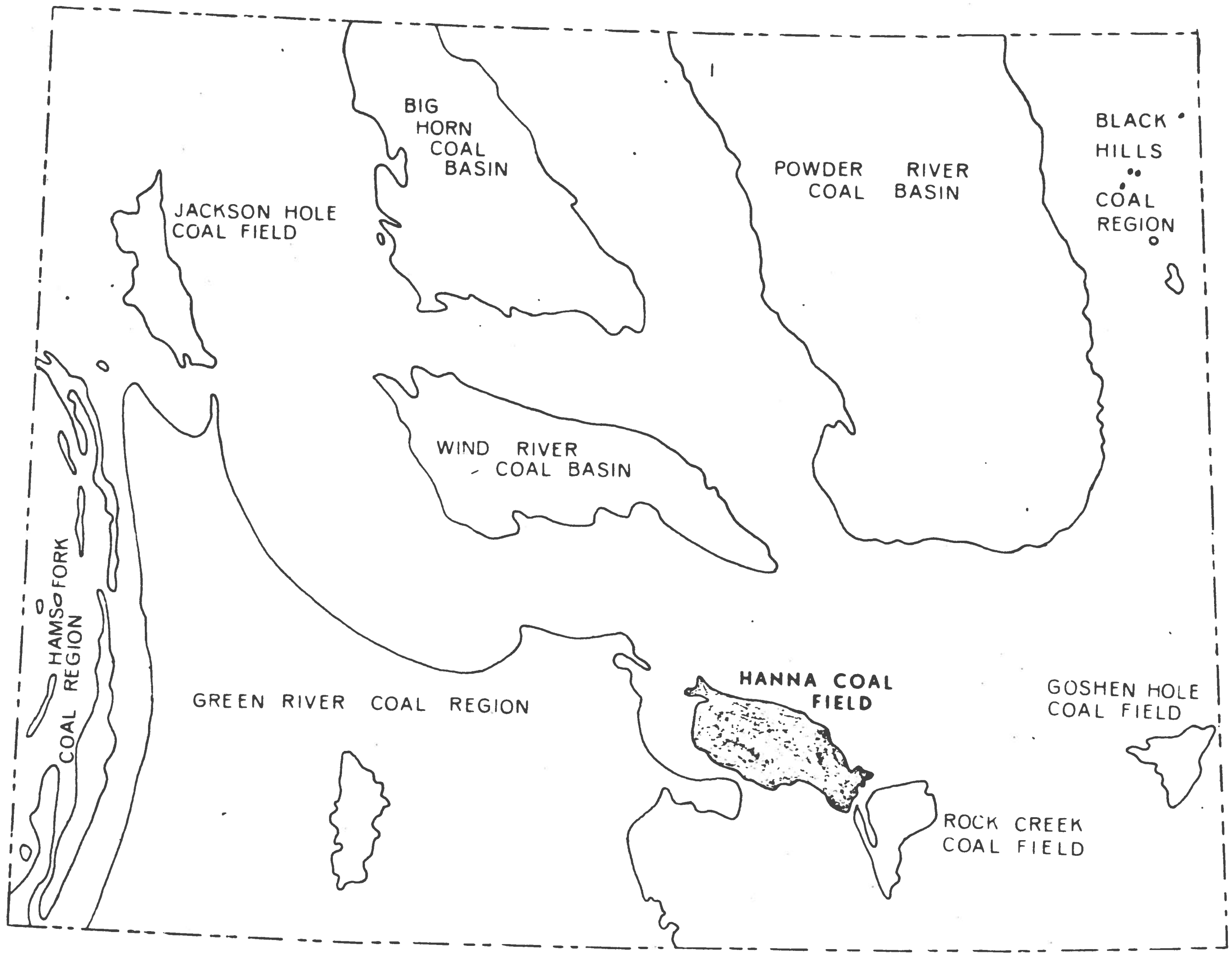

Modified from Berryhill (1950)

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INTRODUCTION

General

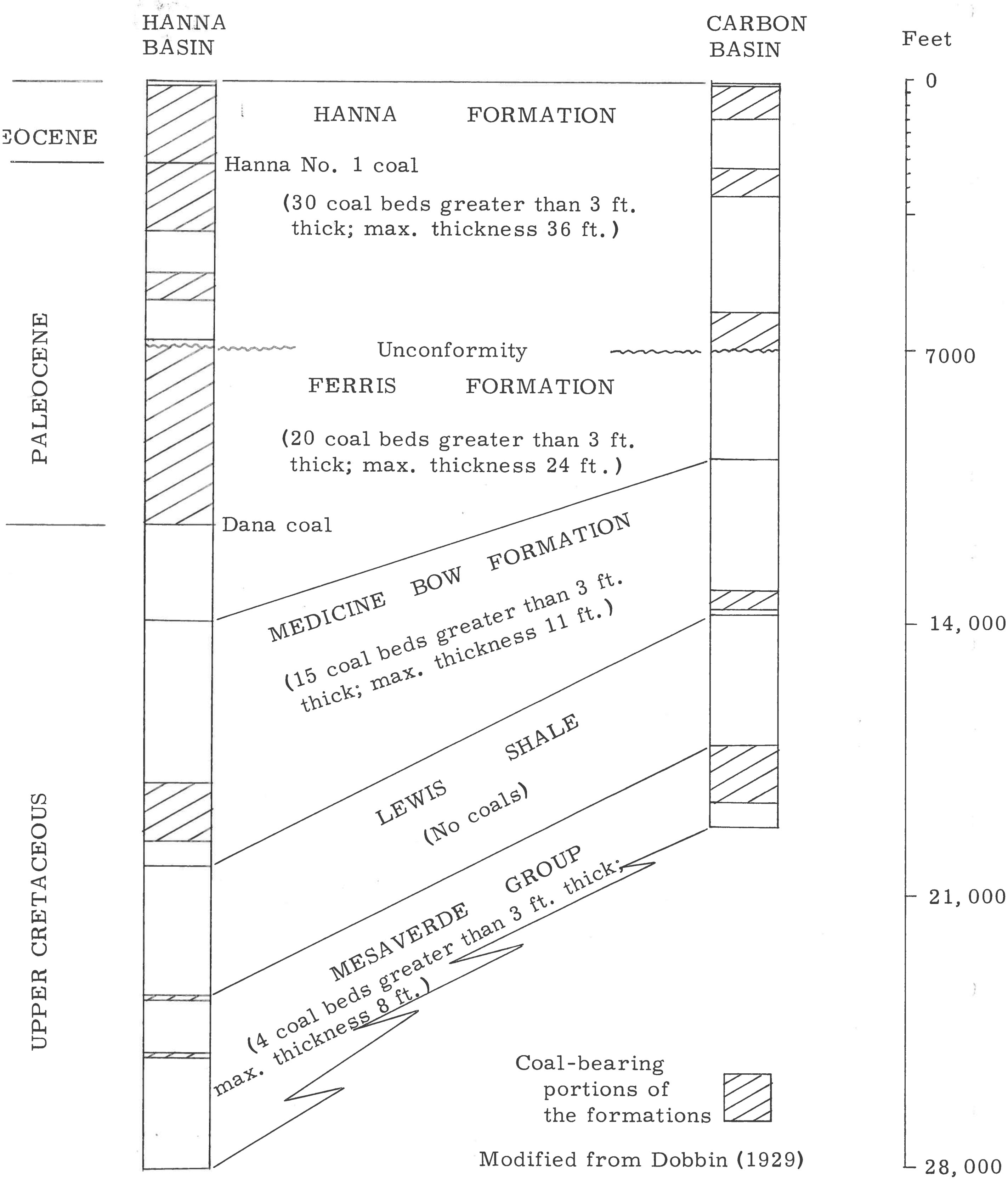
Somewhere between 18,000 and 28,000 feet of Tertiary and Cretaceous coal-bearing rocks of the Hanna Coal Field are exposed in the Hanna Basin in Carbon and Albany counties in south-central Wyoming (Figure 1). The field is bounded by the Shirley, Seminoe, Freezout and Ferris Mountains to the north, by the Rawlins Hills to the west and by the Medicine Bow Mountains to the south. Surface drainage within the field is limited to the northward flowing North Platte River and its tributaries.

The Hanna Basin, which is approximately 40 miles long (east to west) by 25 miles wide, is extremely deep for its area with 30,000 to 35,000 feet of sediments overlying its crystalline basement. Most simply, this structural trough, which formed during the Laramide Orogeny, is divided into two separate basins by a large northeast-trending anticline. The Hanna Basin lies to the northwest of the anticline and the Carbon Basin lies to the southeast. Although somewhat less pronounced folding and faulting occur within the basins, their structural complexity is most pronounced on their periphery.

An aspect almost unique to the Hanna Basin is that this basin's economic importance to date has been limited to but one resource - in this instance - coal.

* Staff Geologist
The Geological Survey of Wyoming
University of Wyoming
Laramie

Figure 2: Coal-bearing rocks of the Hanna and Carbon Basins, Wyoming



Modified from Dobbin (1929)

Although there is oil, gas and uranium potential for the basin, no significant activity or development has occurred.

Coal-bearing rocks

The geographic distribution of coal-bearing rocks in the Hanna Basin can be seen on the guidebook cover and the enclosed geologic map by Weitz and Love (1952). Although coal seams occur in the Upper Cretaceous Mesaverde Group and Medicine Bow Formation, the most significant seams are in the Ferris Formation of Upper Cretaceous and Paleocene age, and the Hanna Formation of Paleocene and Eocene age. Stratigraphic columns in Figure 2 show the approximate position of the more persistent coal seams in both the Hanna and Carbon Basins. Although correlation of individual coal seams between the two basins has not really been verified, previous investigators suggest that the youngest seams of the Hanna Formation are correlative (Dobbin, 1929).

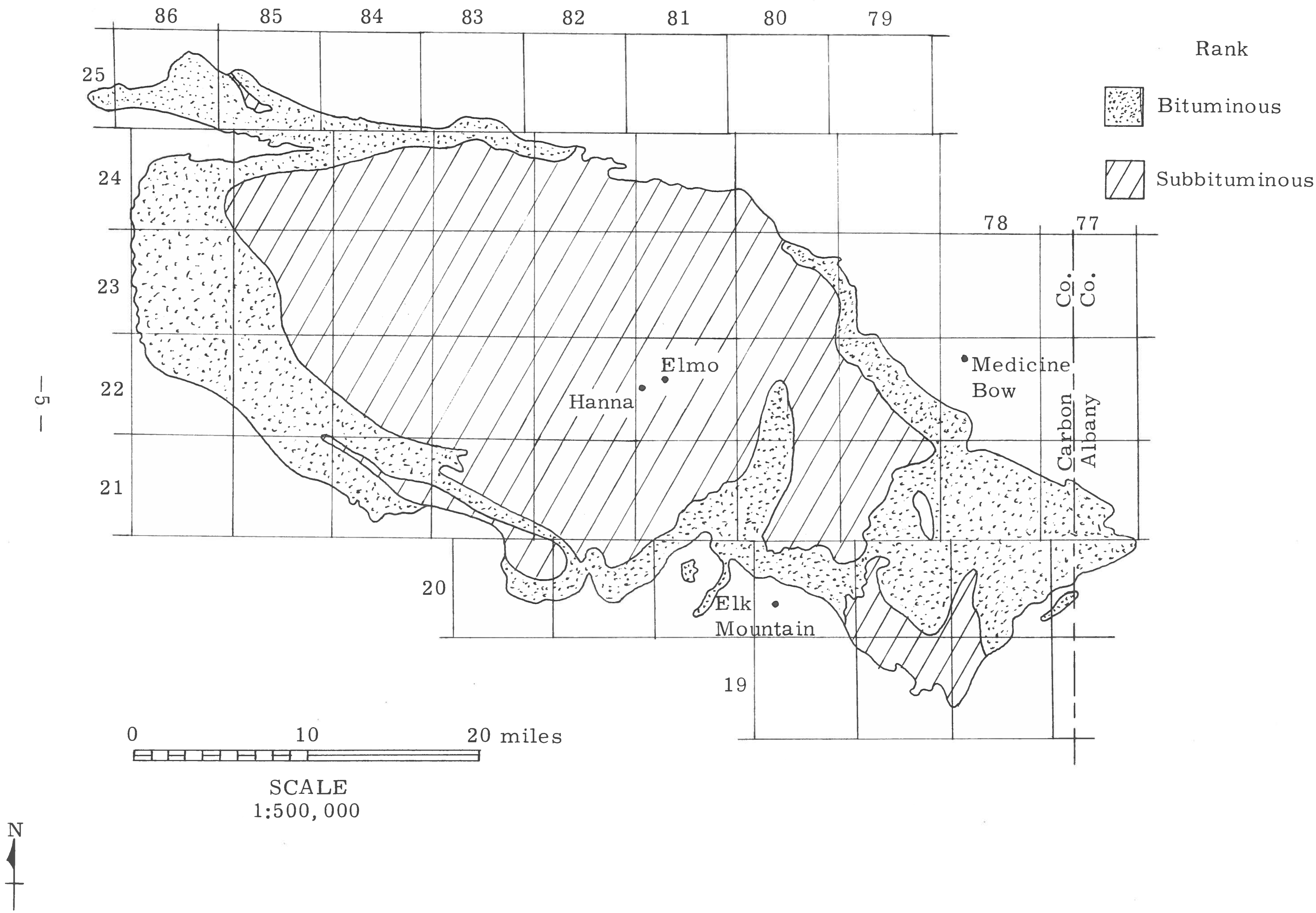
Of the 69 coal beds that exhibit thicknesses greater than 3 feet, 4 occur in the Mesaverde Group, 15 in the Medicine Bow Formation, 20 in the Ferris Formation and 30 in the Hanna Formation (Dobbin, 1929). Seams over 20 feet thick are restricted to the latter two formations.

Coal rank and quality

In general the rank of an individual coal bed in the Hanna Field increases with increasing depth of burial, thereby accounting for an increase in coal rank towards the deeper parts of the basins. The higher rank of older coals is also attributed to greater depth of burial (Unfer, 1951). The geographic distribution of bituminous and subbituminous coal in this field is shown in Figure 3.

The rank of the coals in the Hanna Field ranges from subbituminous C to high volatile C bituminous (Berryhill, 1950). The highest rank coal, high volatile C bituminous, occurs in the Mesaverde Group. Collectively, coals of this

Figure 3: Distribution map of bituminous and subbituminous coals in the Hanna Coal Field



group and the Medicine Bow Formation range downward in rank to subbituminous B. The Hanna Formation and Ferris Formation coals are predominantly subbituminous, although the Hanna No. 2 seam of the Hanna Formation has reportedly been ranked as high as high volatile C bituminous (Berryhill, 1950).

Published coal analyses from the Hanna Field rarely show ash contents greater than 10% and average about 6%. The analyses also show sulfur percentages ranging from a low of 0.2% to a high of 1.1%. The average sulfur content is around 0.5% on an as-received basis. As-received heat values range from a low of 8,840 to a high of 11,530 British Thermal Units per pound. On a moist mineral-matter-free basis heat values range from 9,520 to 13,630 British Thermal Units per pound. It has been estimated that heat values increase as much as 300 B.T.U.'s for each additional 100 feet of overburden (Unfer, 1951).

COAL MINING

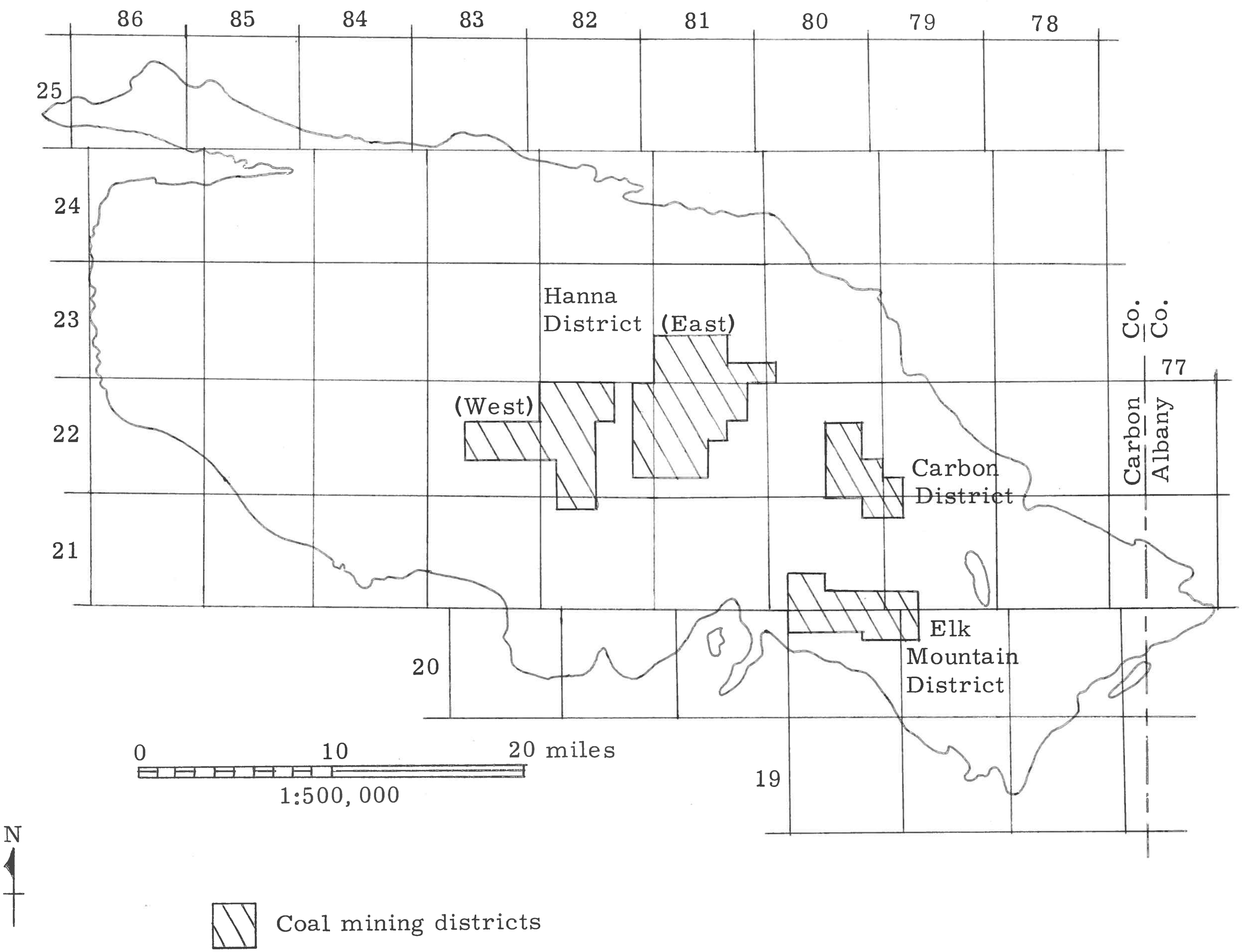
History

Although commercial coal mining operations have shifted position in the Hanna Field several times, this field has nevertheless continued to be productive throughout its 105 year history. In terms of total annual tonnage produced in Wyoming, the Hanna Field now outranks all others except possibly the Glenrock Field in Converse County.

The first significant mining operations in the Hanna Field began in the Carbon Basin in 1868, shifted to the Hanna Basin in 1888, and were supplemented by limited mining in the more southerly Elk Mountain district in the early to middle 1900's. Coal mines in these three mining districts account for more than 99.99% of recorded tonnages from the field (Figure 4).

Since 1868, at least 84 underground mines and strip pits have been opened.

Figure 4: Mining districts in the Hanna Coal Field



Of these, only 29 underground mines and 26 strip mines have reported annual tonnages to the State Inspector of Mines. The 29 underground operations produced 37,643,485 tons of coal by December 31, 1971, while the strip mines produced 12,611,178 tons for a total production of 50,254,663 short tons (Appendix I, Table 1).

Coal production was derived exclusively from underground mining operations until 1937 when Monolith Portland Midwest Company opened the first strip mine in the field. Although the number of active strip mines in the field surpassed the number of underground mines by 1944, it wasn't until the last of the underground mines closed in 1954 that strip mine production exceeded that of the deep mines (Figures 5 and 6). Between 1955 and 1970 strip mining not only accounted for the total reported tonnage but also set an annual tonnage record for the field in 1970. The previous record of 1,479,356 tons set in 1945 was bettered by 133,875 tons (Figure 5). In 1971, a newly opened underground mine and two strip mining operations produced 1,848,509 tons of coal, setting another annual tonnage record, suggesting an accelerated rate of mining beyond any previously predicted.

Carbon coal mining district

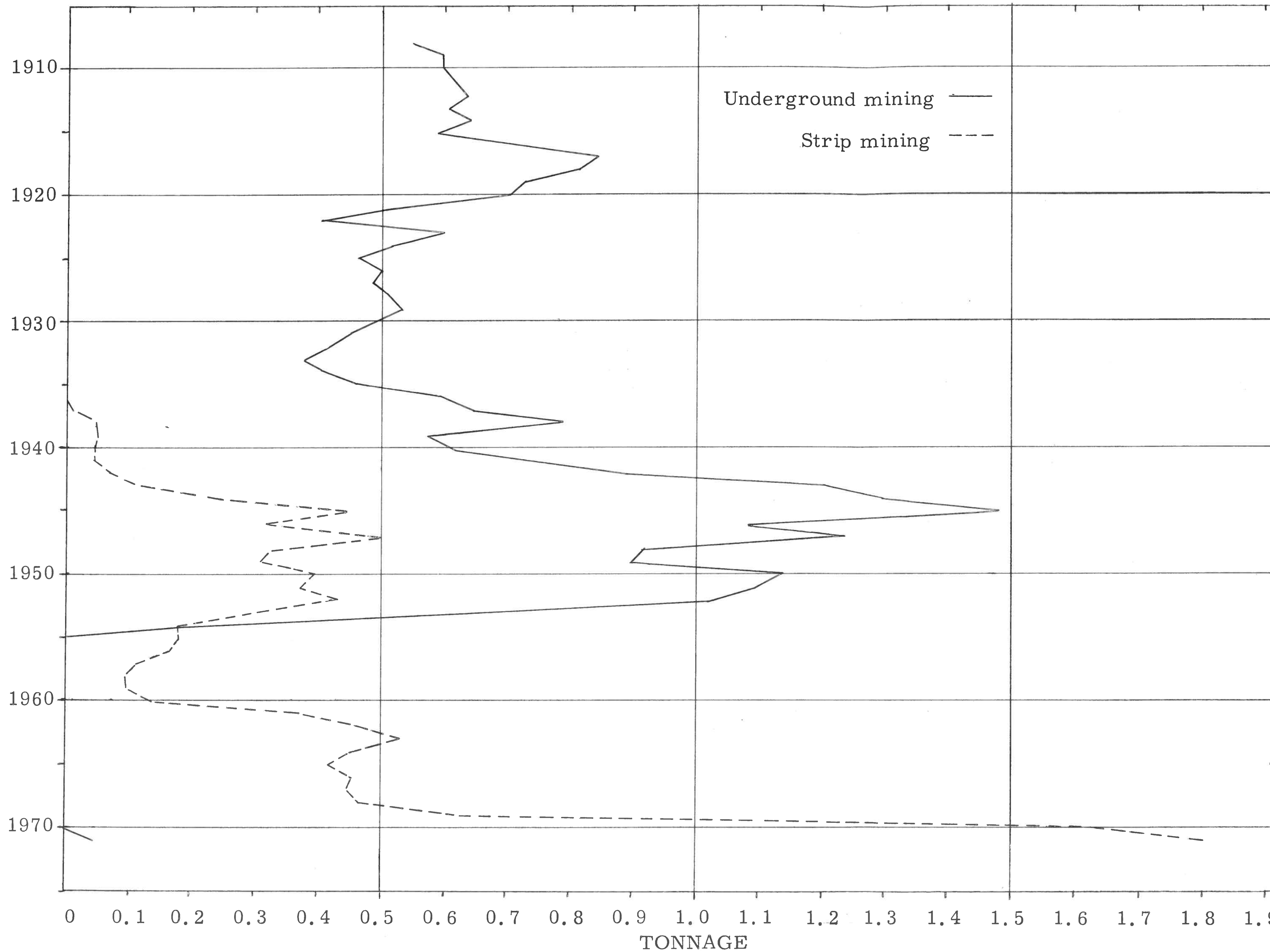
In the Carbon coal mining district, the Wyoming Coal and Mining Company developed the Carbon No. 1 mine in 1868. In all, seven underground mines were opened in the Carbon Basin before this region was abandoned in 1902 (Figure 7). These seven mines produced 4,680,346 tons of coal, which for all practical purposes, were used exclusively by the Union Pacific Railway Company. The total tonnage of coal mined from this region came from the Carbon Nos. 5, 6 and 7 seams of the Hanna Formation. Although the Carbon No. 4 mine was opened on the Carbon No. 4 seam, no tonnage was ever reported because the mine was never put into production.

Hanna coal mining district

As the quality and reserves of the Carbon coal mining area dwindled, the Union Pacific Railway Company relocated their main line to a more northerly route through the Hanna Basin. This relocation not only provided a better railroad grade but also stimulated development of substantially larger coal reserves near the town of Hanna. The shift from the Carbon to the Hanna coal mining district began in 1888 with the opening of the Union Pacific Railway Company's Dana mine. Shortly thereafter, the first of the Hanna mines was opened by the newly incorporated Union Pacific Coal Company. Before the closing of the Hanna No. 4A mine in 1954, a total of eight Hanna mines were opened by the Union Pacific Coal Company (Figures 8 and 9). The Union Pacific mines and six other underground mines in this mining district collectively produced 32,750,102 tons of coal between the years 1888 and 1971. Strip mining in the Hanna Field began in 1937 and has continued to the present. The production attributable to strip mining in the period between 1937 and 1971 came from 20 open pits and totaled 11,808,263 tons. The Hanna coal mining district has been and should continue to be the largest and most productive district in the field for some time to come. Total coal production from this district as of December 31, 1971, has been 44,558,365 tons. Although coal from this region was originally mined for the railroad, it is now being sent to coal-fired power plants, the sugar beet industry, cement manufacturers and other domestic markets. in 1971, these markets were located in Wyoming, Colorado, Iowa, Idaho, Wisconsin, Nebraska, Illinois, and Utah.

Significant underground mining in the Hanna district has been limited to the Hanna Nos. 1, 2, and 5, Lower Dana, No. 80 and 82 seams of the Hanna Formation and the No. 65 seam of the Ferris Formation. Strip mining has been on the Hanna Nos. 1, 2, and 5, Nos. 78, 79, 80, 82, and 84(?85) and Brooks seams of the Hanna Formation.

Figure 5: Annual coal production for years 1908 through 1971 inclusive (in millions of short tons)



SOURCE: U. S. B. M. & State Insp. of Mines

Figure 6: Number of mines by year and type

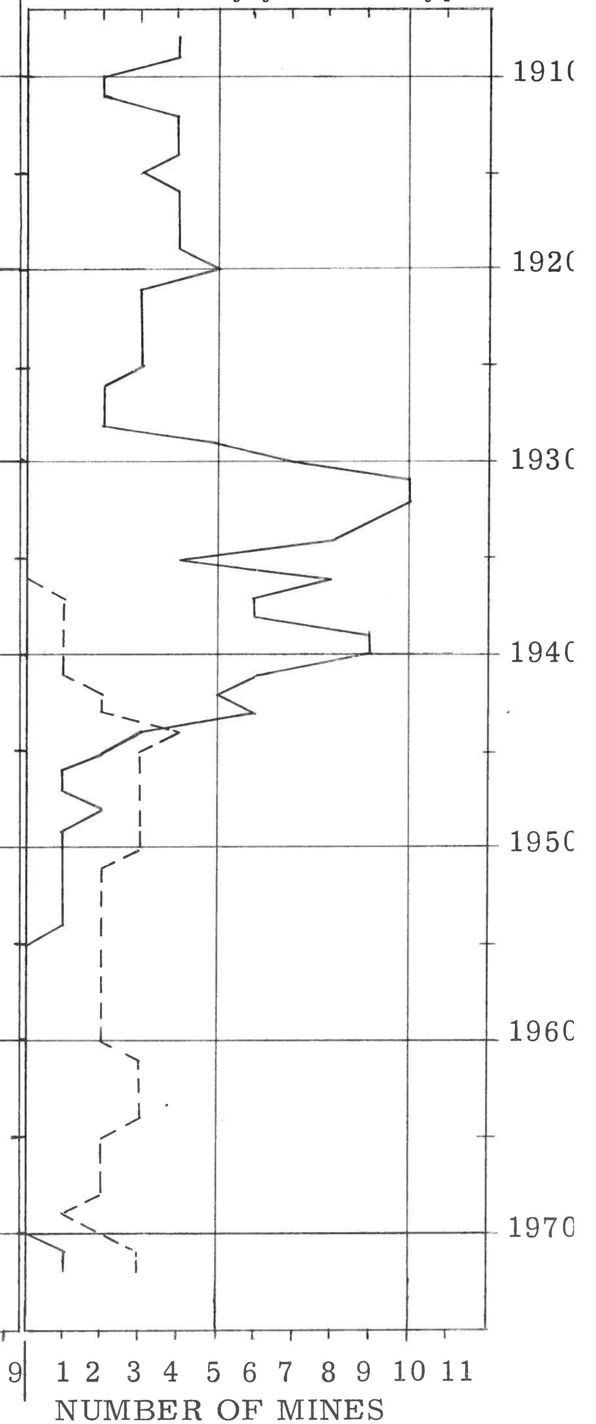


Figure 7: Mined out areas in Carbon coal mining district to January 1972

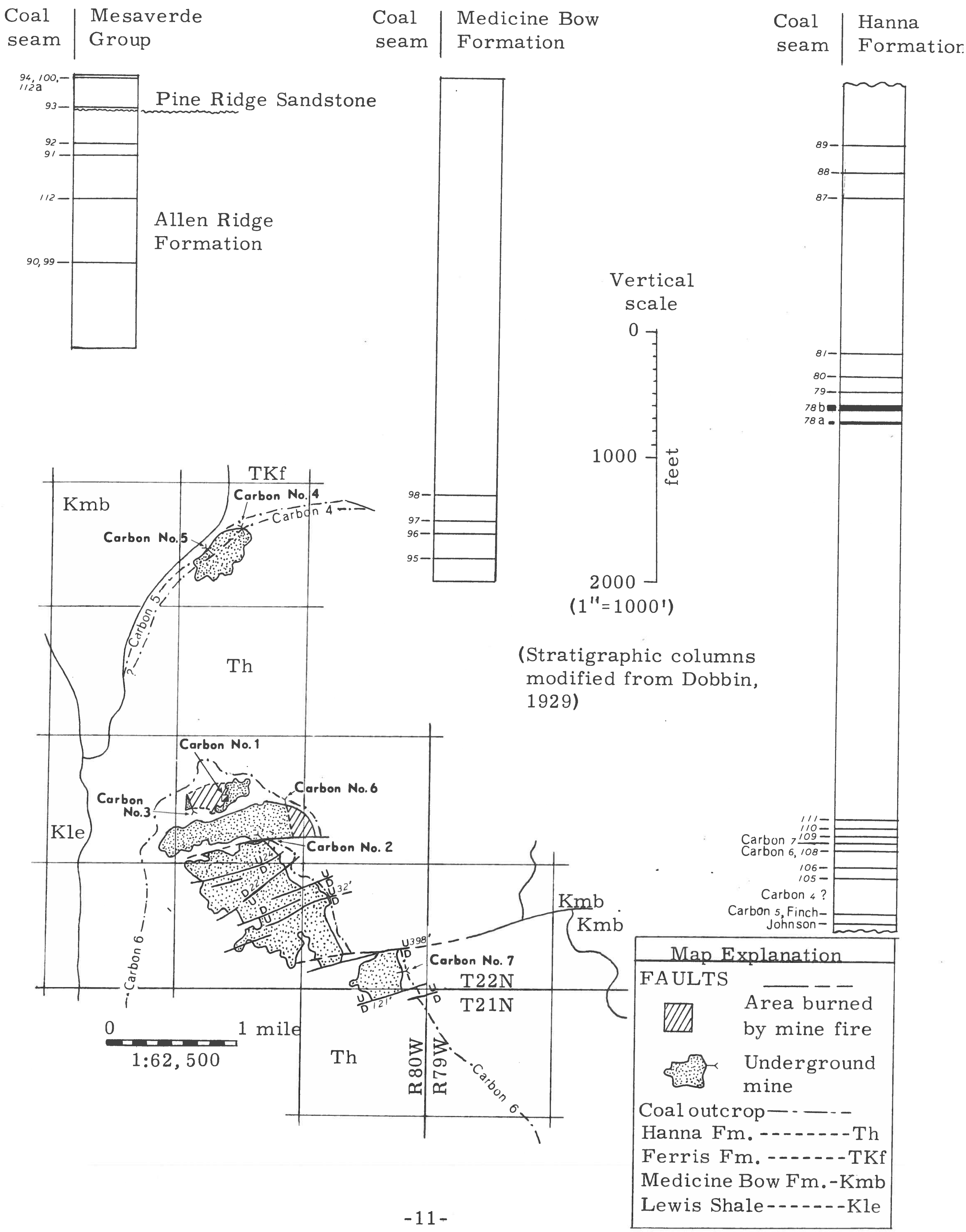
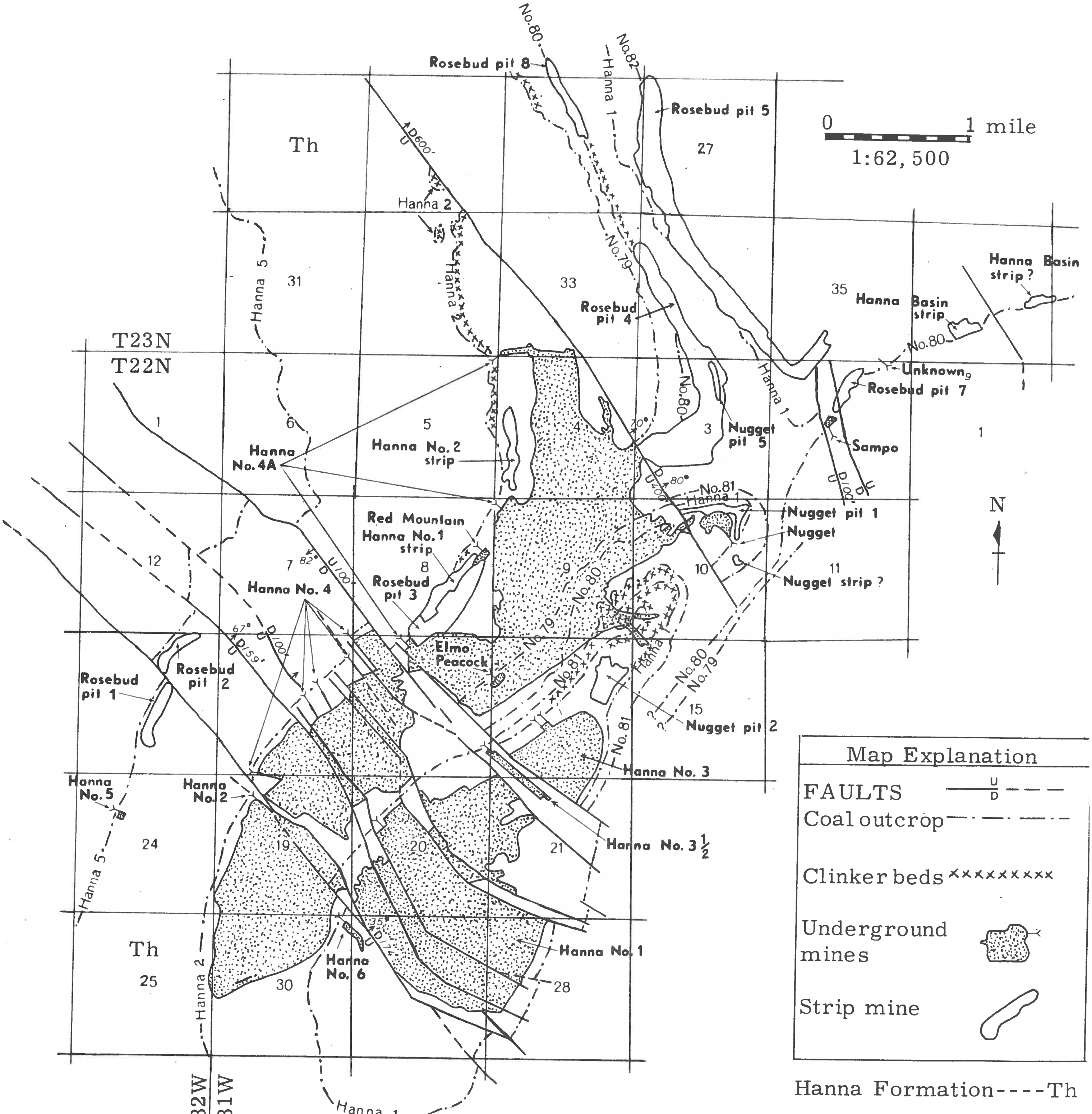


Figure 8: Mined out areas in the eastern portion of the Hanna coal mining district to January 1972



See Figure 9 for stratigraphic column of Hanna Fm. in this area. Also see Figure 10 for other coal-bearing formations.

Figure 9: Mined out areas in the western portion of the Hanna coal mining district to January 1972

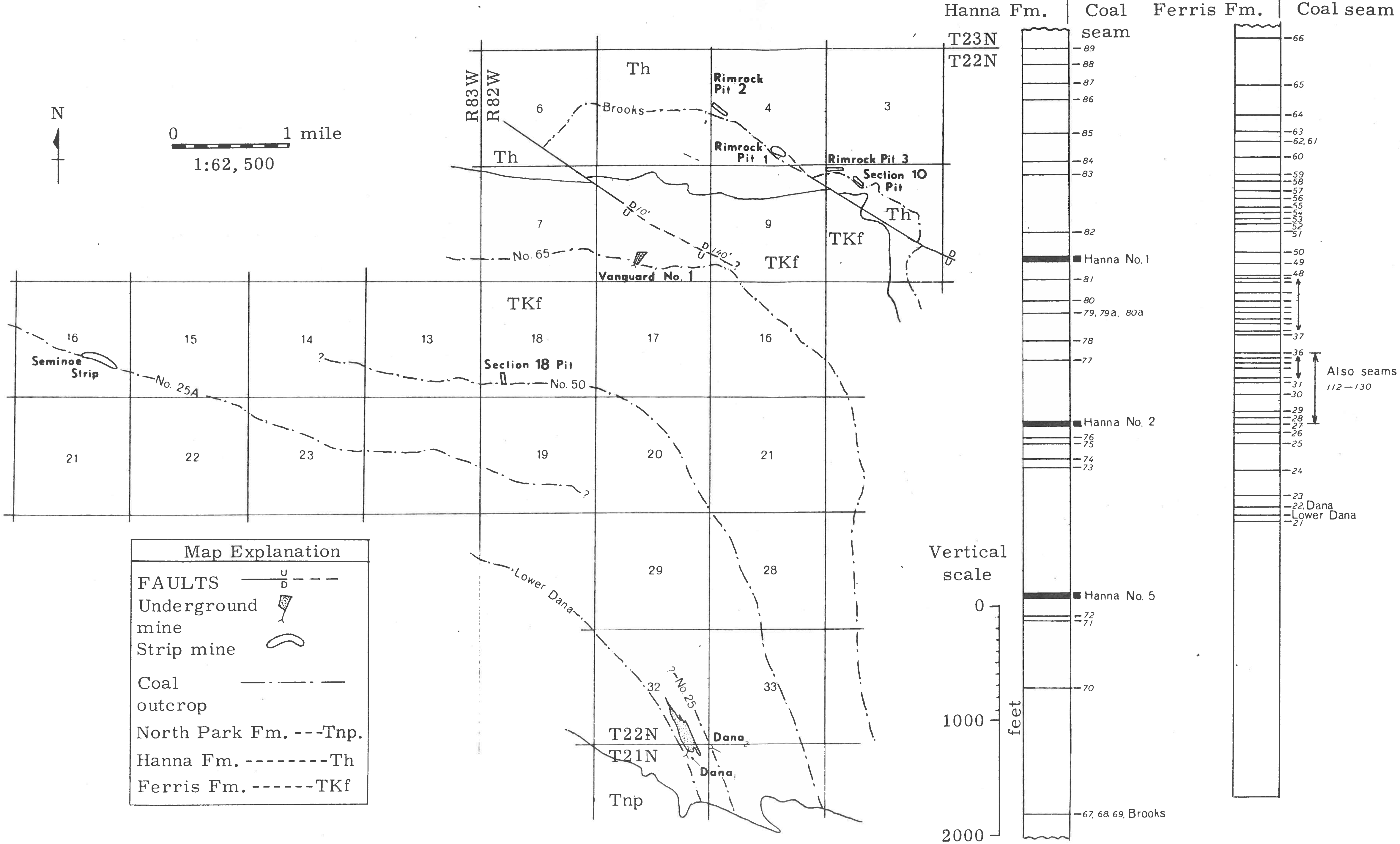
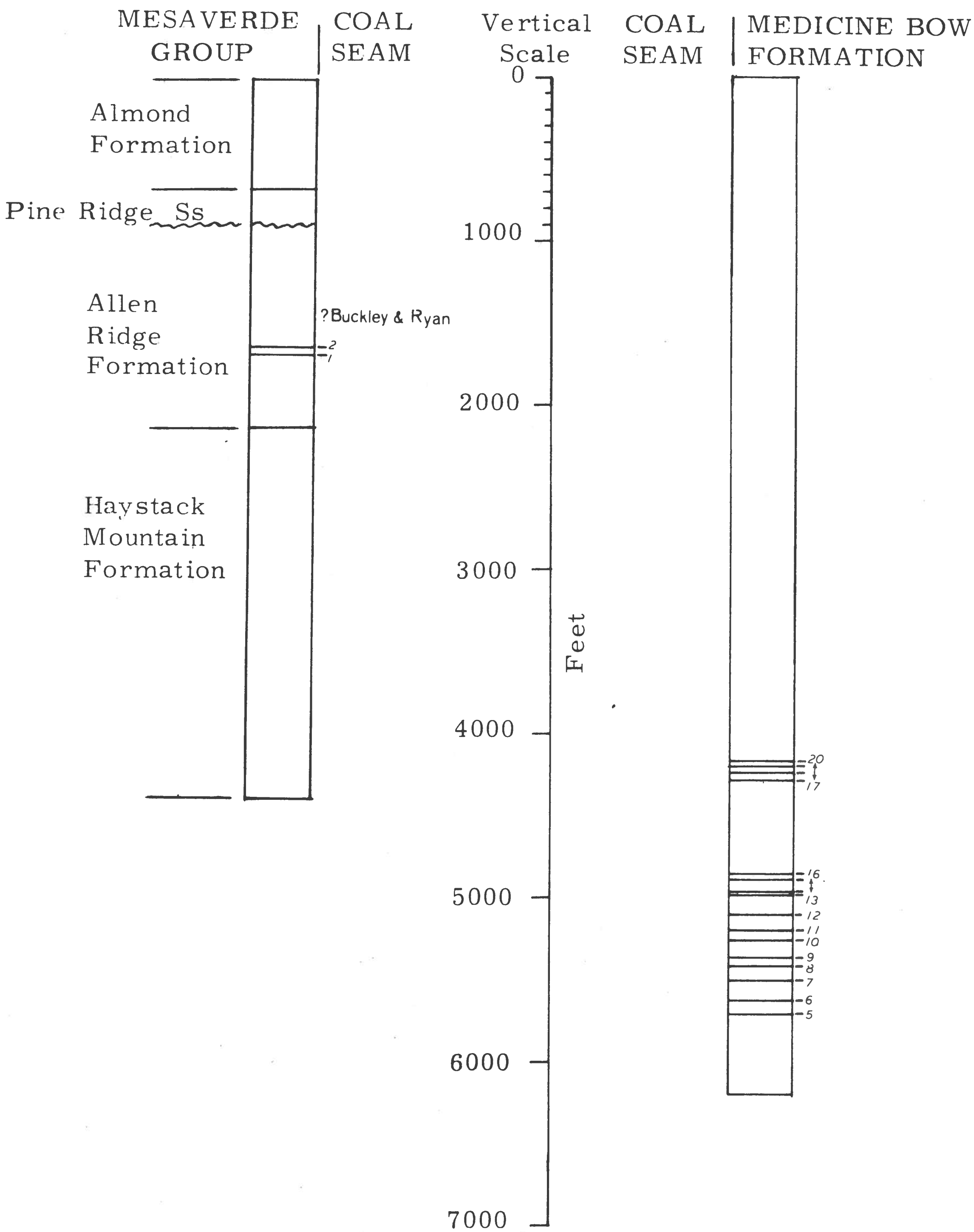


Figure 10: Coals in the Mesaverde Group and Medicine Bow Formation of the Hanna coal mining district



Strip mining in the Ferris Formation has been confined to the No. 25-A and No. 50 seams.

Elk Mountain coal mining district

Although mining began in the Elk Mountain coal mining district in the early 1900's, no significant tonnages were reported until 1929 when Jay L. Johnson's Johnson mine was opened. A total of 208,324 tons of mined coal has been reported from four underground mines that operated in the region until 1945. Strip mining began in 1944 and continued until 1951. Collectively, six open pit mines produced 802,915 tons of coal. After yielding a total of 1,011,239 tons of coal in a 23 year period, the Elk Mountain mining region is now abandoned (Figure 11). Only two major coal seams were mined in this region and they were the Finch and Johnson seams of the Hanna Formation.

Other mining areas

Mines outside the three major mining districts have all been small, short-lived, local, underground operations. Although their annual tonnage was occasionally reported, they were such small mines that their total production can be considered almost negligible. The largest production from a single one of these mines was the 1,229 tons reported from the Miller mine, which operated in the northwestern portion of the field from 1932 to 1936. The sum of all reported coal production from these mines amounts to a mere 4,713 tons. The seams mined by these operations were generally unnamed or, unspecified coals of the Mesaverde Group or Medicine Bow Formation. The Buckley and Ryan seam and the No. 112-A seam of Mesaverde age are the only two seam designations that have been reported.

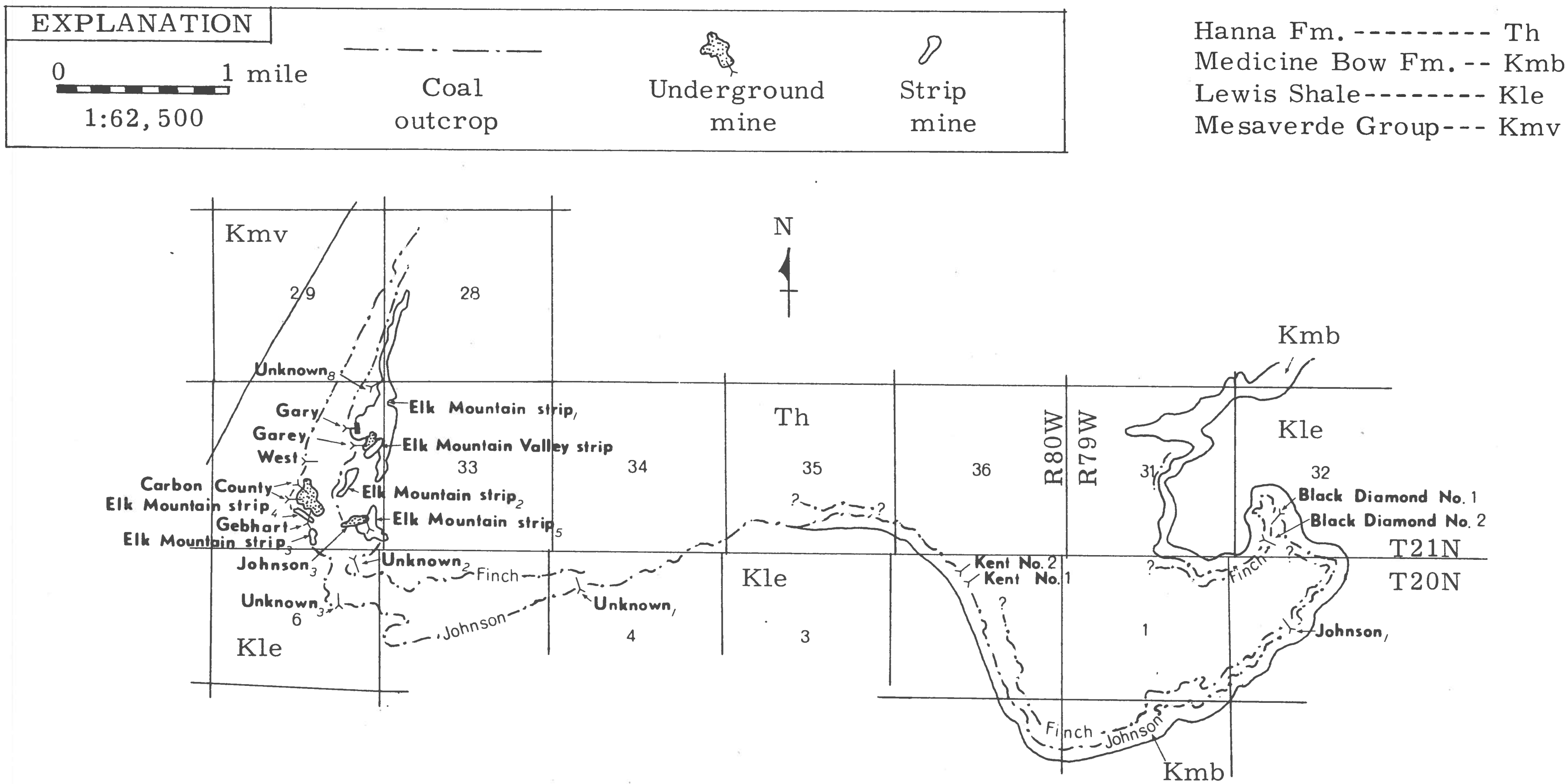
CURRENT MINING OPERATIONS

Rosebud Coal Sales Company, Energy Development Company, and Arch Mineral Corporation are the only companies mining coal in the Hanna Field. All three are located in the Hanna coal mining district (Figures 8 and 9). Rosebud, which is a wholly-owned subsidiary of Peter Kiewit Sons, Inc., is the oldest mining company in the field. It began its first strip mine in 1961. Since then Rosebud has mined over 6,567,116 tons of coal. Production in 1970 was 1,475,354 tons followed by 1,497,567 tons in 1971. Rosebud's dragline with its ~~42~~ 45-cubic yard bucket is the second largest in the field and possibly the third largest in the State. Other details of Rosebud's mining operations are discussed in Appendix II, Stop 1.

Energy Development Company, which is owned by Iowa Public Service Company, not only strip mines coal but also operates the Vanguard No. 1 mine, which is the only active underground mine in the Hanna Field. Energy's stripping operations commenced in 1970, removing 137,877 tons of subbituminous coal. Strip mine production more than doubled in 1971 to 305,542 tons. The Vanguard No. 1 mine, which reported its first 45,400 tons of production in 1971, is still in its early development. See Appendix II, Stop 2 for more details.

The newest mining company in the field is Arch Mineral Corporation, a joint venture of Ashland Oil Company and Hunt Enterprises. Arch opened its Seminoe strip mine in December 1971 and intends to mine more than 2 million tons of coal in 1972. It's ~~65~~ 62-cubic yard dragline is the largest mining coal in Wyoming. Appendix II, Stop 3 has more details of this company's operation.

Figure 11: Mined out areas in the Elk Mountain coal mining district to January 1972



See Figure 7 for stratigraphic columns of coal-bearing formations.

MINING HAZARDS AND PROBLEMS

Mining catastrophes have taken their toll of the coal miners operating in the Hanna Field. The early days of mining in the Carbon and Hanna districts were fraught with mine floods, fires and explosions. Since the deaths of 228 miners from separate explosions in 1903 and 1908, however, there have been no further catastrophes of that nature or magnitude. Like the rest of the nation, underground mining deaths not attributable to explosions, equipment failure or human error, have been from coal and roof falls. Falls of top coal, face coal and roof rock have all accounted for some fatalities. Some of these falls have resulted from coal "bumps," although this phenomenon has only rarely been mentioned in accident descriptions.

Since the closing of the last of the older underground mines 18 years ago, only 2 coal mining fatalities have occurred in the strip mining operations of the basin. Only 23 non-fatal accidents have been reported in this same time period. Both these figures help one recognize that strip mining is a relatively safer mining method than underground mining.

In addition to the hazards mentioned above, faulting, spontaneous combustion, slumping, and clinker beds all create mining problems as well as hazards. Faulting is perhaps the greatest problem to mining in this field, as it was a major factor in the Carbon district and still is a factor in the Hanna district. In the Carbon area at least nine northeast-southwest trending, high angle(?), normal(?) faults dissect the district. Vertical displacements or throws on these faults range from inches to a maximum of 348 feet (Figure 7). The Hanna district is also broken by high angle, normal faults. At least 20 faults, trending northwest-southeast, have been mapped and exhibit throws from a few feet to 600 feet (Figures 8 and 9). Like the Carbon district, the north sides of most of these faults are downthrown.

Slumping is a definite problem affecting some strip mines in the district. Low walls at relatively low dips have slid into boxcuts. Apparently the coal itself has created the glide plane, and moved simply by its own weight. Weathering of exposed coal may be a factor contributing to the failure of the walls in these pits. Such slumping is not only dangerous to personnel but can also damage equipment and disrupt the whole mining operation. One of the two fatalities since 1954 resulted from a large slide.

Some coal seams are more susceptible to spontaneous combustion than others. Operators must take special precautions during excavation and storage of these coals.

Another natural phenomenon encountered in this field as well as in many other areas of Wyoming is red clinker beds. These beds consist of baked and fused rock that originally overlaid burning coal seams. They normally do not extend more than a few hundred feet behind their outcrop and are believed to be the result of outcrop fires started by grass, lightning, or spontaneous combustion. In as much as these clinker beds are widespread, they must be considered in calculating reserves and in mining plans. Interestingly, they prove to be an excellent material for road beds and are often excavated for that purpose.

RECLAMATION

Wyoming's Open Cut Reclamation Act became effective May 24, 1969. The act, which is reproduced on pages 19-24 of Appendix III, is administered by the Commissioner of Public Lands of the State of Wyoming. Through a cooperative agreement with the Federal Government, the Commissioner not only regulates reclamation of State lands but also Federal lands. This is made possible because Wyoming's reclamation act exceeds Federal requirements. The act further allows the Commissioner to formulate rules and regulations for its implementation (pages 1-18, Appendix III).

Salient features of the Open Cut Reclamation Act of Wyoming include the following:

1. Permit fee is $50.00. A permit may be amended without additional fee.
2. A sufficiency of surety bond equal to restoration costs is required. Initially, surety bonds are estimated at $200.00 per acre but this figure is subject to revision once restoration costs are known. Credit is given for acceptable restoration - $185.00 per acre in the case above. The other $15.00 is retained for seeding costs. After a company seeds, this too is credited. (Incidentally, seeding is often done by a local rancher, or farmer, contracted by the mining company. In this way farm equipment need not be purchased.)
3. Backfilling and grading requirements are that peaks and ridges be reduced to rolling topography. This reclamation step should make the mine and spoils blend into the natural surroundings. Mere flattening of ridges and peaks to prescribed minimum widths is no longer acceptable.
4. To control acid mine wastes, the coal seam must be covered with at least 2 feet of soil or clean fill. Other acidic refuse such as tailings from a cleaning facility must also be buried a minimum of

2 feet.

5. Reasonable effort to revegetate disturbed land must be made. Seeding practices will be recommended by the Commissioner.
6. A reclamation report and operations map must be submitted to the Commissioner no later than September 1 of each year in which mining is conducted. All steps taken to effect land reclamation must be discussed and shown.
7. Initiation and/or completion of reclamation is at the discretion of the Commissioner.
8. Persons mining without a permit can be fined up to $1000.00 per violation per day of operation.

The greatest problem to reclamation in the Hanna Coal Field is the difficulty in revegetating the disturbed ground. Rainfall is so sparse that seed germination is extremely difficult and slow. Because of slow growth, wind and what little water that does fall remove much of the seed before it can be established. All vegetation, native or introduced, takes an exceptionally long time to become established let alone well established.

Appendix III also contains a Wyoming Agricultural Experiment Station Research Journal entitled: Reclamation of strip mine spoil banks in Wyoming.

RESOURCES AND PRODUCTION

As shown in Table 2, Berryhill's (1950) estimated original coal resources of the Hanna Field are revised to 3,918,590,000 tons. This resource figure is the total from all categories under less than 3000 feet of overburden. Of this total, approximately 87% of the resources are in the inferred category, 12% in the indicated category and 1% in the measured category.

Table 2: Original coal resources of the Hanna Coal Field in millions of short tons (modified from Berryhill, 1950)

Rank	Coal Thicknesses	Overburden Thicknesses in Feet 0-1000	1000-2000	2000-3000	0-3000
BITUMINOUS	14-42 inches	13.91	16.86	17.33	48.10
	Over 42 inches	19.63	3.62	---	23.25
SUBBITUMINOUS	$2\frac{1}{2}$-10 feet	1554.98	753.72	467.94	2776.64
	Over 10 feet	751.01	229.56	90.03	1070.60
BOTH RANKS COMBINED		2339.53	1003.76	575.30	3918.59

Table 3: Summary of coal resources of the Hanna Coal Field in millions of short tons

Estimated original resource (0-3000 ft. overburden)[1]	Underground mining production (1868 to 1971 inclusive)	Estimated coal lost in underground mining (1868 to 1971)[2]	Strip mining production (1937 to 1971 inclusive)	Estimated coal lost in strip mining (1937 to 1971)[3]	Remaining original resource to January 1, 1972	Remaining resource recoverable by all mining methods to January 1, 1972[4]
3,918.59	37.64	37.64	12.61	2.52	3,828.17	1914.09

1. Revised from Berryhill (1950) 2. 50% recovery 3. 80% recovery 4. 50% recovery

Table 4: Strippable coal resources of Hanna Coal Field in millions of short tons to January 1, 1972

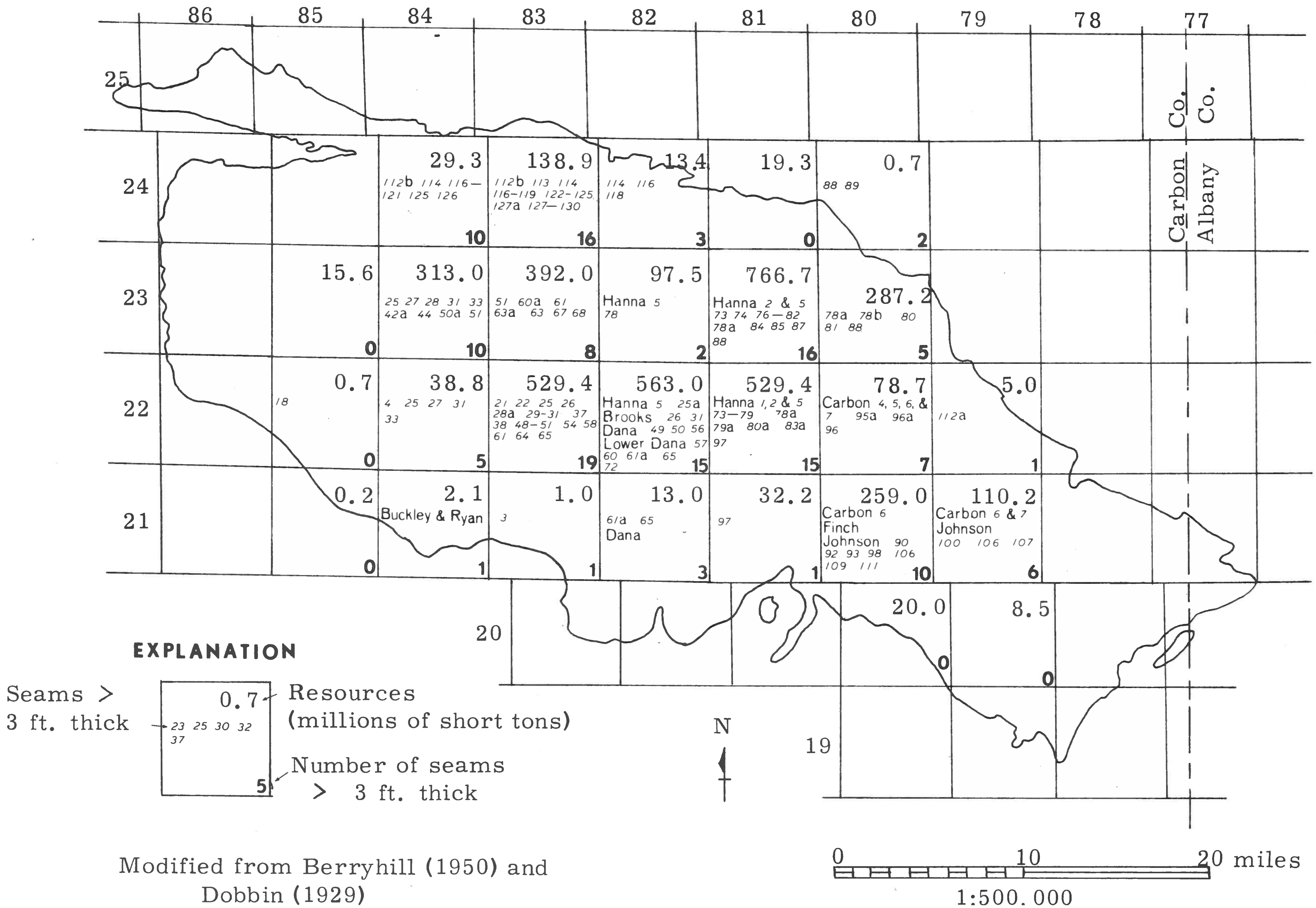
	Overburden Thicknesses in Feet		
	0-100[1]	0-150	0-200[2]
Estimated strippable resource	156.49	---	312.98
Estimated recoverable strippable resource[3]	125.19	---	250.38
Proven strippable resources in Hanna and Ferris Formations (0-150 feet overburden)[4]		20.0	

1. Estimated strippable resource figure is one-tenth of the remaining original resources of bituminous coal over 42 inches thick and under less than 1,000 feet of cover plus one-tenth of subbituminous coal over 5 feet thick and under less than 1,000 feet of cover. For simplification all coal mined and lost to date has been subtracted from these coal thickness categories and the 0-1000 feet overburden category.
2. Twice the 0-100 foot overburden figure.
3. Estimate 20% mining losses.
4. U. S. Bureau of Mines and company records.

The total recorded production from the Hanna Field through 1971 was 50,254,663 tons. Assuming that coal losses in underground mining have been equal to production and have been about 20% in strip mine production, the original resources in the field have been reduced by 90,420,384 tons to January 1, 1972. Of the remaining resource of 3,828,169,616 tons, 50% of it can probably be recovered. Table 3 summarizes original resources, production, mining losses, remaining and recoverable resources. Coal reserve figures have not been calculated, as they must necessarily be based on economic considerations such as mining and transportation costs for which data are not presently available.

A strippable resource figure has been estimated for a 0 - 100 foot and a 0 - 200 foot overburden range (Table 4). The 0 - 100 foot overburden estimate of 156.49 million tons is merely one-tenth of the total remaining resources

Figure 12: Estimated original coal resources by township (millions of short tons)



under less than 100 feet of overburden. The 0 - 200 foot estimate is twice that of the 0 - 100 foot estimate or 312.98 million tons. Although this method is at best a crude approximation, it should be of the right order of magnitude. Recoverable strippable resources in each overburden group were estimated assuming an 80% recoverability factor.

Coal resources in the Hanna field are more than adequate for the predictable future. Should production from this field reach and maintain a conservative level of 5,000,000 tons annually, strippable resources alone could sustain mining for more than 70 years. Total recoverable resources of the field could maintain a similar level of production for more than 390 years. The estimated original resource figures for this field are extremely conservative in that,vast areas around the field's periphery, to the west and north, are not included in the existing estimate of resources (Figure 12).

ACKNOWLEDGMENTS

The writer acknowledges data received from Cleatus France and Don Huckeby of Arch Mineral Corporation, Jim Eman of Big Horn Coal Company, Arnold Hannum of Energy Development Company, George Bristol of Monolith Portland Midwest Company, Dale Emling and Frank Lebar of Rocky Mountain Energy Company, and Steve Swaldi and Rocky Zook of Rosebud Coal Sales Company. Published and unpublished reports of the Wyoming State Mine Inspector, the State Commissioner of Public Lands, the Wyoming Agriculture Experiment Station, the U. S. Bureau of Mines, and the U. S. Geological Survey were invaluable sources of information. The writer also wishes to acknowledge the aid of Dr. D. L. Blackstone, Jr., Geology Department, University of Wyoming. Costs of producing this guidebook were underwritten by the Rocky Mountain

Section of the Geological Society of America and the Geological Survey of Wyoming.

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APPENDIX I

TABLE 1: SURFACE AND UNDERGROUND MINES IN THE HANNA AND CARBON BASINS IN WYOMING

Name of Mine	Location 1/4	SEC	TWP	RGE	Company[2]	Dates of Operation[3]	Mine's Status[4]	Type of Mine[5]	Seam Name[6] and (Thickness)	Age of Seam[7]	Total Production to Jan. 1, 1972 (Short Tons)[8]
Abbott[1]	SEE CARBON COUNTY MINE										
Big Ditch*	SEE CRANE MINE										
Black Diamond No. 1	SW	32	21	79	Unknown	Unknown	ABD	U	Johnson (6'0"-14'0")	T	Unknown
Black Diamond No. 2	SW	32	21	79	Unknown	Unknown	ABD	U	Johnson (6'0"-14'0")	T	Unknown
Buckley & Ryan*	SW	14	21	84	Mr. Buckley & Mr. Ryan	Pre-1925	ABD	U	Buckley & Ryan (4'8"-6'0")	K	Unknown
Carbon County[1]	SW	32	21	80	R. P. Wilson; C. J. Abbott; Carbon County Coal Co.; Earl Johnson	Pre-1936 to 1944	ABD	U	Johnson	T	85, 642
Carbon No. 1[1]	SW	26	22	80	Wyoming Coal & Mining Co.; Union Pacific Railway Co.	1868 to 1881	ABD	U	Carbon No. 6	T	↑
Carbon No. 2	SW	26	22	80	John A. Creighton; Wyoming Coal & Mining Co.; Union Pacific Railway Co.; Union Pacific Coal Co.	1868 to 1900	ABD	U	Carbon No. 6 (?) (Aver. 7'0")	T	4, 680, 346
Carbon No. 3[1]	SW	26	22	80	Wyoming Coal & Mining Co.; Union Pacific Railway Co.	Between 1868 and 1881 exact dates unknown	ABD	U	Carbon No. 6	T	↓

TABLE 1: Continued

Carbon₁ No. 4[1]	NW	14	22	80	Wyoming Coal & Mining Co. (?); Union Pacific Railway Co.	Between 1868 and 1881 exact dates unknown	ABD	U	Carbon No. 4	T	
Carbon No. 5[1]	SW	14	22	80	Wyoming Coal & Mining Co. (?); Union Pacific Railway Co.	Opened (?) Date to 1881	ABD	U	Carbon No. 5 (3'0"-12'0")	T	
Carbon No. 6[1]	NE	26	22	80	Union Pacific Railway Co.	1881 to 1890	ABD	U	Carbon No. 6 (Aver. 7'0")	T	
Carbon No. 7[1]	SE	36	22	80	Union Pacific Coal Co.	1899 to 1902	ABD	U	Carbon No. 7 (Aver. 8'0")	T	
C. B. & H.*	SEE MILLER MINE										
Colorado Coal Corporation[1]	SEE RED MOUNTAIN										
Crane*	Location Unknown				Robert Crane	1930 to 1932; 1939	ABD	U	Unknown	U	1,186
$Dana_1$[1]	NE	5	21	82	Union Pacific Railway Co.; Union Pacific Coal Co.	1888 to 1891	ABD	U	Lower Dana (11'2")	T	62,792
$Dana_2$[1]	NW	4	21	82	Treat & James	1940	ABD	U	No. 25 (6'0"-9'0")	T	333
Edgerton*	Location Unknown				J. J. Edgerton, Medicine Bow	1934 to 1935	ABD	U	Unknown	U	907
Elk Mountain[1]	SEE CARBON COUNTY MINE										
Elk Mountain[1]	SEE GAREY MINE										
Elk Mountain $Strip_1$[1]	NE	32	21	80	Elk Mountain Coal Co.; J. A. Terteling & Sons	1947 to 1951	ABD	S	Finch (18'6")	T	

TABLE 1: Continued

Elk Mountain Strip$_2$[1]	SE	32	21	80	Elk Mountain Coal Co., J.A. Terteling & Sons	Pre-1948	ABD	S	Unknown	T	
Elk Mountain Strip$_3$[1]	SE	32	21	80	Elk Mountain Coal Co., J.A. Terteling & Sons	1947 to 1949	ABD	S	Johnson	T	
Elk Mountain Strip$_4$[1]	SE	32	21	80	Elk Mountain Coal Co., J.A. Terteling & Sons	1947 to 1948	ABD	S	Johnson	T	788,772
Elk Mountain Strip$_5$[1]	SE	32	21	80	Elk Mountain Coal Co., J.A. Terteling & Sons	1947 to 1948	ABD	S	Finch (9'0"-12'0")	T	
Elk Mountain Valley[1]	SEE GAREY MINE										
Elk Mountain Valley No. 1[1]	SEE GAREY MINE										
Elk Mountain Valley No. 2[1]	SEE CARBON COUNTY MINE										
Elk Mountain Valley Strip[1]	NE	32	21	80	Elk Mountain Valley Coal Co., Johnson Brother's	1944	ABD	S	Finch	T	14,143
Elmo Peacock[1]	NW	16	22	81	Elmo Peacock; G.E. Siltamaki	1932 to 1941	ABD	U	No. 79 (U.S.G.S. No. 80-A) (6'0")	T	11,894
Fieldhouse*	NE	23	25	86	Unknown	Pre-1906	ABD	U	Unnamed (7'11")	K	Unknown
Finch[1]	SEE GAREY MINE										
Garey[1]	NE	32	21	80	Finch; H.B. Northrop; Garetson; Elk Mountain Valley Coal Co.; Johnson Brothers	1933 to 1943	ABD	U	Finch (11'0")	T	69,302

TABLE 1: Continued

Gary[1]	NE	32	21	80	James H. Pool; C.R. Cuzick; Howard Corpening; Earl Johnson; Elk Mountain Valley Coal Co.	1939 to 1943	ABD	U	Finch (?) (5'6")	T	16,230
Gary Strip[1]	SEE ELK MOUNTAIN STRIP[1]										
Gary Strip[1]	SEE ELK MOUNTAIN VALLEY STRIP										
Gebhart	SE	32	21	80	Unknown	Unknown	ABD	U	Johnson	T	Unknown
Hanna Basin Strip[1]	SW	36	23	81	Hanna Basin Mining & Construction Co.; Hanna Basin Coal Co.	1959 to 1964	ABD	S	No. 80 (U.S.G.S. No. 79)	T	267,235
Hanna Basin Strip (?)[1]	SE	36	23	81	Hanna Basin Mining & Construction Co.; Hanna Basin Coal Co.	1959 to 1964 (?)	ABD	S	No. 80 (U.S.G.S. No. 79)	T	
Hanna No. 1[1]	NE	20	22	81	Union Pacific Coal Co.	1889 to 1908	ABD	U	Hanna No. 1 (15'0"-30'0")	T	4,016,808
Hanna No. 2[1]	NW	19	22	81	Union Pacific Coal Co.	1889 to 1934	ABD	U	Hanna No. 2 (24'0"-36'0")	T	6,256,157
Hanna No. 3[1]	SW	16	22	81	Union Pacific Coal Co.	1905 to 1920	ABD	U	Hanna No. 1 (19'0"-24'0")	T	2,153,234 (estimated)
Hanna No. 3½[1]	SE	17	22	81	Union Pacific Coal Co.; John W. Hay Coal Co.; Hanna Coal Co.	1912 to 1925	ABD	U	Hanna No. 1 (Aver. 24'0")	T	625,198
Hanna No. 4[1]	SW	18	22	81	Union Pacific Coal Co.	1905 to 1946	ABD	U	Hanna No. 2 (Aver. 36'0")	T	14,866,455

TABLE 1: Continued

Hanna No. 4A[1]	NW	9	22	81	Union Pacific Coal Co.	1947 to 1954	ABD	U	Hanna No. 2 (8'0"-13'0")	T	4,464,204
Hanna No. 5[1]	NW	24	22	82	Union Pacific Coal Co.	1918	ABD	U	Hanna No. 5 (28'8")	T	Unreported but negligible
Hanna No. 6[1]	NE	30	22	81	Union Pacific Coal Co.	1929 to 1933	ABD	U	Hanna No. 1 (28'0")	T	38,918
Hanna No. 1 Strip[1]	SE	8	22	81	Monolith Portland Midwest Co.	1937 to 1968	ABD	S	Hanna No. 2	T	1,769,862
Hanna No. 2 Strip[1]	W	4	22	81	Monolith Portland Midwest Co.	1937 to 1968	ABD	S	Hanna No. 2	T	
Johnson$_1$	SE	6	20	79	Johnson Ranch	Pre-1924	ABD	U	Johnson (13'0")	T	Unknown
Johnson$_2$[1]	SEE CARBON COUNTY MINE										
Johnson$_3$[1]	SE	32	21	80	Jay L. Johnson; E.L. Hicks; P.W. Waghorn; J.C. Johnson	1929 to 1945	ABD	U	Finch	T	37,150
Johnson No. 3[1]	SEE JOHNSON$_3$ MINE										
Johnson Strip[1]	SEE ELK MOUNTAIN VALLEY STRIP										
Kent Mine No. 1	NW	2	21	80	Colorado-Wyoming Coal Co.	1911 to 1923 (?)	ABD	U	Johnson (14'0")	T	Unknown
Kent Mine No. 2	NW	2	20	80	Colorado-Wyoming Coal Co.	1911 to 1923 (?)	ABD	U	Johnson (14'0")	T	Unknown
Kronkheit *	SW	17	25	85	Unknown	Pre-1906	ABD	U	Unnamed (5'0"-8'6")	K	Unknown
Kyle *	(?)	(?)	21	79	William Kyle	1931	ABD	U	Unnamed	K	251
McMillan[1]	SEE RED MOUNTAIN MINE										
McMillen[1]	SEE RED MOUNTAIN MINE										

TABLE 1: Continued

Miller *	SW	35	25	85	M. and D. V. Miller; Merl Miller; C. B. & H. Coal Co.; George Houston; J. R. Christy	1932 to 1936	ABD	U	Unnamed 11'6")	K	1,229
Monolith No. 1 Strip[1]	SEE HANNA NO. 1 STRIP										
Monolith No. 2 Strip[1]	SEE HANNA NO. 2 STRIP										
New Garey[1]	SEE GAREY MINE										
New Gary[1]	SEE GARY MINE										
Nugget[1]	NE	10	22	81	Swenson and Yakes; Nugget Coal Co.	1936 to 1943	ABD	U	Hanna No. 1 (U.S.G.S. Bed No. 79=A or 80-A)	T	191,286
Nugget Pit No. 1[1]	NE	10	22	81	Nugget Coal Co.	Between 1942 and 1958	ABD	S	Hanna No. 1 (U.S.G.S. Bed No. 79-A or 80-A)	T	
Nugget Pit No. 2[1]	NE	16	22	81	Nugget Coal Co.	Between 1942 and 1958	ABD	S	Hanna No. 1 (U.S.G.S. Bed No. 84 or 85)	T	2,760,631
Nugget Pit No. 5[1]	NE	3	22	81	Nugget Coal Co.	Between 1942 and 1958	ABD	S	No. 80 (13'6"-16'0") (U.S.G.S. No. 78)	T	
Nugget Strip(?)[1]	NE	10	22	81	Nugget Coal Co. (?)	Between 1942 and 1958	ABD	S	No. 81 (U.S. G.S. No. 79-A)	T	
O'Brien Spring *	SW	9	24	85	Unknown	Pre-1907	ABD	U	Unnamed (5'0")	K	Unknown
Old Boney *	Location Unknown				Harry Ream	1931 to 1933	ABD	U	Unknown	U	960

TABLE 1: Continued

Old Garey[1]	SEE GAREY MINE										
Old Gary[1]	SEE GAREY MINE										
Peacock[1]	SEE ELMO PEACOCK MINE										
Penn Wyoming*	NW	20	25	85	Unknown	Pre-1906	ABD	U	Unnamed (4'10")	K	Unknown
Public*	Location Unknown				Public Coal Co.	1948	ABD	U	Unknown	U	120
Reams*	SEE OLD BONEY MINE										
Red Mountain[1]	NE	8	22	81	McMillen: Colorado Coal Corporation	1929 to 1936	ABD	U	Hanna No. 2	T	17,423
Rimrock Strip Pit1[1]	SE	4	22	82	Energy Development Co.	1970 to Present	INA	S	Brooks (8'0")	T	443,419 (Rimrock Strip Pits 1–3)
Rimrock Strip Pit2[1]	SW	4	22	82	Energy Development Co.	1970 to Present	INA	S	Brooks (Aver. 5'0")	T	
Rimrock Strip Pit3[1]	NW	10	22	82	Energy Development Co.	1970 to Present	INA	S	Brooks (Aver. 8'0")	T	
Rock Crossing*	SE	33	24	81	Unknown	Pre-1906	ABD	U	Unnamed (4'5")	T	Unknown
Rosebud Pit 1[1]	SE	13	22	82	Rosebud Coal Sales Co.	1961 to Present	INA	S	Hanna No. 5	T	6,567,116 (Rosebud Pits 1–8)
Rosebud Pit 2[1]	NE	13	22	82	Rosebud Coal Sales Co.	1961 to Present	INA	S	Hanna No. 5	T	
Rosebud Pit 3[1]	SE	8	22	81	Rosebud Coal Sales Co.	1961 to Present	INA	S	Hanna No. 2	T	
Rosebud Pit 4[1]		3	23	81	Rosebud Coal Sales Co.	1961 to Present	A	S	No. 80 (U.S. G.S. No. 78) (Aver. 15'6")	T	
Rosebud Pit 5[1]		34	23	81	Rosebud Coal Sales Co.	1961 to Present	A	S	No. 82 (U.S. G.S. No. 80) (Aver. 9'0")	T	
Rosebud Pit 7[1]	N	2	22	81	Rosebud Coal Sales Co.	1961 to Present	INA	S	No. 80 (U.S. G.S. No. 79)	T	
Rosebud Pit 8[1]	N	28	23	81	Rosebud Coal Sales Co.	1961 to Present	A	S	No. 80 (U.S. G.S. No. 78) (Aver. 24'0")	T	

TABLE 1: Continued

Saltiel*	Location Unknown				M. M. Butler; Seminoe Dam	1939	ABD	U	Unknown	U	60
Sampo[1]	SW	2	22	81	Sampo Coal Company; Sampo Cooperative Coal Co.	1908 to 1909 (?)	ABD	U	No. 80 (U.S. G.S. No. 79) (35'0")	T	Unknown
Section 10 Pit[1]	NW	10	22	82	Energy Development Co.	1970 to Present	INA	S	Brooks (8'0")	T	Included in Rimrock Strip Figures
Section 18 Pit[1]	SW	18	22	82	Energy Development Co.	1970 to Present	A	S	No. 50 (Aver. 15'0")	T	Included in Rimrock Strip Figures
Seminoe Mine		16	22	83	Arch Mineral Corporation	1971 to Present	A	S	No. 25-A (U.S.G.S. No. 31 ?)	T	
$Unknown_1$	NW	4	20	80	Unknown	Unknown	ABD	U	Finch (?) or Johnson (?)	T	Unknown
$Unknown_2$	NW	6	20	80	Unknown	Unknown	ABD	U	Finch or Johnson	T	Unknown
$Unknown_3$	NE	6	20	80	Unknown	Pre-1929	ABD	U	Johnson	T	Unknown
$Unknown_4$*	SE	1	20	83	Unknown	Pre-1955	ABD	U	Unknown	K	Unknown
$Unknown_5$*	SW	12	20	83	Unknown	Pre-1955	ABD	U	Unknown	K	Unknown
$Unknown_6$*	NE	26	22	79	Whistler or Wissler	Pre-1924	ABD	U	No. 112-A (Aver. 4'0")	K	Unknown
$Unknown_7$*	NW	34	21	79	Unknown	Pre-1924	ABD	U	No. 100(?)	K	Unknown
$Unknown_8$	NE	32	21	80	Unknown	Pre-1947	ABD	U	Finch	T	Unknown
$Unknown_9$	NE	2	22	81	Unknown	Unknown	ABD	U	No. 80 (U.S. G.S. No. 79)	T	Unknown
$Unknown_{10}$*	SE	8	24	82	Unknown	Pre-1929	ABD	U	Unnamed	K	Unknown
$Unknown_{11}$*	NE	11	24	83	Unknown	Pre-1929	ABD	U	No. 116	K	Unknown
Vanguard No. 1[1]	SW	8	22	82	Energy Development Co.	1971 to Present	A	U	No. 65 (6'0"-8'0")	T	45,400
Waghorn[1]	SEE $JOHNSON_3$ MINE										
West	SE	32	21	80	West Ranch	Pre-1925	ABD	U	Finch (10'0")	T	Unknown
Wilson[1]	SEE CARBON COUNTY MINE										

TABLE 1: Continued

Wilson No. 2 Entry	SEE CARBON COUNTY MINE										
Wissler *	NE	22	22	79	J. Albert Wissler	Pre-1925 to 1940	ABD	U	No. 112-A (4'0")	K	Unknown

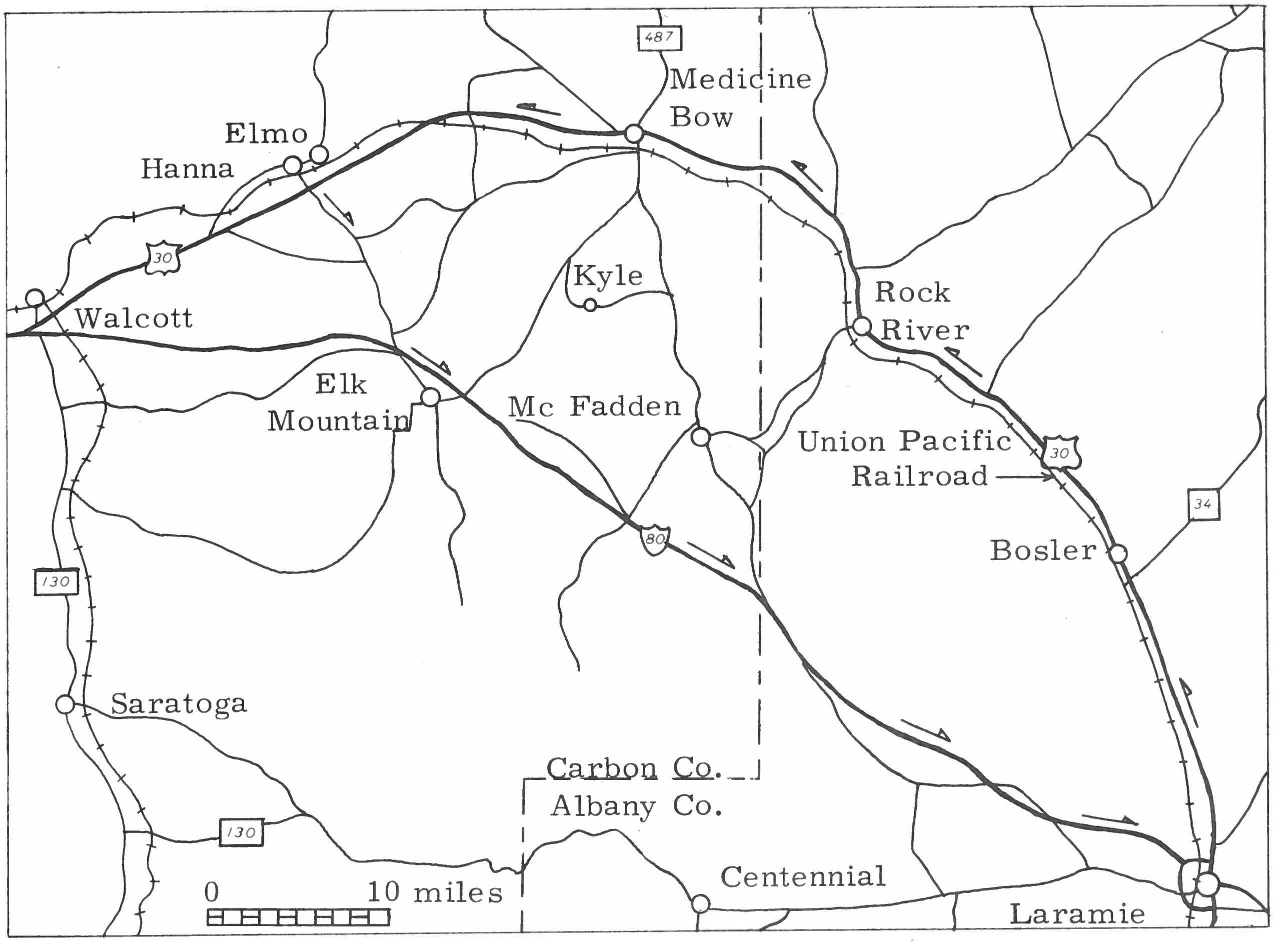
EXPLANATION:

1 Mine map on file with Wyoming Geological Survey, Laramie, Wyoming.
2 Companies and/or owners are chronologically arranged from oldest to most recent.
3 Recorded as accurately as possible but may be incomplete.
4 A-Active; ABD-Abandoned; INA-Inactive, but not necessarily abandoned
5 U-Underground; S-Strip Mine
6 United States Geological Survey seam designation in U.S.G.S. Bulletin 804 is given in parentheses when it differs from the operator's designation.
7 K-Cretaceous; T-Tertiary; U-Unknown
8 Although the tonnage for many mines is listed as unknown, these mines were small enough that their tonnage is negligible. Tonnage for all the major mines are known.
* Mine located outside major mining districts.

Data for this table came from company records, the annual reports of the Wyoming State Mine Inspector (1908-1970) and U. S. Geological Survey Bulletins.

APPENDIX II

Figure 13: Field trip route map



ROAD LOG AND TRIP STOPS

Laramie to
Hanna

0.0 Start log in parking lot on north side of University of Wyoming Geology Building. Turn west out of lot onto Lewis St.

0.1

0.1 U. S. B. M.'s Laramie Energy Research Center is on the south side of Lewis St. Oil shale research is emphasized. Continue west on Lewis St. to intersection with N. 3rd St. (Hwy. 30).

0.4

0.5 Turn north on Hwy. 30.

1.0

1.5 Triassic Chugwater Fm. dips westward on both sides of the highway for the next 0.8 miles. Medicine Bow Mountains can be seen to the west and the Laramie Range to the east.

0.6

2.1 U. S. B. M.'s 10 - and 150 - ton oil shale retorts can be seen to the west.

1.0

3.1 Gravel pits in flood plain of Big Laramie River to the west.

Laramie to Hanna

1.1		
	4.2	Gravel pits on both sides of the highway.
0.6		
	4.8	Gypsite (Quaternary age) deposits for the next 1.3 miles.
1.5		
	6.3	Chugwater outcrops exposed on both sides of the road.
1.0		
	7.3	Chugwater in west roadcut.
3.6		
	10.9	Wall Creek Sandstone Member of the Frontier Fm. (Cretaceous) exposed in Union Pacific Railroad cut to the west.
1.9		
	12.8	Light-colored Niobrara calcareous shale (Cretaceous) exposed in borrow pits for the next 2.5 miles.
2.5		
	15.3	Northernmost exposure of Niobrara Fm.
2.6		
	17.9	Junction of Hwys. 30 and 34.
0.2		
	18.1	Laramie River flows northeasterly.
1.4		
	19.5	Bosler. Steele Shale (Cretaceous) is poorly exposed for several miles.
0.5		
	20.0	Pediment surfaces to north and east.
0.7		
	20.7	Laramie Peak on skyline to northeast. This peak, elevation 10,270 feet, is the highest point on the Laramie Range and served as a landmark to travelers in the Oregon Trail.
2.4		
	23.1	Elk Mountain, elevation 11,156 feet, to west. It is the northern terminous of the Medicine Bow Mountains and is composed of Precambrian rocks which have been thrust eastward onto the Cretaceous sediments.
6.9		
	30.0	Hanna Formation (?) exposed in northeast roadcut.
1.1		
	31.1	Exposure of Lewis Shale (Cretaceous), gray in color, in roadcut to northeast and for the next two miles.
1.7		
	32.8	Original grade of the Union Pacific Railroad as built in 1868 can be seen best on the northeast side of the road.
0.4		
	33.2	Lewis Shale exposed to northeast.
0.5		
	33.7	Pine Ridge Sandstone Fm. of the Mesaverde Group (Cretaceous) in roadcuts.
1.0		
	34.7	Type locality of Pine Ridge Sandstone above the railroad to the west.
0.6		
	35.3	Railroad and highway cut in Mesaverde Group. Mesaverde here is marine and fossiliferous.
1.6		
	36.9	Approximate contact of the Mesaverde and the underlying Steele Shale.
1.4		

Laramie to
Hanna

38.3 Rock Creek

0.3

38.6 Steele Shale exposed in margin of terrace.

0.6

39.2 Town of Rock River.

1.7

40.9 Site of the Fort Halleck--Fort Laramie trail to east. Fort Halleck was built at the north foot of Elk Mountain in 1862 and was a stra-
2.2 tegic post and station on the Overland stage route.

43.1 Panoramic view of the Laramie Range to the north and east.

1.5

44.6 Steele Shale in roadcut.

1.3

45.9 Mesaverde Group in the low hills to the west. Steele Shale between
2.8 highway and hills.

48.7 Contact between Steele Shale on the south and the Niobrara Fm. on
0.2 the north.

48.9 South-dipping outcrops of white-weathering Niobrara argillaceous
0.4 limestone to the east.

49.3 Sage Breaks Shale Member, lowest unit of the Niobrara, exposed
0.5 in roadcut.

49.8 Wall Creek Sandstone Member of the Frontier Fm. along highway.

0.1

49.9 Museum built entirely of dinosaur bone north of road.

0.5

50.4 Wall Creek Sandstone forms hogback to the south. Highway is built on Frontier Shales. Silver-gray siliceous Mowry Shale north of highway. The dip slope on the skyline is formed by upper sandstone of the Cloverly Fm. The Cloverly hogback is on the south flank of the Como Bluff anticline. The inface of the hogback is called Como
1.7 Bluff.

52.1 Frontier-Mowry contact

0.2

52.3 The plunging nose of the Como Bluff anticline is shown to the southwest by the Wall Creek Sandstone changing strike from east-west
0.3 to northeast, a change of 130°.

52.6 Axis of Como Bluff anticline in Mowry Shale.

0.5

53.1 Steele Shale in borrow pit. Steele Shale under lies road from here
0.7 to Medicine Bow.

53.8 To the rear is Como Bluff. Cloverly Formation caps the varicolored shale of the Jurassic Morrison Fm. Below it is the Sundance Fm.
0.5 Triassic redbeds occupy the axial parts of the anticline.

54.3 Medicine Bow River

0.8

Laramie to
Hanna

	55.1	To the north, the Wall Creek Sandstone dips south and forms a hogback on the south flank of the Flat Top anticline. Freezeout Hills are to the northwest and the Shirley Mountains to the northwest.
1.9		
	57.0	Town of Medicine Bow. The Virginian Hotel is so named because Medicine Bow was the scene of Owen Wister's novel, "The Virginian".
0.3		
	57.3	Junction of Highway 30 and Highway 487. Entering the Hanna Basin on Steele Shale and alluvium.
2.5		
	59.8	Road to north
1.2		
	61.0	Transition zone between Steele Shale and lower Mesaverde. Lower Mesaverde is marine, middle unit is continental, upper unit is marine.
3.5		
	64.5	Contact between Mesaverde and Lewis Shale. Elk Mountain to the south. Thin oyster beds are present in uppermost Mesaverde near the railroad to the south. These marine units grade into paludal sediments, coal and channel sandstones, to the south.
0.2		
	64.7	Sandy zone within the Lewis Shale south of the road.
0.5		
	65.2	Approximate contact of Lewis Shale and Medicine Bow Fm.
0.8		
	66.0	Approximate contact of Medicine Bow Fm. and Ferris Fm.
0.5		
	66.5	Approximate contact of Ferris Fm. and Hanna Fm.
0.2		
	66.7	Tree covered hill on skyline to south is the the Mesaverde outcrop on Simpson Ridge. Simpson Ridge is a complex fold and exhibits extreme flowage within the Steele Shale.
0.4		
	67.1	Road to south leads to old railroad station of Como. The deserted town of Carbon lies 4 miles to the south on this road. Low hills to the south are Ferris Fm. Low hills to north are Hanna Fm.
1.0		
	68.1	Approximate contact between Ferris Fm. and Hanna Fm.
1.1		
	69.2	Bridge across Union Pacific Railroad tracks.
1.6		
	70.8	Traveling on Hanna Fm. Coal strip mining operations on the Hanna Fm. can be seen to the north.
3.3		
	74.1	Red clinker beds in the Hanna Fm. to the north.
2.2		
	76.3	Axis of Hanna syncline. Axis trends northeast-southwest. Abundant northwest-southeast trending faults cut the Hanna syncline.
0.8		
	77.1	Turn north to Hanna, on Wyoming 72.
0.7		
	77.8	Cross old railroad spur line.
0.2		

Laramie to
Hanna

78.0 The new homes to the west are being built by Cimmred through the encouragement of Energy Development Company. Cimmred plans to build approximately 30 dwellings. All houses are available to
0.1 any eligible buyer and are in no sense company houses.
78.1 Energy Development Company's office on the east side of the road.
0.4
78.5 Crossing main line of Union Pacific Railroad.
1.3
79.8 Monolith Portland Midwest's abandoned strip mines on west side of the road for the next 1.1 miles. These mines were abandoned before enactment of Wyoming's Open Pit Land Reclamation Act.

80.1 STOP 1: Office of Rosebud Coal Sales Company. (Note the Union Pacific Coal Company's abandoned Hanna No. 4A underground mine entrance to north of building.) This stop will consist of a tour of Rosebud's operation to include their tipple, an active open pit (Pit No. 4) and a reclamation site (Pit No. 1). Mr. John McLean, Night Superintendent, will be our guide.

Currently, Rosebud has two active open pit mines on Bed No. 80 of the Hanna Formation (Pit Nos. 4 and 8) as well as one temporarily inactive pit (Pit No. 7). Pit No. 5, which is also inactive, is on Bed No. 82 of the same formation (Figure 8). These seam designations differ from those on the U. S. Geological Survey's Bulletin 804 map because of correlation problems across a large, previously unrecognized fault (Figure 8).

Bed No. 80 averages 15.5 feet thick in Pit No. 4 and 24 feet in Pit No. 8. An average as-received analysis of this subbituminous coal is as follows:

Moisture	14.50 %
Ash	6.94 %
Sulfur	0.78 %
Heat value	10,523 Btu/lb.

Bed No. 82 averages 9 feet in thickness in Pit No. 5 and is of subbituminous rank. An average analysis of this seam is:

Moisture	13.46 %
Ash	6.94 %
Sulfur	0.78 %
Heat value	10,699 Btu/lb.

Rosebud employs one 45-and two 12-cubic yard draglines to remove overburden that ranges up to a

Laramie to Hanna

current maximim of 120 feet but averages about 60 feet. Shovels of 4-, 7- and 11-cubic yard capacity are used for loading. Trucks carry the coal from the pits to the tipple. Although Rosebud's present tipple is capable of handling their production, they have plans to construct a unit train loading facility.

Rosebud is shipping coal to buyers in Wyoming, Colorado, Iowa, Idaho, Utah, Nebraska, and Wisconsin. The coal is used primarily for power generation. Some is sold to the beet sugar and cement industries.

Production this year is expected to be between 1.2 and 1.3 million short tons.

STOP 2: Energy Development Company's office. Stop 2 will be a tour of Energy's Vanguard No. 1 underground mine (above-ground facilities only), loading facilities to include a three mile conveyor belt and unit train loading dock, Section 10 open pit mine No. 7, and a reclamation site (Rimrock No. 1). See Figure 9 for locations. Mr. Arnold Hannum, Mine Superintendent, will be our guide.

Energy Development is currently mining one subbituminous seam of the Ferris Formation (Bed No. 65) and one of the Hanna Formation (Brooks seam). Bed No. 65 is being mined in the Vanguard No. 1 deep mine where it ranges from 6 to 8 feet thick. A typical as-received analysis of this seam in early 1972 was as follows:

Moisture	11.6 %
Ash	7.1 %
Sulfur	0.7 %
Heat value	11,020 Btu/lb.

Maximim overburden in the Vanguard No. 1 mine will be between 300 and 900 feet. This mine is presently being developed with one Jeffrey continuous miner.

Energy Development has had four open pit mines on the Brooks seam but is currently only mining from the Section 10 Pits (No. 6&7). The Brooks seam ranges from 5 to 8 feet thick and is subbituminous. A typical analysis in early 1972 was:

Moisture	13.66 %
Ash	6.50 %
Sulfur	0.45 %
Heat value	10,806 Btu/lb.

Laramie to
Hanna

Energy has also strip mined Bed No. 50 of the Ferris Formation. It averaged 15 feet thick in the Section 18 pit.

The overburden in Energy's open pit mines is less than 40 feet and is removed by 30-cubic yard scrapers. Coal is then loaded onto 70 ton haul units and transported to their tipple. Energy's tipple is especially designed to load 100-car unit trains in 4 hours.

Coal from Energy's mines is shipped by railroad to Sioux City, Iowa where it is used for power generation. Energy anticipates mining 1,000,000 tons of coal in 1972.

STOP 3: Arch Mineral Corporation's office. This stop will be a tour of Arch's loading facilities, the Seminoe strip mine and their reclamation. Mr. Cleatus France, Western Division Engineer, will host this stop.

Arch Mineral Corporation is mining Bed No. 25, which is one of three mineable seams of the Ferris Formation in this area. Arch's seam designations are somewhat different from those published by the U. S. Geological Survey (Dobbin, 1929). At this time Bed No. 25 is believed to be correlative with the U. S. Geological Survey's Bed No. 31. Bed No. 25 averages 22 feet thick and is subbituminous in rank. An average analysis shows:

Moisture	13.96 %
Ash	6.68 %
Sulfur	0.37 %
Heat value	10,000 Btu/lb.

The other mineable seams are Bed Nos. 21 (below Bed No. 25) and 34 (above Bed No. 25).

Overburden up to 150 feet is anticipated and will be removed by Arch's dragline with its giant 62-cubic yard bucket. While loading is accomplished by a 16-cubic yard shovel, haulage to the loading dock is by 100-ton Euclid trucks. The tipple is designed for loading 100-car unit trains in 3 hours.

Arch Mineral's Seminoe mine ships its coal to buyers in Illinois, Indiana and Missouri. The coal is primarily used for power generation. Arch's 1972 Seminoe mine production is expected to be approximately 2 million tons.

0.0 Resume road log from Arch Mineral's office. Proceed east on clinker-surfaced road. Road is built on Ferris Formation. Strike of the beds is nearly parallel to the road; dips are northeast at 17 to 26 degrees. The higher ground just south of the road is called St.

0.6 Mary's Ridge.

Laramie to
Hanna

0.6 Energy Development Company's Vanguard No. 1 mine can be seen almost on the horizon to the northeast.

4.0

4.6 Crossing cattle ground. Ferris coal seams are well exposed on the first ridge to the north. Abandoned Dana Station along Union Pacific Railroad mainline can be seen to the south.

1.7

6.3 Energy Development Company's tipple and belt line are barely visible above the low hills to the north. Ridge in the foreground to the north contains seams 25-34 of the Ferris Formation. Major portion of the Hanna Basin lies to the north of this road.

0.5

6.8 Road junction--side road to the northeast goes into Hanna. Continue straight. This road passes over Ferris seams 25 through 28 (striking nearly north-south; with dips to the east up to 21 degrees).

0.5

7.3 Crossing mainline of the Union Pacific Railroad.

0.5

7.8 Crossing old U. S. Route 30, now abandoned.

0.2

8.0 Road junction. Ferris coals exposed in roadcuts. Turn east onto Hwy. 30. Road built on Ferris Fm. for the next 2.0 miles. Roadcuts expose Ferris sandstones, shales and coals. Ferris seams 50-65 are crossed (strike nearly north-south; dips are east up to 35 degrees).

2.3

10.3 Approximate contact of Hanna and Ferris Formations.

0.4

10.7 Sandstone near base of the Hanna Fm. is exposed in roadcuts at crest of hill.

0.9

11.6 Panoramic view to the north and then east shows the reclaimed Rosebud Nos. 1 & 2 strip mines midway between the road and skyline, followed by excavated red clinker beds behind Hanna, Monolith Portland Midwest Company and Rosebud strip mines on the skyline further east, the town of Elmo, and abandoned Nugget Coal Company strip mines east of Elmo.

1.0

12.6 Hanna No. 2 seam of the Hanna Fm. is exposed in the walls of the ravine on both sides of the road.

1.2

13.8 Road junction. Turn south on Wyoming Route 72 toward Elk Mountain. Road still built on Hanna Fm.

0.5

14.3 Crossing axis of Hanna Syncline.

0.6

14.9 Coals, shales and sandstones of the Hanna Fm. in roadcuts to the northeast. Hanna No. 1 and lower seams are exposed in these roadcuts.

1.1

16.0 Sandstone units of the Hanna Fm. can be seen to the northeast of the road. Dips are up to 10 degrees to the northwest. Now well onto the south flank of the Hanna Syncline.

1.1

17.1 Northwest-southeast trending fault passes through the crest of this hill about where the road is located. Hanna Fm. is exposed in

Laramie to Hanna		
0.1		roadcuts on both sides the road.
	17.2	Crossing abandoned Lincoln Highway.
0.1		
	17.3	Approximate contact of the Hanna and Ferris Formations. Ridge to the northeast is held up by Hanna sandstones. A large, northwest-southeast trending fault lies just to the south of the low hills
1.0		southwest of the road. Road is now on Ferris Fm.
	18.3	Escarpments north and west of the road are held up by Hanna sandstones offset by the fault just mentioned. Ferris sandstones
0.4		form the ridges to the east.
	18.7	Crossing intermittent drainage course just south of the Ferris--Medicine Bow formation contact. Road built nearly on the trace of the fault previously mentioned. Medicine Bow Fm. on the east
0.4		side of the road; Ferris Fm. on the west.
	19.1	Road now on the Medicine Bow Fm. Northwest flank of the Saddleback Hills anticline can be seen to the southeast. Northern terminous of Elk Mountain anticline to the southwest (Mesaverde Group). Low hills north of the anticline are held up by the Medi-
1.2		cine Bow Fm.
	20.3	Approximate contact of the Medicine Bow Fm. and the Lewis Shale
0.8		was just north of this intermittent stream gully.
	21.1	Roadcut exposes dark-colored Lewis Shale to the east.
1.2		
	22.3	Bloody Lake barely visible at the base of the Mesaverde ridge to the west. Feeder pipeline from the Simpson Ridge field to the east
0.4		crosses the road to Colorado Interstate's 20-inch pipeline.
	22.7	Approximate contact of the Lewis Shale and Mesaverde Group in
0.5		this valley.
	23.2	Mesaverde coals exposed in roadcuts going up small hill.
0.4		
	23.6	Crest of hill. Axis of Saddleback Hills anticline to northeast. Mesaverde underlies axial portion of the anticline and forms hog-
0.6		backs on its flanks.
	24.2	Mesaverde coal exposed in roadcut on east side of road.
0.7		
	24.9	Road junction. Turn east on Interstate 80.

Laramie to
Hanna

Road Log References:

1. Laramie to Medicine Bow modified from: Thomas, H. D. and Conley, C. D., 1964, Laramie to Medicine Bow, U. S. Highway 30 in Highway Geology of Wyoming: Wyoming Geological Association, Casper, p. 215-218.

2. Medicine Bow to Hanna turn off (77.1 miles) modified from: Keller, E. and Klaenhammer, C., 1964, Medicine Bow to Rawlins, U. S. Highway 80 and 30 in Highway Geology of Wyoming: Wyoming Geological Association, Casper, p. 219-220.

3. Hanna turnoff to Rosebud Coal Sales office by Glass, G. B., 1972.

4. Arch Mineral Corporation office to Interstate 80 by Glass, G. B. and Jones, R., 1972.

STATE OF WYOMING

RULES AND REGULATIONS

Promulgated under the

OPEN CUT LAND RECLAMATION ACT

by

The Commissioner of Public Lands

Effective August 7, 1969

A. E. King
Commissioner of Public Lands
113 State Capitol Building

Cheyenne, Wyoming

Rules and Regulations

COMMISSIONER OF PUBLIC LANDS

State of Wyoming

I certify that the copy hereto attached is a true copy of the rules of the

COMMISSIONER OF PUBLIC LANDS

relating to the Open Cut Land Reclamation Act in accordance with Chapter 192, Session Laws of Wyoming, 1969, and that the original rules are on file in this department. These are new rules.

Prior to adoption these rules were made available for public inspection on the 23rd day of May, 1969.

The effective date of the attached rules is twenty days after filing by the Secretary of State as indicated by the authenticating file stamp.

Signed this 18 day of July, 1969.

A. E. King

A. E. KING

COMMISSIONER OF PUBLIC LANDS

James E. Barrett

Approved as to Authority and Substance
Office of the Attorney General

SECRETARY OF STATE FILING STAMP

18th July
67 11:46 A

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CHAPTER I

RULES OF PRACTICE AND PROCEDURE

Section 1. Authority. These Rules are adopted in accordance with the terms and provisions of Chapter 192, Session Laws of Wyoming 1969 and the Wyoming Administrative Procedure Act, Chapter 108, Session Laws of Wyoming 1965, and shall apply in all proceedings before the Commissioner or his examiners relating to the reclamation of mined land, and to the administration of the Open Cut Land Reclamation Act (Chapter 192, Session Laws of Wyoming 1969) and the Rules and Regulations adopted by the Commissioner thereunder.

Section 2. Definitions. All of the definitions set forth and contained in the Open Cut Land Reclamation Act are incorporated herein by reference. For the purpose of hearings to be held under the Act, the following definitions shall apply:

a. The applicant shall be the operator, person, persons, firm, companies, partnerships, associations, or corporations, as well as the Commissioner, seeking relief before the Commissioner. The term "applicant" may otherwise be styled "petitioner" or "complainant".

b. The operator, person, persons, firms, companies, partnerships, associations, or corporations, including the Commissioner, against whom any proceeding or application for relief is brought, is the respondent.

c. A hearing is any contested case, as defined in Section 1(b)(2), Wyoming Administrative Procedure Act (Sec. 9-276.19 Wyo. Statutes 1957 as amended) or any formal or informal proceeding before the Commissioner or his examiner brought pursuant to any law of the State of Wyoming or any rule or regulation of the Commissioner, whether or not the same is adversary in nature.

Section 3. Commencement of Proceedings. All proceedings shall be commenced by filing a written petition, complaint, application, or order to show cause, wherein shall be alleged the acts or omissions of acts claimed in violation of the Open Cut Land Reclamation Act, or of any of the lawful rules, regulations, or orders promulgated by the Commissioner thereunder and by authority thereof. A proceeding shall be deemed commenced on the date a petition, complaint, application, or order to show cause is filed in the office of the Commissioner.

Section 4. Petitions or Complaints. An applicant desiring, or required by law, to institute a hearing shall prepare and file with the Commissioner three copies of a petition, complaint or order to show cause, together with a filing fee of $25.00. The petition, complaint or order to show cause shall set forth:

a. The name and address of each respondent.

b. A statement, in ordinary and concise language, of the facts upon which the petition, complaint or order to show cause is based, including, whenever applicable, particular reference to the statute or statutes, or rules, regulations and orders that the applicant alleges have been violated.

Section 5. Notice. Notice of hearings shall conform to Section 7(b) of the Wyoming Administrative Procedure Act (Sec. 9-276.25). The manner and time for giving notice shall be as follows:

a. When the Commissioner determines that he shall hold a hearing on his own motion, he shall give notice at least fifteen (15) days in advance of the hearing date to all parties by registered or certified mail, except as provided in Section 5(d).

b. When an operator or party desires that a hearing be held, he shall file his complaint or application at least fifteen (15) days in advance of the date when he wishes a hearing to be held. The Commissioner shall forthwith set a date for hearing and notify the applicant thereof; provided, that notice of the date of the hearing shall be sent to the applicant at least ten (10) days before the hearing date.

c. The parties and the Commissioner may waive Section 5 (a) and (b) by common consent.

d. When the Commissioner determines that a hearing should be held under Section 11 of the Act, relating to bond forfeiture proceedings, he shall give at least thirty (30) days' notice by registered or certified mail.

e. In addition to the notice above provided for, the Commissioner may, in his discretion, require additional notice to be given in such manner as he shall direct.

Section 6. Answer or Appearance. The respondent or respondents shall be allowed fifteen (15) days from the date of service of notice upon him or them in which time to serve in accordance with Rule 4, Wyoming Rules of Civil Procedure, an answer or other appearance. If an order to show cause has been issued, the respondent need not answer such order nor enter an appearance before the date set for hearing.

Section 7. Docket. When a hearing is instituted, it shall be assigned a number and entered with the date of its filing on a separate page of a docket provided for such purpose. The Commissioner shall establish a separate file for each such docketed case, in which shall be systematically placed all papers, pleadings, documents, transcripts, evidence and exhibits pertaining thereto, and all such items shall have noted thereon the docket number assigned, and the date of filing.

Section 8. Default in Answering or Appearing. In the event of failure of any respondent to answer or otherwise appear within the time allowed, and provided that the foregoing rules as to service have been complied with, the respondent or respondents so failing to answer or otherwise plead or to appear, shall be deemed to be in default, and the allegations of the complaint, petition, or order to show cause, as the case may be, may be taken as true and the Order of the Commissioner entered accordingly.

Section 9. Subpoenas. As authorized by Section 7(d) of the Wyoming Administrative Procedure Act (Sec. 9-276.25(d)) subpoenas for appearance and to produce books, papers, documents or exhibits will be issued by the Commissioner upon proper written request of any party.

Section 10. Hearing. At the date, time, and place of hearing set down by the Commissioner, and in accordance with the notice given, the Commissioner or his examiner shall hear all matters presented. All issues and matters enumerated and described in the pleadings given shall be presented by the applicant.

Section 11. Order of Procedure at Hearing. As nearly as may be, hearings shall be conducted in accordance with the following order of procedure:

a. The Commissioner shall announce that the hearing is convened upon the call of the docket number and title of the matter and case to be heard, and thereupon the Commissioner shall direct the reading into the record of the petition or formal notice given, together with appearances in the form of answers or other appearances made by any respondent or respondents, and shall note for the record all subpoenas issued and all appearances of record, including counsel of record.

b. The applicant shall thereupon proceed to present his evidence. Witnesses may be cross-examined by the respondent or respondents. All exhibits offered by and on behalf of the applicant shall be marked by letters of the alphabet beginning with "A". With the approval of the Commissioner or his examiner and after service of copies upon all parties of record, the direct testimony of a witness in writing, either in narrative or question and answer form, may be received into the record as if read, upon the witness being sworn and identifying same, all in accordance with Section 8 of the Wyoming Administrative Procedure Act (Section 9-276.26 Wyoming Statutes 1957 as amended). Such testimony in writing shall be subject to cross examination and shall be received into the record subject to a motion to strike.

c. The respondent or respondents shall, in the order of answers or appearances made, be heard in the same manner as the applicant's evidence, witnesses and exhibits have been heard and presented. Each respondent's exhibits shall be marked separately so as to identify the respective respondents and numbered commencing with the number "1".

d. Opening statements may be made and rebuttal evidence presented.

e. Closing statements, at the conclusion of the presentation of evidence, may be made by the applicant and by the respondent. The time for oral argument may be limited by the Commissioner or his examiner.

f. After all proceedings have been concluded, the Commissioner shall dismiss and excuse all witnesses and declare the hearing closed. Any party who may wish or desire to tender written briefs of law to the Commissioner may do so.

Section 12. Witnesses to be Sworn. All persons testifying at any hearing before the Commissioner or his examiner shall stand and be sworn.

Section 13. Attorneys. The filing of an answer or other appearance by an attorney constitutes his appearance for the party for whom the pleading is filed. The Commissioner shall be notified in writing of his withdrawal from any hearing. Any person appearing before the Commissioner or his examiner in a representative capacity shall be precluded from examining or cross-examining any witness unless such person is an attorney licensed to practice law in the State of Wyoming, or is a non-resident attorney associated with an attorney qualified to practice law in the State of Wyoming. This rule shall not be construed as prohibiting any person from representing himself in any hearing, but any such person appearing personally must abide by the rules of evidence as specified in the Wyoming Administrative Procedure Act.

Section 14. Attorney General to be Present. In all matters before the Commissioner or his examiner, the Commissioner may request the Attorney General of the State of Wyoming, or a representative of his staff, to be present throughout the hearing.

Section 15. Record of Proceedings -- Reporter. Unless otherwise agreed by the parties and consented to by the Commissioner, all hearings, including all testimony, shall be reported verbatim by a competent reporter. The compensation of such reporter shall be paid as required by law and as ordered by the Commissioner. If a transcript of testimony is required by the Commissioner, the cost thereof shall be paid by the Commissioner, or as otherwise provided by law. The Commissioner may direct any party or parties to assume the cost of the transcript if transcribed at his or their request.

Section 16. Depositions. In all contested cases coming before the Commissioner or his examiner, the taking of depositions and discovery shall be available to the parties in accordance with the provisions of Section 7(4)(g) of the Wyoming Administrative Procedure Act (Sec.9-276.25(4)(g) Wyoming Statutes 1957 as amended).

Section 17. Decision, Findings of Fact, Conclusions of Law, Order. The Commissioner shall, within thirty (30) days following the full and complete hearing, make and enter a written decision and order containing Findings of Fact and Conclusions of Law. Each of the parties appearing before the Commissioner at said hearing shall, upon request of the Commissioner, prepare and submit, either at the conclusion of the hearing or within such time thereafter as the Commissioner may grant, recommended Findings of Fact and Conclusions of Law for consideration by the Commissioner before the Order proper is entered. The recommended Findings of Fact and Conclusions of Law submitted by the parties appearing before the Commissioner shall become part of the official record. Such decision and order as shall be filed by the Commissioner will, without further action, become the decision and order of the Commissioner. Forthwith upon entry and filing of the judgment and order, the Commissioner shall send a copy by prepaid mail to each party, or their attorneys of record.

Section 18. Appeals. Appeals to the district court from decisions of the Commissioner are governed by Section 14 of the Wyoming Administrative Procedure Act (Sec. 9-276.32 Wyoming Statutes 1957 as amended) and Rule 72.1 of the Wyoming Rules of Civil Procedure.

Section 19. Transcript in Case of Appeal. In case of an appeal to the district court as above provided, the party appealing shall secure and file a transcript of the testimony and all other evidence offered at the hearing, which transcript must be verified by the oath of the reporter who took the testimony as a true and correct transcript of the testimony and other evidence in the case. The compensation of the reporter for making the transcript of the testimony and all other costs involved in such appeal shall be borne by the party prosecuting such appeal.

Section 20. Examiners. The Commissioner may appoint one or more hearing examiners, in accordance with the laws of the State of Wyoming. Any matter which may be heard before the Commissioner may be heard by one of his examiners. Promptly after the conclusion of any hearing conducted by an examiner, the examiner shall certify the record of the hearing to the Commissioner and make his report and recommendations for the disposition of the matter or proceeding by the Commissioner. The Commissioner shall consider the report and recommendations of the examiner, and the record of the hearing, and shall enter his order within thirty (30) days after the conclusion of the hearing.

Section 21. Exemptions. Any operator who feels that his operation should be exempted, in whole or in part, from reclamation as required by the Act may request a hearing before the Commissioner or an examiner. If such operator proves by a preponderance of the evidence that the nature of his operation is such that grading, impounding of toxic or radioactive effluent, or covering exposed mineral seams with clean spoil material is not practicable because of physical difficulties involved, then he shall be granted an exception from the requirements shown to be impracticable. An order granting such an exemption is subject to later review and modification in the light of changed circumstances.

Section 22. Amendment of Rules. These Rules may be amended and any such amendments shall become effective as provided by Sections 3 and 4 of the Wyoming Administrative Procedure Act (Sec. 9-276.21 and 9-276.22 Wyoming Statutes 1957 as amended).

Section 23. Exclusions. Nothing in these Rules shall be construed to prohibit the Commissioner from holding informal proceedings, hearings or conferences for the purpose of aiding the Commissioner in ascertaining and determining facts necessary for the performance of his duties. Any person believing himself aggrieved by a determination made by the Commissioner following an informal proceeding, hearing or conference, and who is otherwise entitled thereto, may, upon filing a petition or complaint pursuant to Section 4 of these Rules, obtain a full hearing or review upon the merits, which matter shall be heard and tried de novo.

CHAPTER II

APPLICATION FOR PERMITS - AMENDMENT OF PERMITS

Section 1. Applications. All applications for permits or amendment of permits under the Open Cut Land Reclamation Act shall be made upon the appropriate form furnished by the Commissioner, containing the information called for by Section 5 of the Act. Such applications shall be submitted in duplicate. When returned with the validating signature of the Commissioner, a copy of the application shall constitute a permit. A copy of the application form is to be found as Appendix A to these Rules.

Section 2. Incomplete Forms. Such forms shall be completely filled out. If a section is left incomplete, an adequate explanation must be attached or the application will be subject to rejection at the discretion of the Commissioner.

Section 3. Prior Mining. When an operator makes application for a permit covering lands whereon there have been previous mining operations, he may submit with the application form a map or aerial photograph sufficiently detailed to indicate clearly the nature and extent of the prior operations.

Section 4. Amendment of Permits. Amendments can be issued to allow new open cut mining in areas contiguous to or nearby the original permit area. Contiguous or nearby land is land any portion of which is within 6 miles of, bordering on, cornering on, or within the same township as, land governed by the permit sought to be amended.

Section 5. Description. In giving the location of the operation pursuant to Section 5(4) of the Act, an operator may use metes and bounds properly tied in to a survey or he may use a protracted survey, if no survey of the land to be covered by the permit has been made. If the land covered by the application is a numbered claim in an established mining district, then the land may be described by claim number and district, with protraction to an established survey.

Section 6. Fee. The application for permit shall be accompanied by a check, sight draft, or money order, made payable to the Commissioner of Public Lands, in an amount of $50.00. If such a check is not paid by the drawee for any reason, no action will be taken upon the application until payment is received by the Commissioner. The Commissioner shall notify an operator promptly of such non-payment.

Section 7. Bond.

a. At the time of filing an application, an operator may submit a bond in an amount estimated to be sufficient to equal the cost of reclamation required by the Act and these Rules for the permit area. If the amount of the bond so furnished is reasonable, and if the application is otherwise in order, the Commissioner shall issue a permit conditioned on the operator's meeting the further requirements of this section.

b. Such a conditional permit shall allow the operator holding it to engage in new open cut mining until and unless the Commissioner cancels it pursuant to subsection (e) below.

c. After a conditional permit has been issued on an estimated bond, the Commissioner shall as promptly as possible determine the amount of the necessary bond in conformance with the Act, and notify the operator in writing of the amount thereof.

d. If the estimated bond equals or exceeds the amount set by the Commissioner, the bond shall be adjusted accordingly and the conditional permit shall be made permanent.

e. If the amount of the bond set by the Commissioner exceeds the estimated bond submitted by the operator, the operator shall, within fifteen (15) days of the receipt of the notice required by subsection (c) above, either submit a new bond in the amount set by the Commissioner, or make application for a hearing on the amount of his bond. If the operator does not submit such a new bond, or make application for a hearing on the amount of his bond, within the time prescribed, his conditional permit shall be cancelled.

f. If the operator shows by a preponderance of the evidence at a hearing pursuant to subsection (e) that the amount of the bond set by the Commissioner was excessive, then the bond shall be set at such lesser amount as the operator and the Commissioner negotiate to meet the requirements of Section 8 of the Act and the appropriate sections of these Rules.

g. If the operator submits a new bond in the amount set by the Commissioner, or if the operator and the Commissioner agree upon a lesser sum, the operator's conditional permit shall be made permanent.

Section 8. <u>Operations for which Permits are Required; Operations for which Reclamation is Required</u>.

a. Definitions.

(1) New open cut mining is open cut mining which will create affected land.

(2) Affected land is an area of land from which overburden shall have been removed, or upon which overburden or refuse shall have been deposited, or both, after May 23, 1969.

b. An operator must obtain a properly issued permit before engaging in new open cut mining.

c. Except as is otherwise provided by rule or by order of the Commissioner, reclamation procedures as specified in the Act and in these Rules shall be carried out on all affected land.

d. No operator shall be compelled to perform at his own expense measures required hereunder with respect to operations that were completed or were substantially completed prior to the effective date of the Act. Any operator desiring to take advantage of this exception may do so upon proper proof, submitted at a hearing, that his operation was completed or was substantially completed prior to May 23, 1969.

e. An operator who is engaged in prospecting does not need to obtain a permit. Prospecting is the making of preliminary tests to determine the probable value of a natural deposit.

f. Pits and quarries opened after May 23, 1969 which are under the supervision and control of any government agency whose regulations are equal to or greater than those imposed by Section 6 of the Act may be operated without obtaining a permit from the Commissioner. The Commissioner will not require reclamation with respect to such operations. An operator may request an exemption from the Act at a hearing, at which he shall show that his operation is under the supervision and control of a government agency having regulations which require reclamation comparable to or in excess of that required by Section 6 of the Act. An order granting such an exemption is subject to later review in the light of changed circumstances.

CHAPTER III

RECLAMATION REQUIREMENTS

Section 1. Grading Requirements. Except as is otherwise provided by an Order of the Commissioner or by rule,

a. ridges shall be graded to a minimum width of ten (10) feet at the top;

b. peaks shall be graded to a minimum width of fifteen (15) feet at the top.

The surfaces so produced shall be reasonably level. An operator who has complied with these requirements will be deemed to have conformed with the requirement of Section 6(a) of the Act that peaks and ridges be reduced to a rolling topography. Exceptions to this requirement may be granted for good cause shown.

Section 2. Dams in Final Cuts. The operator shall construct earth dams in final cuts of all operations where lakes may be formed if it is necessary to impound water or other effluent which is sufficiently toxic or radioactive to be dangerous or harmful to or destructive of plant, animal, or human life.

Section 3. When Dams Need Not Be Constructed. A dam need not be constructed in a final cut if the formation of a lake will interfere with underground or other mining operations or will damage adjoining property.

Section 4. Standards of Permissible Toxicity and Radioactivity. These standards have not been established. When they are formulated, they will be included here by amendment. Until such standards are adopted, the Commissioner may require dams in final cuts upon proper proof made at a hearing.

Section 5. Reseeding. Reseeding will be required whenever practicable. If an operator feels that a reseeding program required by the Commissioner is impracticable, or that the effort required of him is unreasonable, he may request a hearing on the subject before the Commissioner or an examiner. If at the hearing the operator shows that the program recommended by the Commissioner is impracticable or is unreasonable, then such practicable and reasonable alternative program as the operator and the Commissioner negotiate shall be substituted.

Section 6. Unsuccessful Program. If a reseeding program is conducted in strict accordance with the recommendations of the Commissioner, the operator who holds the permit on the reseeded land shall be discharged from his obligation with respect to the reseeded land even if the program does not prove to be successful.

Section 7. Experimentation. In order to develop suitable methods of revegetation, the Commissioner and any operator may enter into agreements respecting experimental reseeding in satisfaction of the operator's obligation. When an operator shall have completed the experiments agreed to, he shall be released from any further obligations with respect to the affected land covered by the agreement.

Section 8. Cost of Reseeding. Until sufficient experience is gained for the Commissioner to make specific seeding requirements, the cost of preparing the soil and reseeding land in this State will be presumed to be $50.00 per acre, unless otherwise shown on a reclamation plan submitted and accepted in conformance with Chapter VI of these Rules.

Section 9. Time for Reseeding. Unless otherwise permitted by the Commissioner, seed shall be applied after the time the frost leaves the ground in the spring and before the frost enters the ground in the fall. Seed shall not be sowed when the weather is windy or otherwise unsuitable for the work.

Section 10. Topsoil. Topsoil may be piled apart from other overburden, to be placed on top of spoil material when grading is otherwise complete.

CHAPTER IV

ANNUAL REPORT AND MAP

Section 1. Report. Prior to September 1 of each year in which mining operations are ~~completed~~ conducted within a permit area, the operator holding the permit shall submit a report indicating in detail all measures taken to effect land reclamation on the affected land. Such report shall be typewritten and signed by the operator. It shall clearly indicate the number of acres of affected land, the nature and depth of the overburden (peaks and ridges), grading carried out, details of any reseeding, estimation of the success of previous reseeding, the number of acres reclaimed and any other facts pertinent to the reclamation program.

Section 2. Map. To accompany the report, an operator shall submit a map showing the following:

a. Identification of the area by legal description to correspond with the permit.

b. Location of pit or pits and spoil piles.

c. Outline of the affected area, with a notation in the legend as to the number of affected acres.

d. Location and amount of land previously reclaimed within the permit area and the year in which it was reclaimed.

e. Name of the geologist, engineer, or surveyor who prepared the map.

f. Date the map was prepared or updated.

g. North point.

h. Name of the USGS quad covering the same areas, if any.

i. Drainage on and away from the area of affected land, showing directional flow of water, drainways, natural watercourses and streams (intermittent or flowing) receiving discharge.

The map shall be prepared at a scale suitable to facilitate interpretation. A map using the base customarily used by the operator, and at the same scale, showing the data called for above, will be acceptable.

CHAPTER V

BONDING REQUIREMENTS

Section 1. Security Allowed. Under Section 8 of the Act, an operator may meet the bonding requirements by furnishing

a. a surety bond;
b. cash and government securities;
c. a bond with property sureties; or
d. at the discretion of the Commissioner, a bond with land and improvements and facilities thereon as security, no surety required.

Section 2. Operator's Option. An operator may furnish the security called for by Section 8 and Chapter V, Section 1 (a)(b)(c) of these Rules at his own option. If an operator wishes to offer land with improvements and facilities as provided in Chapter V, Section 1(d), he must submit evidence that the value of the security to be furnished will meet or exceed the requirements of Section 8 of the Act and the appropriate Rules adopted thereunder.

Section 3. Amount of Bond. If the operator does not elect to submit an estimated bond along with his application, or promptly after reviewing the estimated bond so submitted and in accordance with Chapter II, Section 7 of these Rules, the Commissioner will set the amount of the bond required by Section 8 of the Act. The amount is to be equal to the cost of restoration required by the Act. He will take into account grading requirements, soil preparation and reseeding, necessity of constructing a dam in the final cut to impound harmful effluent, and the need to bury exposed mineral-bearing strata with spoil material.

Section 4. Hearing. If an operator feels that the amount set by the Commissioner is excessive, he may request a hearing on the subject of the amount of his bond. If such operator shows by a preponderance of the evidence that the amount the Commissioner set was excessive, then the bond shall be set at such lesser sum as the operator and the Commissioner shall negotiate, provided, that such sum shall be adequate to meet the requirements of Section 8 of the Act and the appropriate sections of these Rules.

Section 5. Grading as Part of Mining Process. If an operator agrees to perform grading, in accordance with the specifications in these Rules, as a continuing part of the mining process and not as a separate procedure, the Commissioner shall reduce the amount of security required accordingly. If it appears at a later time that the operator who made such agreement is not in fact grading peaks and ridges on affected land in conformance with Section 6 of the Act and these Rules, then the Commissioner may, upon proper proof at a hearing or by negotiation with the operator, require an increase in the security in an amount sufficient to cover the cost of the necessary grading. This section does not apply if a reclamation plan has been submitted and accepted under Chapter VI of these Rules.

CHAPTER VI

RECLAMATION PLAN

Section 1. Operator May Submit Plan. An operator may at his own option submit a reclamation plan covering a specified permit area or portion thereof to the Commissioner at any time. The plan should include adequate details as to when and how the proposed reclamation will be done.

Section 2. Commissioner to Examine Plan. Upon receipt of a reclamation plan, the Commissioner will within a reasonable time evaluate the proposals in terms of the reclamation required by the Act. If reclamation called for by the plan does not conform to the requirements of the Act and the Rules and Regulations adopted thereunder, or is not feasible, or is otherwise undesirable because of conflict with the purposes set forth in Section 2 of the Act, the Commissioner may reject the plan in part or in its entirety. If the Commissioner rejects a plan or any part thereof, he shall give reasons in writing together with recommendations for modification of the plan to meet his objections.

Section 3. Operator's Option if Plan is Rejected. If his reclamation plan is rejected by the Commissioner, an operator may revise the plan so as to meet the Commissioner's objections, or he may make application for a hearing on the subject of his original plan.

Section 4. Acceptance of Plan; Order. If the plan is satisfactory, the Commissioner shall accept it. After accepting a plan, the Commissioner shall promptly issue an order adopting the plan, and stating that compliance with the plan by the operator will fulfill the requirements of the Act with respect to the permit area involved. After the issuance of such order, the plan may be modified only by common consent of the operator and the Commissioner, or upon a showing of justifiable cause at a formal hearing brought by either the operator or the Commissioner.

Section 5. Bond to be Modified or Set in Accord with the Plan. If an accepted plan has reasonable and adequate cost data included within it, the Commissioner shall set, reduce, or increase the bond of the operator who submitted the plan so that the bond equals the cost of reclamation called for by the plan.

Section 6. Continuing Reclamation; Bond. If any reclamation procedure under the plan is to be made a continuing part of the mining operation on the permit area affected, and is not to be done at a later time when mining operations are otherwise completed, then the cost of the procedures which are to be done simultaneously with mining shall not be included in calculating the operator's bond. Provided, that if reclamation work is not being accomplished in conformance with the plan, the Commissioner may hold a hearing at which the operator shall be required to show cause why the bond should not be modified to include the cost of procedures not completed according to the plan. If at such hearing the operator does not show good reason why he has not proceeded according to the reclamation plan, or why his bond should not be increased, then the Commissioner shall increase the bond to a sum which will reasonably cover the cost of the necessary reclamation.

CHAPTER VII

APPENDIX OF FORMS

Section 1. Application for Permit. The application shall contain substantially the following:

Form 1
July 1969

STATE OF WYOMING
OFFICE OF STATE LAND COMMISSIONER
113 State Capitol Building
Cheyenne, Wyoming 82001

APPLICATION FOR PERMIT UNDER
THE OPEN CUT LAND RECLAMATION ACT
(Chapter 192, Session Laws of Wyoming, 1969)

1. Name of Operator:______________________________
   Address:______________________________

2. Name of Owner (if not Operator):______________________________
   Address:______________________________

3. Minerals to be mined:______________________________

4. Type of Operation, to be, or is being conducted______________________________
   ____
   ____

5. Approximate volume of overburden has been previously removed__________
   ______________________________cubic yards

6. Approximate volume of overburden remaining to be removed__________
   ______________________________cubic yards

7. Give the location of the operation by legal subdivision, section, township and range. If there is no survey, give location by protracted survey, metes and bounds, and claim number and mining district.

8. Date when operation commenced, or will commence______________________________

9. Name and address of the person or persons to whom any notice under the provisions of the Open Cut Land Reclamation Act or Rules and Regulations adopted thereunder may be sent:
   ____
   ____
   ____

10. I,________________________(individual or company) have the right and power by legal estate owned to mine by open cut mining the lands described herein.

____
Applicant

This application may be accompanied by an estimated bond pursuant to Chapter II, Section 7 of the Rules. If an estimated bond is not included a permit cannot be issued until the Commissioner or his representative has set the amount of the bond.

This application, when returned to you with the validating signature of the Commissioner of Public Lands, becomes your permit.

This permit is issued (1) on a permanent basis
(2) on a conditional basis as specified in Chapter II, Section 7 of the Rules and Regulations.

____
Commissioner of Public Lands

Section 2. <u>Bond of Operator</u>. The operator's surety bond shall be substantially in the following form:

Form 2
July 1969

State of Wyoming

BOND OF OPERATOR

KNOW ALL MEN BY THESE PRESENTS, THAT WE________________________ ________________________________, as principal, and____________________ ____, a Surety Company authorized to do business in the State of Wyoming, as surety, are held and firmly bound unto the State of Wyoming, in the sum of ____Dollars ($__________) lawful money of the United States, to be paid to the Commissioner of Public Lands, as agent for the State of Wyoming for the use and benefit of the State of Wyoming and the reclamation under the Open Cut Reclamation Act of affected land, for which payment, well and truly to be made, we bind ourselves, and each of us, and each of our heirs, executors, administrators, successors, and assigns, jointly and severally by these presents.

Signed with our hand and seals this _____day of________________, in the Year of our Lord,________.

The condition of the foregoing obligation is such that,

WHEREAS, the Commissioner of Public Lands issued a ____________ permit, numbered_________________and dated__________________________, to engage in the new open cut mining upon the following described lands, to-wit:

NOW, THEREFORE, if said principal shall reclaim said land, and shall fully comply with the Open Cut Land Reclamation Act, and the rules and Regulations relating thereto promulated by the Commissioner of Public Lands, then the above obligation shall be void and of no effect, otherwise to remain in full force and virtue.

Signed, sealed and Delivered
in the presence of:

____
Attest or Witness

____
Witness

____
Witness

________________________(SEAL)
Principal

BONDING COMPANY

BY________________________

Attest:____________________

Resident Agent:________________
____

Approved as to form and execution:

____
Attorney General

By:____________________Assistant

Date:________________________

Corporate Seal of Bonding Company must be affixed.

CHAPTER 3

MINING OPERATIONS GENERALLY

ARTICLE 5

OPEN CUT LAND RECLAMATION

SUMMARY

The purpose of this law is to provide for the relamation and conservation of land subjected to surface disturbance by open cut mining. This is to be brought about by requiring that any mining operation carried on by surface opening shall be carried out under the requirements of this act.

Under Section 3-96.5 any operator desiring to engage in a new open cut mining operation must submit a written application to the Commissioner of Public Lands. The information required in this application is spelled out in this section.

The duties of every operator are spelled out in Section 20-19.6. These duties as stated here however, are only general in nature and more detailed requirements are issued from the office of the Commissioner.

The Commissioner or his representative may enter upon the lands of the operator at all reasonable times for the purpose of inspection. The Commissioner may also require the operator to file a bond payable to the State of Wyoming for the condition that the operator performs all the requirements of this act and complies with the rules of the Commissioner.

Any person who engages in open cut mining without securing a permit from the Commissioner is guilty of a misdemeanor and may be fined up to $1,000.00 per violation with each day of operation without the permit deemed a separate violation.

CHAPTER 3.

MINING OPERATIONS GENERALLY.

Article 5.
Open Cut Land Reclamation.

Section.

§ 30-96.1.--This act [§§ 30-96.1 to 30-96.13] may be known and cited as "The Open Cut Land Reclamation Act."

Effective date, May 24, 1969.

§ 30-96.2. Declaration of policy.--It is hereby declared to be the policy of this state to provide, for the reclamation and conservation of land subjected to surface disturbance by open cut mining and thereby to preserve natural resources, to aid in the protection of wildlife and aquatic resources to establish agricultural, recreational, home and industrial sites, to protect and perpetuate the taxable value of property, and to protect and promote the health, safety and general welfare of the people of this state.

§ 30-96.3. Definitions.--Whenever used or referred to in this act [§§ 30-96.1 to 30-13], or in rules and regulations promulgated hereunder, unless a different meaning clearly appears from the context:

(a) "Overburden" means all of the earth and other materials which lie above natural deposits of coal, clay, stone, sand, gravel, or other minerals, and also means such earth and other materials distrubed from their natural state in the process of open cut mining from exposed natural deposits.

(b) "Open cut mining" means the mining of coal, clay, stone, sand, gravel, or other minerals by removing the overburden lying above natural deposits thereof, and mining directly from the natural deposits thereby exposed.

(c) "Operator" means any person, form or corporation engaged in and controlling an open cut mining operation.

(d) "Pit" means a tract of land, from which overburden has been or is being removed, for the purpose of open cut mining.

(e) "Affected land" means the area of land from which overburden shall have been removed, or upon which overburden or refuse has been deposited, or both, after the effective date of this act.

(f) "Refuse" means all waste material directly connected with open cut mining.

(g) "Ridge" means a lengthened elevation of overburden created in the open cut mining process.

(h) "Peak" means a projecting point of overburden created in the open cut mining process.

(i) "Commissioner" means the commissioner of public lands of the State of Wyoming.

Editor's note.--The definition of "overburden" is set out in this Supplement just as it appears in the printed acts.

Effective date.--Laws 1969, ch. 192, carried no provision as to its effective date, but was approved March 6, 1969.

§ 30-96.4. Compliance generally; exceptions.--(a) From and after the effective date of this act [§§ 30-96.1 to 30-96.13] no mining operation or operation by which solid minerals are presently being extracted or are intended to be extracted from the earth by means of surface opening shall be commenced, conducted, or carried on or abandoned or closed save in accordance with and in confirmity to the requirements thereof. Provided nevertheless: it being recognized that measures taken hereunder are performed in the public interest and constitute an expense to the operator, and while this act shall apply to all mining operations being conducted at the time of or commenced after the effective date hereof, no operator shall be compelled to perform at his own expense measures required hereunder with respect to operations that were completed or substantially completed prior to the date hereof.

(b) Provided, however, that all pits and quarries opened after the effective date of this act, which are under the supervision and control of any government agency whose regulations are equal to or greater than those imposed by section 6 of this act [§ 30-96.6], are not subject to the further provisions of this act [§§ 30-96.1 to 30-96.13].

§ 30-96.5. Permit; bond generally; fee.--Any operator desiring to engage in a new open cut mining shall make written application to the commissioner for a permit. Application for such permit shall be made upon a form furnished by the commissioner, which form shall contain the following:

(1) The name of the operator and, if other than the owner, the name and address of the owner.

(2) The mineral to be extracted and the type of operation to be conducted.

(3) The volume of earth to be removed, as accurately as the same may then be estimated, and the volume which has been previously removed, if any.

(4) The location of the operation by legal subdivision, section, township and range, and county.

(5) The date when such operation was commenced or, as to new operations, the date when operation shall commence.

(6) The name and address of the person or persons to whom any notice under the provisions of this act [§§ 30-96.1 to 30-96.13] shall be sent.

(7) A statement that the applicant has the right and power by legal estate owned to mine by open cut mining the lands so described. Such application shall be accompanied by (a) a bond or security meeting the requirements of section 8 of this act [§ 30-96.8]; and (b) a fee of fifty dollars ($50.00). Upon receipt of such application, bond or security and fee due from the operator, the commissioner shall issue a permit to the applicant which shall entitle him to engage thereafter in new open cut mining on the land therein described.

An operator desiring to have his permit amended to cover additional contiguous or nearby land may file an amended application with the commissioner. Upon receipt of the amended application, and such additional bond as may be required under the provisions of this act [§§ 30-96.1 to 30-96.13], the commissioner shall issue an amendment to the original permit covering the additional land described in the amended application, without the payment of any additional fee.

An operator may withdraw any land covered by a permit, excepting affected land, by notifying the commissioner thereof, in which case the penalty of the bond or security filed by such operator pursuant to the provisions of this act shall be reduced proportionately.

§ 30-96.6. Duties of operator.--Every operator to whom a permit is issued pursuant to the provisions of this act [§§ 30-96.1 to 30-96.13] may engage in open cut mining upon the lands described in the permit upon the performance of and subject to the following requirements with respect to such lands:

(a) Grading shall be carried on to reduce peaks and ridges to a rolling topography.

(b) The operator shall construct earth dams in final cuts of all operations where lakes may be formed if it is necessary to construct a dam in order to impound water or other liquids issuing from a mining operation where such effluent is sufficiently toxic or radioactive to be dangerous or harmful to or destructive of plant, animal, or human life; provided further, that the formation of said lakes will not interfere with underground or other mining operations, damage adjoining property, and is done in compliance with laws, rules and regulation administered by the office of the state engineer.

(c) The operator shall cover, if practical in the discretion of the commissioner, the exposed face of a mineral seam, where acid-forming or combustible materials are present, to a depth of not less that 2 feet or more as may be required by the commissioner, with earth or spoil material.

(d) Where practicable, reasonable effort must be made to encourage the revegetation of lands disturbed by mining operations. The commissioner shall recommend seeding practices adapted to the soil and climatic conditions.

(e) The operator shall submit to the commissioner no later than September 1 of each year during which mining operations are conducted a map in a form approved by the commissioner showing the location of the pit or pits by section, township, range and county, with such other description as will identify the land upon which the operator has conducted open cut mining during the year ended on said date and has completed mining operations thereon, with a legend upon such map showing the number of acres of affected land. The operator shall also submit with such map a report stating in detail all steps taken by the operator to effect land reclamation on the affected land.

§ 30-96.7. Entry upon lands for inspection.--The commissioner, or his accredited representatives, may enter upon the lands of the operator at all reasonable times for the purpose of inspection, to determine whether the provisions of this act [§§ 30-96.1 to 30-96.13] have been complied with.

§ 30-96.8. Bond of operator; substitution of surety; violations; commissioner may reclaim land; notice of compliance; reducing penalty of bond.--Any bond herein provided to be filed with the commissioner by the operator shall be in such form as the commissioner prescribes, payable to the State of Wyoming, conditioned that the operator shall faithfully perform all requirements of this act [§§ 30-96.1 to 30-96.13] and comply with all rules of the commissioner made in accordance with the provisions of this act. Such bond shall be signed by the operator as principal, and by a good and sufficient corporate surety, licensed to do business in the state, as surety. The penalty of such bond shall be in an amount equal to the cost of restoration required by this act as determined by the commissioner. In lieu of such bond, the operator may deposit cash and government securities or a bond with property sureties with the commissioner in an amount equal to that of the required bond on conditions as above prescribed. In the discretion of the commissioner, surety bond requirements may be fulfilled by the operator posting a bond with land and improvements and facilities thereon as security, in which event no surety shall be required. The penalty of the bond or amount of cash and securities shall be increased or reduced from time to time as provided in this act. Such bond or security shall remain in effect until the mined acreages have been reclaimed, as provided under the permit, and approved and released by the commissioner, and shall from time to time cover only actual mined acreages and may be increased or reduced to cover only such acreages as remained unrestored.

A bond filed as above prescribed shall not be canceled by the surety except after not less than ninety (90) days' notice to the commissioner, and upon the commissioner's written consent thereto, which shall forthwith be given if the conditions of the bond have been performed.

If the license to do business in the state of any surety upon a bond filed with the commissioner pursuant to this act [§§ 30-96.1 to 30-96.13] shall be suspended or revoked, the operator, within thirty (30) days after receiving notice thereof from the commissioner, shall substitute for such surety a good and sufficient corporate substitution of surety as herein provided, the commissioner shall have the right to suspend the permit of the operator to conduct operations upon the land described in such permit until such substitution has been made.

The commissioner shall give written notice to the operator of any violation of this act [§§ 30-96.1 to 30-96.13] or noncompliance with any of the rules and regulations promulgated by the commissioner hereunder, and if corrective measure, approved by the commissioner, are not commenced within ninety (90) days the commissioner may proceed as provided in section 11 of this act [§ 30-96.11] to request forfeiture of the bond. Such forfeiture shall fully satisfy all obligations of the operator to reclaim the affected land under the provisions of this act [§§ 30-96.1 to 30-96.13].

The commissioner shall have the power to reclaim, in keeping with the provisions of this act, any affected land with respect to which a bond has been forfeited.

Whenever an operator shall have completed all requirements under the provisions of this act as to any affected land, he shall notify the commissioner thereof. If the commissioner shall release the operator from further obligations regarding such affected land, the penalty of the bond shall be reduced proportionately.

§ 30-96.9. Deposit of fees and forfeitures.--All fees and forfeitures collected under the provisions of this act [§§ 30-96.1 to 30-96.13] shall be deposited with the state treasurer in a special fund for reclamation purposes.

§ 30-96.10. Administration and enforcement of act.--This act [§§ 30-96.1 to 30-96.13] shall be administered by the commissioner of public lands of the State of Wyoming who shall have power to appoint such subordinater as he may deem necessary at salaries to be determined by the personnel commission of the State of Wyoming, and who shall be paid monthly by the state treasurer on the warrant of the state auditor. It shall be the duty of said commissioner to administer all of the provisions of this act and to secure enforcement of the same.

§ 30-96.11. Bond forfeiture proceedings.--The attorney general, upon request of the commissioner, shall institute proceedings to have the bond of the operator forfeited for violation by the operator of any of the provisions of this act [§§ 30-96.1 to 30-96.13]. Before making such request of the attorney general, the commissioner shall notify the operator in writing of the alleged violation or noncompliance and shall afford the operator the right to appear before the commissioner at a hearing to be held not less than thirty (30) days after the receipt of such notice by the operator. At the hearing the operator may present for the consideration of the commissioner statements, documents and other information with respect to the alleged violation. After the conclusion of the hearings, the commissioner shall either withdraw the notice of violation or shall request the attorney general to institute proceedings to have the bond of the operator forfeited as to the land involved.

§ 30-96.12. Rules and regulations.--The commissioner shall adopt and promulgate reasonable rules and regulations respecting the administration of this act [§§ 30-96.1 to 30-96.13] and covering requirements for land reclamation for each category of material mined for all mining operations carried on within the State of Wyoming, and in doing so shall comply with the Administrative Procedure Act. [§§ 9-276.19 to 9-276.33] of the State of Wyoming.

§ 30-96.13. Penalty.--Any person required by this act [§§ 30-96.1 to 30-96.13] to have a permit who engaged in new open cut mining without previously securing a permit to do so as prescribed by this act is guilty of a misdemeanor, and on conviction thereof shall be fined not more than one thousand dollars ($1,000.00). Each day of operation without the permit required by this act shall be deemed a separate violation.

RECLAMATION OF STRIP MINE SPOIL BANKS IN WYOMING

September 1971
Research Journal 51
Agricultural Experiment Station
University of Wyoming, Laramie

PREFACE

In this publication I have attempted to assemble all research results available on reclamation of Wyoming strip mine spoil banks.

This publication has been compiled from theses written by Pete Jacoby, Leandro Lujan, and Wesley Thompson, three University of Wyoming range management graduate students. Reports by Morton May, U. W. professor of range management, and unpublished field data collected in 1969 have been added to the information obtained from the theses.

Pete Jacoby took all photographs used in this publication.

Robert Lang, Professor
Range Management

ACKNOWLEDGMENTS

The authors and the Wyoming Agricultural Experiment Station express appreciation to the late Glen Sorenson, president, Kemmerer Coal Company, for his encouragement and active cooperation in the research reported herein.

Appreciation is also expressed for financial support granted to this project by the Kemmerer Coal Company because without it this research could not have been accomplished. Their financial support amounted to $26,461.50 for five and a half years work between 1964 and 1969.

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CONTENTS (Continued)

Reclamation of Strip Mine Spoil Banks In Wyoming

Morton May and Robert Lang*
Leandro Lujan, Peter Jacoby and Wesley Thompson**

Part I—GENERAL INFORMATION

Approximately 15,000 surface mines, affecting more than three and a half million acres of land, occur in the United States. Many are scattered throughout states west of the 100th meridian. From the standpoint of plant growth, climatic conditions in these states, with the possible exception of Hawaii, are extreme. Seventy-five percent of the area receives less than 20 inches annual precipitation and 20 percent of it receives less than 10 inches of precipitation annually. It is estimated that in many areas, losses from sublimation and evaporation leave less than 50 percent of the measured precipitation for plant growth.

Superimposed on this picture of limited precipitation are seasonal temperature ranges from −60° to 120° F, short frost-free periods, and wide variations in overburden material from surface mines.

Problems of revegetating strip mine overburden piles in western United States differ from those in more humid regions. Because there had been no research in this area or under these climatic conditions, a cooperative study was initiated with the Kemmerer Coal Company in 1964. The study had the following objectives:

1. To determine adaptability of native or introduced plant species for revegetating overburden piles;
2. To determine if fertilization, mulching, snow fencing for water accumulation, and/or various mechanical soil treatments would significantly affect vegetation establishment and growth.

Review of Literature

Czapowskyj and McQuilkin (1966) conducted reforestation research on strip mine spoils in the anthracite region of Pennsylvania using eight conifer species, two larch species, and black locust. They concluded (1) that overall survival of all tree species planted was 40 to 60 percent and that this was adequate, (2) that heights of trees planted on spoil was comparable to heights on natural soils, and (3) that the most important factors affecting survival and growth were soil type, soil texture, pH, grading history, and slope position.

Whitt (1968), reporting on strip mined land in general, stated that the United States has about two million acres of strip mined land needing revegetation. With greater efforts than those made in the past, these lands could be reclaimed and put to a variety of uses.

Morgan and Parks (1967) conducted research on reclamation of mined phosphate land in Tennessee. Since the land was to be farmed, it was necessary to level the overburden, an operation costing an average of $160 per acre. Studies of soils and crops grown on the levelled overburden were made and compared with non-disturbed land adjoining the mined site. They concluded: (1) Mined soil had a higher percentage of clay and more pore space than non-mined soil, (2) Mined soil had less organic matter and a lower pH than non-mined soil, and (3) With proper fertilization (nitrogen was the element most needed) crop yields from mined soil about equalled those from non-mined soil.

Agnew (1966) studied hydrologic factors related to strip mined coal areas in Indiana. He reported that surface mined areas contributed an additional quarter second foot of water to the stream flow. He also said surface mined areas soak up water during periods of heavy precipitation releasing 15 percent less water into the stream than non-mined lands.

Chapman (1967) studied effects of spoil grading on tree growth. He concluded that analysis of clay content of the soil should have first priority since the amount and type of clay determined soil porosity. Porosity determines air and water pene-

*Professors of Range Management
**Graduate Students in Range Management

tration and therefore tree growth. Spoils with more than 15 percent clay should have as little grading as possible, Chapman said. Complete grading reduced water infiltration and percolation which increased runoff and erosion and resulted in poor tree establishment and growth.

Lorino and Gatherum (1965) studied tree survival and yield on seven to eight year old plantings of two broadleaf and five coniferous species. They studied tree survival and yield in relation to spoil acidity, exchangeable aluminum, exchangeable and soluble bases, nitrifiable nitrogen, cation exchange capacity, soluble salt concentration, and available phosphorous and potassium. They found cottonwood survival was not clearly related to any soil factors studied. Green ash survival was somewhat related to exchangeable aluminum, soluble salt, and pH. Of the coniferous species, pines, in general, did not grow well on spoils where the exchangeable and soluble base content was high. Eastern red cedar survival was positively correlated with pH and negatively correlated with exchangeable aluminum and soluble salt concentration.

Seidel (1961) conducted a study of seeded versus planted black walnut trees on spoil banks in Chenokee County, Kansas. He found that after 10 years, percentage survival was about the same for seeded and planted trees but seeded trees averaged 1.3 feet taller than planted trees.

Most spoil reclamation research had been conducted in more humid climates than Wyoming's and usually revegetation attempts were with tree species.

Description of Study Area

Location

The Kemmerer coal fields are in southwestern Wyoming about four miles southwest of the city of Kemmerer.

The terrain is rolling hills and ridges separated by broad open flats. The strip mines lie on a ridge caused by the Lazeart Syncline and overlook Hilliard Flats which is traversed by many intermittent streams.

Vegetation

The study area is a part of the Northern Desert Shrub region and is dominated by big sagebrush *(Artemisia tridentata)*. Other important shrubs are shadscale *(Atriplex confertifolia)*, several species of rabbitbrush (*Chrysothamnus* spp.), greasewood *(Sarcobatus vermiculatus)*, snakeweed *(Gutierrezia sarothrae)*, nuttall saltbush *(Atriplex nuttallii)*, and winterfat *(Eurotia lanata)*.

Important grasses associated with these shrubs are bluebunch wheatgrass *(Agropyron spicatum)*, western wheatgrass *(Agropyron smithii)*, bottlebrush squirreltail *(Sitanion hystrix)*, needleandthread, *(Stipa comata)*, basin wildrye *(Elymus cinereus)*, and various species of bluegrass *(Poa* spp.). Cheatgrass brome (*Bromus tectorum*) is an important invader. On the eastern slopes of ridges and in draws where snow drifts accumulate are stands of aspen *(Populus tremuloides)* and serviceberry *(Amelanchier alnifolia)*.

Vegetation on spoil banks, while sparse, is characteristic of early stages of secondary succession in that most species are annuals and introduced. On younger spoil banks, Russian thistle *(Salsola kali)*, fireweed summercypress *(Kochia scoparia)*, and cheatgrass brome were common. On older spoil banks, bottlebrush squirreltail, foxtail barley *(Hordeum jubatum)*, and a few native shrubs have become established.

Precipitation

Annual precipitation in the study area is unpredictable with periodic drought the rule rather than the exception. Based on a 32-year average for Kemmerer, annual precipitation is 9.42 inches. Much of the total annual precipitation occurs as snow with an average annual fall of 56.5 inches. Highest precipitation is in spring and early summer with May and June averaging slightly over one inch each. Precipitation during this period occurs mainly as rain.

Precipitation as snow has several peculiarities. It usually occurs after the ground is frozen so any snow which melts is subject to runoff rather than percolation into the soil. Snow also is blown about and distributed in uneven patterns. Many areas catch little snow while others such as gullies and leeward sides of wind obstructions receive large amounts. Snow also is vulnerable to sublimation, a process by which solids pass directly into a gaseous state without being transformed to liquid. It is not uncommon for 60 to 80 percent of a snowfall to be sublimated, leaving 20 to 40 percent of the moisture content to be transformed into water, which may or may not penetrate the soil surface. It is not unreasonable to estimate that of the 9.42 inches of annual precipitation, less than five inches are available for plants.

Temperature

Based on long time records, average annual monthly air temperatures range from a low of 12° F in January and February to a high of 63° F in July. These temperatures, recorded at Kemmerer, can be related to similar climatic conditions at the Kemmerer coal field, approximately four miles to the southwest.

Air and soil temperatures at the study area vary with exposure, topography, and microclimatic level, between different color combinations of the over-burden material.

Grazing Factors

The study area is unfenced rangeland, and is periodically grazed during spring and early summer by bands of herded sheep. Stock trail over the spoil banks and use water trapped in pits, all of which are accessible. Study plots are unfenced and subject to grazing as would be the entire area if revegetated.

Wildlife also live in the study area, using pit water when necessary. Deer are abundant and according to mining personnel are increasing in numbers.

Spoil Characteristics

Spoil material of the Kemmerer coal fields is derived from the Adeville Formation, local name for part of the Mesa Verde Formation of Upper Cretaceous age. Average formation thickness is about 6,000 feet and contains some 30 coal seams ranging in thickness from two to 120 feet (Coal Age, September, 1963: Townsend, 1960).

The spoils of the study area were quite different from soil in surrounding, undisturbed areas. The tremendous disturbance caused by deep cuts and mixing of subsoil strata during mining operations created extreme variability in spoil characteristics within the stripped area. Variation in pH, for example, ranged from 2.2 to 7.3. These extreme values were observed within a distance of three to four feet. The study area as a whole, however, according to Finn's rule (1958), was classified as acidic; only five out of 21 pH readings had pH values greater than 7.0, but no values above 7.3 were recorded in the area (Table 1).

Some spots, having "wet" or "greasy" appearances, were quite high in aluminum content and were extremely low in pH. No vegetation was observed on such spots (Figure 1).

Overburden material contained large amounts of clay. The most frequently found soil textures were clays and clay loams. Spoil materials were high in soluble salts. Calcium and magnesium were quite high, especially when compared with adjacent native soils.

The amount of organic matter, according to soil analyses, was very high. Coal present in spoil material caused analyses to show more organic matter than was actually present (Table 1).

An interesting observation was made when pH readings were taken on the soil materials, 100 feet and 200 feet away from the spoils. The following readings were obtained:

Location	Number of readings	pH average
Spoil materials	16	6.40
100 feet from spoils	5	6.64
200 feet from spoils	5	7.68

In spite of great variability in spoil material characteristics, some common factors also prevailed throughout the area: high clay percentage, high soluble salt content, low pH values, and seemingly high organic matter content.

Topography of Spoil Banks

The strata overlying coal seams had been removed by dragline and either transported by truck to a dumping site or stacked by the dragline near the removal site. Differences in methods of deposition resulted in spoil piles of varying profiles. Figure 2 shows the type of bank with a flat top and solitary long slope (A) and the conical shaped spoil banks formed by the dragline deposition (B). The latter is formed by trucking the spoil from another site, dumping it near the edge, and having bulldozers level the top to enable further deposition.

From a revegetation viewpoint, several disadvantages lie in these two types of spoil banks. Erosion is very pronounced and the possibility of seeding and mulching with mechanical means is nil. Hand seeding and mulching is costly and the manipulation of mulching material on the slopes is difficult and often hazardous. Irrigation on such spoil banks is impractical, if not impossible.

The third type of spoil bank (C), without extremely steep slopes, would probably present the best opportunity for successful revegetation. It would enable mechanical seeding and mulching and also would offer good possibilities for irrigation. To conform old spoil banks to this profile would be expensive and would uncover unoxidized material that would slow revegetation.

TABLE 1. SUMMARY OF SOILS DATA FOR OVERBURDEN MATERIALS APPROXIMATELY 14 YEARS OLD.

Location and treatment	Texture	pH	Millimhos/cm. soluble salts	P_2O_5 lbs/a.	Organic matter	Milliequivalents of soluble cations per 100 gram of soil			
						Calcium	Potassium	Sodium	Magnesium
Site I, 66†	Clay	6.7	4.0	110.0	4.9	2.08	0.11	0.38	2.00
Site I, 00*	Clay	6.6	4.5	138.0	4.2	2.16	0.13	0.42	4.02
Site I, 33†	Clay	6.9	4.2	71.3	4.9	2.16	0.13	0.42	3.54
Site I, Ir**	Silty clay loam	6.5	5.3	67.0	5.2	1.87	0.10	0.43	6.28
Site II, 66	Clay	5.8	3.9	149.5	2.9	1.21	0.05	0.25	1.97
Site II, Ir.	Silty clay loam	6.0	5.0	172.5	5.9	1.69	0.12	0.42	5.61
Site II, 33	Clay loam	5.2	4.2	345.0	5.4	1.46	0.30	0.38	3.40
Site II, 00	Clay loam	5.6	4.0	207.0	4.4	1.37	0.06	0.35	2.42
Site III, 66	Clay	6.2	5.0	122.0	4.7	1.44	0.04	0.32	2.53
Site III, 00	Clay	7.1	0.6	74.0	3.5	0.19	0.04	0.28	0.12
Site III, 33	Clay	7.3	4.3	25.0	4.2	1.55	0.12	0.33	2.63
Site III, Ir.	Clay	7.1	4.5	16.0	6.3	1.47	0.11	0.33	1.58
Site IV, 66	Clay	7.0	3.2	90.0	5.6	1.55	0.11	0.27	1.35
Site IV, Ir.	Clay	6.3	4.0	62.0	7.0	1.59	0.06	0.26	1.16
Site IV, 33	Clay loam	6.3	3.5	104.0	5.6	1.19	0.10	0.23	1.20
Site IV, 00	Clay loam	6.5	3.5	57.5	7.6	1.56	0.10	0.24	1.31

**Ir stands for irrigated plot.
*00 stands for control plot.
†Lbs of N added per acre.

Figure 1. "Wet" or "greasy" appearance is characteristic of acidic spots high in aluminum content. Note absence of vegetation.

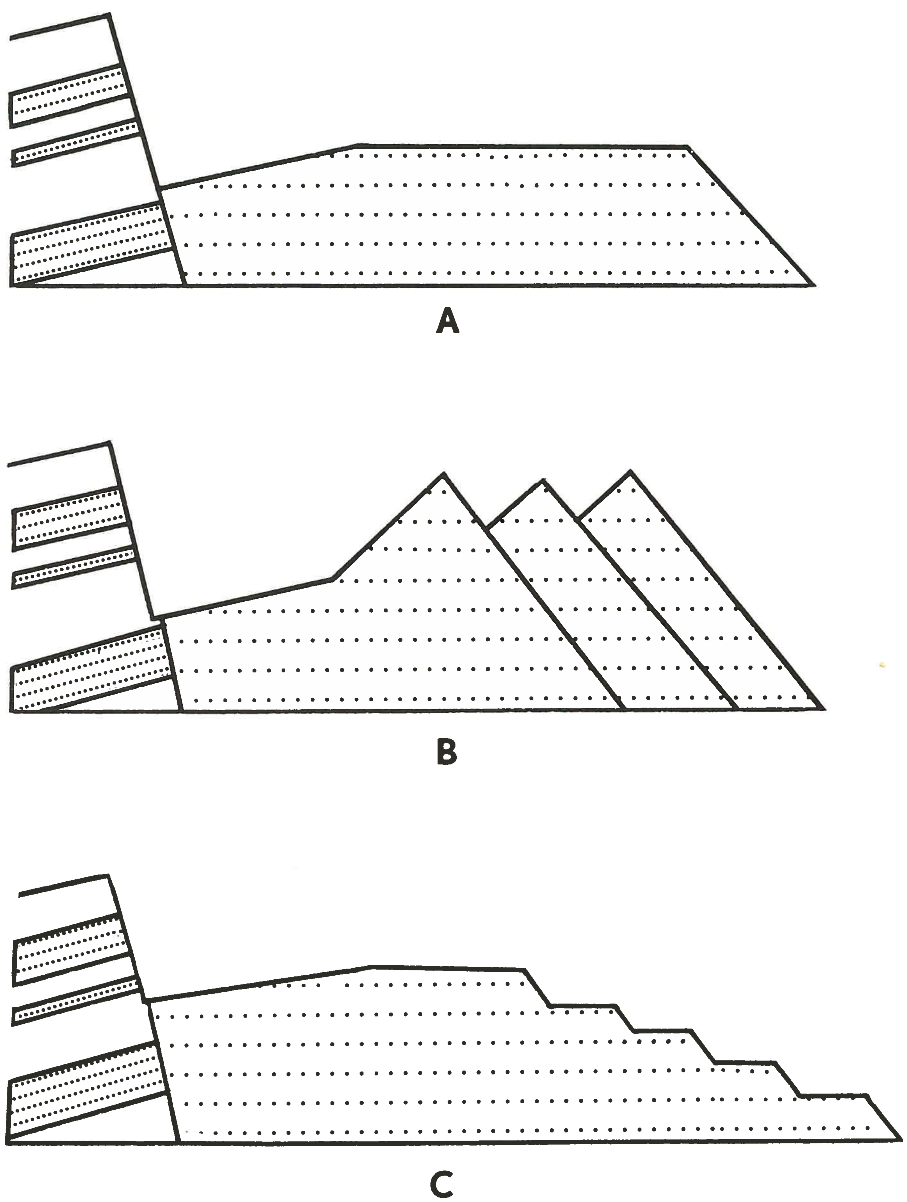
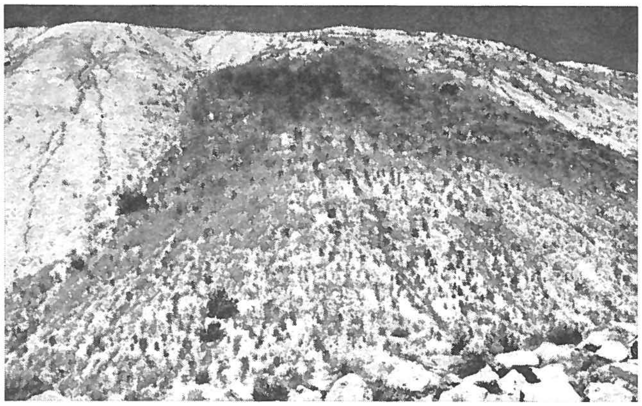


Figure 2. Profiles of spoil bank types are shown: truck and dozer type (top); dragline type (middle); terrace type (bottom).



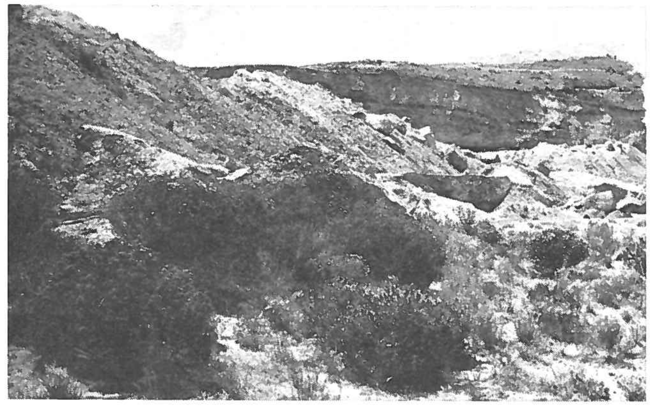


Figure 3. A general view (left) of natural revegetation on a 15-year old spoil bank contrasts with the photo at right which shows a closeup of plants on this spoil.

Topsoil, although not essential for plant establishment, may shorten the time lag in plant succession. Figure 3 shows a general and closeup view of natural revegetation on a 15-year old spoil bank. Plant growth from voluntary species has nearly stabilized the bank against erosion on this site.

Topographic modifications, from surface mining, include numerous pits in the study area. Reclamation plans call for filling these pits with spoil. Many have beneficial value as natural reservoirs and should be left undisturbed. Water from ground seepage and precipitation becomes trapped and serves as a source of water for livestock, wildlife, and irrigation (Figure 4). Most water in the Kemmerer coal field area has been tested and declared suitable for livestock and agricultural uses. Fish have been transplanted in selected pits, and salamanders are found in many ponds.

Characterization of Different Aged Spoil Banks

During this study, three different aged spoil banks were characterized and studied for natural plant succession in an attempt to recognize and describe definite stages in the process. Species composition and ground cover were determined by the ocular estimate by plot method. The three age groups corresponded with those on which treatments were tested.

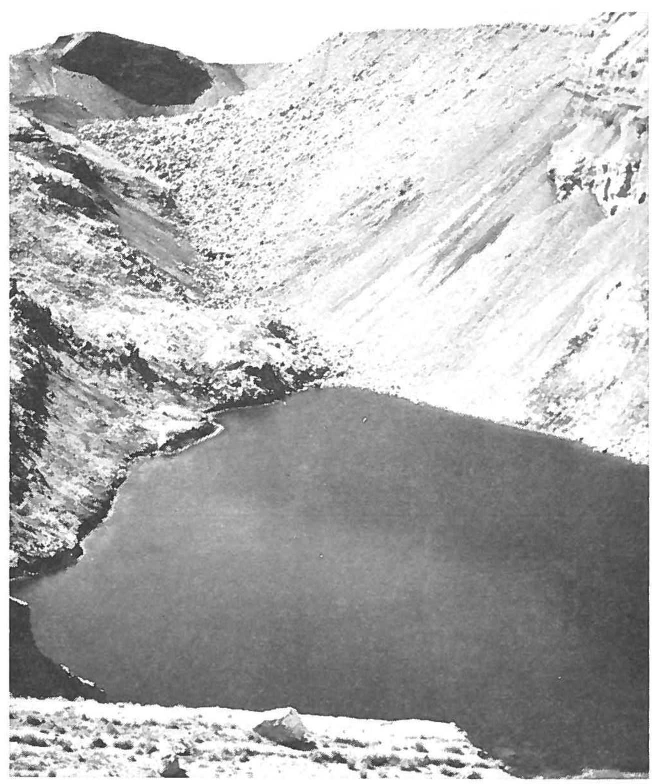


Figure 4. A large fresh water pit supplies drinking water for livestock and game and could be used for irrigation.

Young Spoil Bank

The youngest spoil was characterized by very loose material, being highly susceptible to erosion, and by forming a thin, hard crust on the surface when undisturbed. Vegetation, usually sparse, was similar in composition on slopes from top to bottom, and there was no apparent influence caused by directional exposure. Specie invasion from surrounding areas onto the foot of the spoil bank slopes was discouraged by the constant down-movement of the spoil which covered the volunteering species (Figure 5).

Figure 5. A young spoil bank is shown on the left. Note the erosion as compared to the older spoil bank on the right.

Species of the pioneer community were chiefly wind dispersed types. Seed, blown onto the spoil, found its way into surface cracks and collected in small gullies caused by water erosion.

The primary pioneer species was Russian thistle. It made up 98 percent of the vegetation and contributed from 15 to 20 percent ground cover. This species contributed about 95 percent vegetation observed on spoil banks less than four years old.

Other species included Nuttall saltbush, thickspike wheatgrass *(Agropyron dasystachyum)*, and bottlebrush squirreltail.

Mid-Age Spoil Bank

The medium age spoil studied was eight years old. More stable on level areas than young spoil banks, the material still was loose and highly subject to erosion on slopes. Plants were clustered where snow accumulation was evident, suggesting moisture availability or seed accumulation by wind. Total vegetative cover was estimated at slightly over 15 percent.

Russian thistle was still the most abundant species having 95 percent frequency in samples. Bottlebrush squirreltail, cheatgrass brome, Canada thistle *(Cirsium arvense)*, and basin wildrye were in lesser abundance. The latter four also grew on surrounding areas not affected by strip mining.

Cheatgrass brome occurred in all samples as a highly aggregated species. The mulch it produced seemed to provide suitable habitat for new plant establishment.

Old Spoil Bank

The 15-year old spoil studied was the oldest bank in the study area. Like the mid-age spoil, the 15-year old bank was stable on the top and level areas but, for the most part, was unvegetated on erodable slopes. Total cover was estimated to be between 30 and 35 percent with more plant species than the mid-age bank.

Some portions of the spoil bank were stabilized by cheatgrass, and in these areas scattered plants from the surrounding communities had become established.

In one particular area on the spoil bank, topsoil removed from another area had been deposited. This area, defined by reddish sandstone and clay soils, supported far more vegetation than nearby overburden (Table 2). Species found in this area included big sagebrush, bottlebrush squirreltail, foxtail barley, thickspike wheatgrass, and cheatgrass.

Vegetation on the spoil bank top showed evidence that wind dispersal was the main influence in plant distribution. Ninety percent of the samples were bottlebrush squirreltail, with foxtail barley and Russian thistle next in abundance. On margins between the spoil bank and native range, species appeared such as rubber rabbitbrush *(Chrysothamnus nauseosus)*, basin wildrye, big bluegrass *(Poa ampla)*, silver sagebrush *(Artemisia cana)*, thickspike wheatgrass, slender wheatgrass *(Agropyron trachycaulum)*, Indian ricegrass *(Oryzopsis hymenoides)*, and kochia *(Kochia americana)*.

Types of Research Conducted

Three types of research were conducted on the Kemmerer coal spoil banks. These types of research were with (1) trees using various species, fertilizer, and irrigation, (2) grass seeds using four species and various means of holding moisture, and (3) transplanting sod chunks and sprigs of two rhizomatous species with different means of holding moisture.

TABLE 2. SPECIES OCCURRING IN SAMPLES TAKEN ON ALL SPOIL BANKS

Species	Observed on age groups	Percentage cover	Percentage composition
Salsola kali	3	15-20	95-98
Salsola kali	9	15	90-95
Salsola kali	15	10	5-10
Sitanion hystrix	3	present	—
Sitanion hystrix	9	present	—
Sitanion hystrix	15	12-15	50
Atriplex nuttallii	3	present	—
Atriplex nuttallii	9	present	—
Atriplex nuttallii	15	present	—
Agropyron dasystachyum	3	present	—
Agropyron dasystachyum	9	—	—
Agropyron dasystachyum	15	present	—
Bromus tectorum	9	present	—
Bromus tectorum	15	present	—
Cirsium arvense	9	present	—
Cirsium arvense	15	present	—
Elymus cinereus	9	present	—
Elymus cinereus	15	present	—
Chrysothamnus nauseosus	9	present	—
Chrysothamnus nauseosus	15	present	—
Poa ampla	15	2-3	5
Artemisia cana	15	1	2
Agropyron trachycaulum	15	2-3	5
Oryzopsis hymenoides	15	2-3	5
Kochia americana	15	2	3

In all three types, age of the spoil pile was considered a factor.

The procedure, results, and conclusions for each type of research will be treated separately in Parts II, III, and IV.

Part II—TREE PLANTING RESEARCH

Methods of Study for Tree Planting Research

In April, 1965, 800 trees of five species were planted on overburden banks that were about 14 years old. Species planted were caragana *(Caragana aborescens)*, eastern juniper *(Juniperus virginiana)*, Russian olive *(Elaeagnus angustifolia)*, Siberian elm *(Ulmus pumila)*, and skunkbush sumac *(Rhus trilobata)*.

Four planting sites were selected as follows: Site I on the flat top of the highest spoil bank, Site II on the flat top of a lower spoil bank, Site III on the upper northeastern and eastern facing slopes of the bank of Site II, and Site IV on the lower eastern and southeastern slopes of the bank of Site I. At each site four plots were established each consisting of 10 trees per species giving 50 trees per plot and 200 trees per site.

Each of the four plots within a site received a different treatment: two plots were treated with fertilizer (one 33 and one 66 pounds of nitrogen per acre in the form of ammonium nitrate), the third plot was irrigated, and the fourth received no nitrogen or irrigation (control). Plots were irrigated by hauling water in barrels from the water pits and applying it with a portable pump and plastic hose. Records were kept of survival and growth for each species and treatment.

Trees also were planted around some water pits. At these locations chokecherry *(Prunus melancarpa)*, golden willows *(Salix alba)*, native plum *(Prunus Americana)*, and cottonwood (*Populus* spp.) were used. These species were chosen because they have greater water requirements than the five species planted on the dry spoil banks.

Soils

Soil samples were collected from all 16 plots, from locations where variations in spoil characteristics were noted, as well as from adjacent nondisturbed areas. All samples, taken from the top six inches, were analyzed at the University of Wyoming Soils Laboratory for acidity (pH); texture; organic matter; phosphorus, aluminum (soluble), calcium, magnesium, potassium and sodium.

Soil samples at three, six, and 12 inches of depth were collected for moisture determinations from each site and adjacent nondisturbed areas. Moisture determinations were made by oven drying the soils at 105° to 110° C for 24 hours. Moisture in the soil was expressed as a percentage of the soils oven dried weight.

Greenhouse Study

A greenhouse study was initiated to test fertility of spoil material from each site. Crested wheatgrass *(Agropyron cristatum)*, Indian ricegrass, western wheatgrass, and field milkvetch *(Astragalus agrestis)* (a perennial forb from spoil banks in Montana) were planted in pots of spoil material from each location.

To test the response to fertilizer, an application equivalent to 40 pounds of nitrogen per acre was used on half the pots to compare with no nitrogen on the other half.

Vegetation and Topography

An inventory of vegetation on the spoil banks and adjacent nondisturbed area was conducted. The objective was to determine major vegetation differences between the spoil banks and adjacent nondisturbed areas.

The spoil banks topographic features were recorded because of their importance in the process of natural revegetation and in the survival and establishment of the planted trees. Slopes of the spoil banks were measured with an Abney level and exposures determined by a compass.

Results and Discussion of Tree Planting Research

Tree Survival and Growth

Analysis of the data indicated a strong correlation between tree survival and growth and their locations on the spoils.

Russian olive was the best adapted of the five species tested on the Kemmerer spoil banks (Table 3). The first growing season (1965) ended with the average survival percentage for this species being 80 percent. Survival records up to 100 percent were observed in Site III on the irrigated and control plots, and in Site I on the control plot. In mid-June 1966, survival percentages were generally lower than the previous fall. Site IV showed the lowest survival record of two and a half percent compared with 60 percent in Site III, 45 percent in Site II and 40 percent in Site I. By July, 1969, average Russian olive survival on all sites was 20 percent.

TABLE 3. PERCENTAGE SURVIVAL OF RUSSIAN OLIVE *(ELAEAGNUS ANGUSTIFOLIA)* BY SITE, TREATMENT, AND YEAR.

Treatment	Percent survival		
Site I—Flat top-high spoil bank	July 1965	June 1966	July 1969
0 lbs. N per acre	100	80	20
33 lbs. N per acre	40	10	10
66 lbs. N per acre	70	40	0
Irrigated only	90	60	50
Site II—Flat top-low spoil bank			
0 lbs. N per acre	90	30	10
33 lbs. N per acre	70	40	0
66 lbs. N per acre	50	10	0
Irrigated only	90	70	70
Site III—Upper slope of Site II			
0 lbs. N per acre	100	70	70
33 lbs. N per acre	90	60	60
66 lbs. N per acre	80	30	20
Irrigated only	100	90	80
Site IV—Lower slope of Site I			
0 lbs. N per acre	50	0	0
33 lbs. N per acre	80	0	0
66 lbs. N per acre	60	0	0
Irrigated only	90	10	0

Russian olive also made the greatest growth. Five inches were recorded on irrigated and control plots on Site III (Figure 6) and two and a half inches were recorded on Sites I and II. On Site IV only one inch was recorded.

Siberian elm (Table 4) was second in survival and growth on the sloped sites (Figure 7). Caragana (Table 5) grew better than Siberian elm on flat sites. Average percentage survival for Siberian elm on Site III at the end of the first year was 52 percent, compared with 48 percent in June, 1966, and 35 percent in July, 1969. Siberian elm seems to be well adapted to growth on such locations. This was not true in other locations, however. On Site I, average survival rate for Siberian elm was 42 percent at the end of the first year, compared with 12 percent on June 13, 1966, and five percent in July, 1969. The mortality rate for caragana was lower on flat locations than on slopes and it was on flat sites where it showed the best survival.

It was concluded from this study that the best locations for revegetating spoil with trees were the eastern and northeastern slopes near the top of spoil piles. Here the soil warms in early spring when moisture is available for trees to begin growing. These locations are better protected from the strong winds in this region. Russian olive and Siberian elm had the best survival and growth there. Caragana rated third, survived best and grew well on the flat tops of the spoil banks. Sumac (Table 6) and red cedar (Table 7) did best on Site III, but neither proved adaptable for revegetation of the areas.

Treatments

Of the treatments tested (two levels of nitrogen fertilization and irrigation), irrigation alone seemed to be effective in establishment and growth of trees. Not all species tested reacted to irrigation in terms of survival (Table 8). When considering all sites, the percentage survival of Russian olive, Siberian elm, and caragana was significantly higher when the trees were irrigated during the first growing season than when they were not irrigated. When survival was checked in 1969 (four years after planting) the irrigated plots of these species

Figure 6. Russian olive on Site III was photographed in July, 1969.

TABLE 4. PERCENTAGE SURVIVAL OF SIBERIAN ELM *(ULMUS PUMILA)* BY SITE, TREATMENT, AND YEAR

Treatment	Percent survival		
Site I—Flat top-high spoil bank	July 1965	June 1966	July 1969
0 lbs. N per acre	30	20	10
33 lbs. N per acre	40	20	0
66 lbs. N per acre	60	0	0
Irrigated only	40	10	10
Site II—Flat top-low spoil bank			
0 lbs. N per acre	40	30	0
33 lbs. N per acre	10	0	0
66 lbs. N per acre	40	10	0
Irrigated only	30	40	0
Site III—Upper slope of Site II			
0 lbs. N per acre	60	60	50
33 lbs. N per acre	60	50	10
66 lbs. N per acre	10	0	0
Irrigated only	80	80	80
Site IV—Lower slope of Site I			
0 lbs. N per acre	30	0	0
33 lbs. N per acre	20	0	0
66 lbs. N per acre	80	0	0
Irrigated only	70	20	0

Figure 7. Siberian Elm on Site III was photographed in July, 1969.

TABLE 5. PERCENTAGE SURVIVAL OF CARAGANA *(CARAGANA ABORESCENS)* BY SITE, TREATMENT, AND YEAR.

Treatment	Percent survival		
Site I—Flat top-high spoil bank	July 1965	June 1966	July 1969
0 lbs. N per acre	40	30	30
33 lbs. N per acre	20	10	10
66 lbs. N per acre	60	30	20
Irrigated only	40	50	40
Site II—Flat top-low spoil bank			
0 lbs. N per acre	70	10	0
33 lbs. N per acre	40	10	0
66 lbs. N per acre	10	10	0
Irrigated only	60	50	50
Site III—Upper slope of Site II			
0 lbs. N per acre	50	30	20
33 lbs. N per acre	70	30	20
66 lbs. N per acre	40	40	0
Irrigated only	90	90	90
Site IV—Lower slope of Site I			
0 lbs. N per acre	50	0	0
33 lbs. N per acre	20	0	0
66 lbs. N per acre	30	10	0
Irrigated only	30	10	0

TABLE 6. PERCENTAGE SURVIVAL OF SKUNKBUSH SUMAC *(RHUS TRILOBATA)* BY SITE, TREATMENT, AND YEAR.

Treatment	Percent survival		
Site I—Flat top-high spoil bank	**July 1965**	**June 1966**	**July 1969**
0 lbs. N per acre	40	40	40
33 lbs. N per acre	0	0	0
66 lbs. N per acre	20	20	0
Irrigated only	0	0	0
Site II—Flat top-low spoil bank			
0 lbs. N per acre	20	10	0
33 lbs. N per acre	0	0	0
66 lbs. N per acre	0	0	0
Irrigated only	0	10	0
Site III—Upper slope of Site II			
0 lbs. N per acre	50	60	30
33 lbs. N per acre	20	10	10
66 lbs. N per acre	10	10	0
Irrigated only	10	10	0
Site IV—Lower slope of Site I			
0 lbs. N per acre	10	0	0
33 lbs. N per acre	0	0	0
66 lbs. N per acre	0	0	0
Irrigated only	40	20	0

had three to four times greater percentage survival than the non-irrigated plots (Table 8). The average height growth was about two inches greater on the irrigated plots than on other treatments.

Based on this study, watering trees in any spoil bank revegetation program is highly recommended, especially during middle and late summer when moisture availability is low. Use of nitrogen is not recommended although it is possible that a combination of nitrogen and irrigation would prove feasible. None of the irrigated plots in this study received fertilizer.

Greenhouse Study

The greenhouse study of various grasses and forbs seeded in pots showed that with proper moisture the species tested would germinate and grow on the spoil material. When the "soil" dries, a hard crust develops, preventing seedlings from penetrating the soil. Seeding should be in early spring when the overburden is usually wet and no hard surface has developed.

Best germination percentages were obtained from crested and western wheatgrass. Indian ricegrass did not germinate but this was due to the inherent dormancy of this seed. Seeds of field milkvetch, collected from overburden piles in Montana, had extremely low germination. Bottlebrush squirreltail volunteered in most pots where Indian ricegrass and field milkvetch were seeded. Evidently the seed was in the overburden material and it germinated and grew well in the greenhouse, showing that it is well adapted to this type of overburden material.

The greenhouse study also showed that overburden material had enough fertility to support good vegetative cover. No sign of nutrient deficiencies was noted in plants grown in the greenhouse. However, the addition of ammonium nitrate at the rate of 40 pounds of nitrogen per acre caused a significant increase in plant material produced (Table 9). This study, as well as the plants growing on the spoil banks themselves, showed that the overburden material had enough fertility to support good vegetative cover except in the very acid, high aluminum content spots mentioned earlier.

TABLE 7. PERCENTAGE SURVIVAL OF EASTERN JUNIPER *(JUNIPERUS VIRGINIANA)* BY SITE, TREATMENT, AND YEAR.

Treatment	Percent survival		
Site I—Flat top-high spoil bank	**July 1965**	**June 1966**	**July 1969**
0 lbs. N per acre	0	0	0
33 lbs. N per acre	0	0	0
66 lbs. N per acre	0	0	0
Irrigated only	0	0	0
Site II—Flat top-low spoil bank			
0 lbs. N per acre	0	0	0
33 lbs. N per acre	0	0	0
66 lbs. N per acre	0	0	0
Irrigation only	0	0	0
Site III—Upper slope of Site II			
0 lbs. N per acre	10	10	10
33 lbs. N per acre	0	0	0
66 lbs. N per acre	10	0	0
Irrigated only	0	0	0
Site IV—Lower slope of Site I			
0 lbs. N per acre	0	0	0
33 lbs. N per acre	0	0	0
66 lbs. N per acre	0	0	0
Irrigated only	0	0	0

TABLE 8. COMPARISON OF AVERAGE PERCENTAGE SURVIVAL OF FIVE TREE SPECIES IN THREE YEARS FOR PLOTS IRRIGATED AND NOT IRRIGATED DURING THE FIRST GROWING SEASON.

Species	Treatment all sites	July 1965	June 1966	July 1969
Russian olive				
(Elaeagnus angustifolia)	Irrigated	92.5	57.5	50.0
	Not-irrigated	73.3	30.8	15.1
Skunkbush sumac				
(Rhus trilobata)	Irrigated	12.5	10.0	0.0
	Not-irrigated	14.2	12.5	5.2
Siberian elm				
(Ulmus pumila)	Irrigated	55.0	37.5	22.5
	Not-irrigated	40.0	16.2	5.9
Caragana				
(Caragana ab ɔrescens)	Irrigated	55.0	50.0	45.0
	Not-irrigated	40.0	17.5	8.3
Eastern juniper				
(Juniperus virginiana)	Irrigated	0.0	0.0	0.0
	Not-irrigated	1.7	0.9	0.9
Average all species	Irrigated	43.0	31.0	23.5
and all sites	Not-irrigated	33.8	15.7	7.5

TABLE 9. OVEN DRIED WEIGHT OF FORAGE PRODUCED IN THE GREENHOUSE ON OVERBURDEN MATERIAL FROM FOUR SITES. WEIGHTS ARE IN TOTAL GRAMS PER FIVE POTS.

Species	Control	40 pound Nitrogen/acre
Overburden material, Site I		
Agropyron smithii	25.1	30.5
Agropyron cristatum	90.4	160.6
Oryzopsis hymenoides	2.0	2.8
Astragalus agrestis	1.0	0.0
Overburden material, Site II		
Agropyron smithii	15.9	79.3
Agropyron cristatum	93.3	157.9
Oryzopsis hymenoides	44.0*	5.3
Astragalus agrestis	13.5*	0.1
Overburden material, Site III		
Agropyron smithii	13.9	101.1
Agropyron cristatum	77.5	59.2
Oryzopsis hymenoides	41.0*	40.2*
Astragalus agrestis	55.6*	5.8
Overburden material, Site IV		
Agropyron smithii	65.3	87.1
Agropyron cristatum	106.5	158.9
Oryzopsis hymenoides	5.1*	0.0
Astragalus agrestis	48.8*	3.3

*In these pots bottlebrush squirreltail grass volunteered; therefore, the weights reported were for bottlebrush squirreltail rather than the species seeded.

Summary and Conclusions of Tree Planting Research

Summary

Four sites were selected on two 14-year old spoil piles. Two were on the flat tops of spoils and two on slopes with different exposures. At each site, four plots were established, each receiving a different treatment, 66 pounds of nitrogen (ammonium nitrate) per acre, 33 pounds of nitrogen per acre, irrigation, and control. Five tree and shrub species were planted: caragana, sumac, Russian olive, Siberian elm, and red cedar. Each plot consisted of 10 trees of each species, or 200 trees per site.

Analyses of the spoil material were conducted to determine texture, acidity, organic matter, soluble salts, potassium, sodium, phosphorus, magnesium, calcium, and aluminum. Similar soil analyses were conducted on adjacent undisturbed native rangeland.

Soil moisture records were taken during the year to investigate the effect of moisture on survival and growth of the planted species.

A greenhouse study was conducted to determine fertility of the overburden.

A basic survey of vegetation on both the overburden material (14 years old) and adjacent undisturbed native vegetation was undertaken to compare the percentage cover and species composition of these two areas.

Climatic conditions were studied using data from the Kemmerer weather station about four miles from the study area. The frost-free period in this area is approximately 130 days, and the mean annual precipitation is 9.12 inches. Precipitation in 1965, the first year of the study, was 13.76 inches.

Conclusions

1. Russian olive trees responded the best to the spoils environment, based on survival per-

centage and growth, of all species tested. This was regardless of location. Second was caragana on flat tops and third best was Siberian elm on the northeastern and eastern slopes. Red cedar and sumac survival was very poor at all locations.

2. The most favorable sites, as determined by percentage survival and growth of all species, were the northeastern and eastern upper slopes. Survival records of 80 percent and higher were recorded on these locations, one year after the trees were planted. Southern and southeastern lower slopes were the most unfavorable sites. The flat tops of the banks were usually favorable sites, except where salts accumulated or on localized acidic spots.

3. Watering the trees during mid and late summer greatly increased survival percentage growth and vigor. Survival differences as high as 50 percent were observed between trees on irrigated plots and these which were not irrigated, fertilized, or received no treatment (control).

4. The application of fertilizer (ammonium nitrate) did not significantly affect tree survival or growth.

5. Strong westerly winds caused some tree mortality by breaking and causing faster drying of the overburden material, especially on the flat tops of the spoil piles.

6. Extremely acidic conditions existed in localized spots. The pH was very low and aluminum content high and no vegetation was observed growing on these acid spots.

7. Accumulation of soluble salts, due to poor drainage, was observed frequently on the flat tops of the spoils. These conditions drastically reduced vegetative cover and growth. Overburden material averaged about 13 times as much soluble salts as adjacent undisturbed soils.

8. The overburden material contained a much higher proportion of clay than the adjacent, native soils. Thus, spoil banks were readily eroded and poor drainage conditions usually developed on flat locations. In addition when the soil dried, it formed a very hard surface layer which the young seedlings penetrated with great difficulty.

Part III—GRASS SEEDING RESEARCH

Methods of Study for Grass Seeding Research

The first seeding research on the Kemmerer spoil bank material was initiated in 1965 using intermediate wheatgrass *(Agropyron intermedium)*, pubescent wheatgrass *(Agropyron trichophorum)*, smooth bromegrass *(Bromus inermis)* and crested wheatgrass.

In 1966 these grass species, plus Russian wildrye *(Elymus junceus)* and alsike clover *(Trifolium hybridum)* were seeded on three different aged spoil banks and with various methods of mulching and water supplementation.

In late November, 1967, a seeding trial was initiated using a straw mulch held down with chicken netting. Seedings were made on the tops and on eastern slopes of a three-year and a nine-year old spoil bank using intermediate wheatgrass, crested wheatgrass, and smooth bromegrass. Good seedling emergence was noted on all sites in spring, 1968. Also planted was a seeding trial using native and introduced species collected in the Kemmerer area in summer, 1967. This seeding was planted in the same manner as above on the same two spoil banks, except that these were placed behind snowfence on top of the banks. The species seeded were as follows: intermediate wheatgrass, slender wheatgrass, thickspike wheatgrass, crested wheatgrass, bottlebrush squirreltail, foxtail barley, smooth bromegrass, cheatgrass brome, basin wildrye, Kentucky bluegrass *(Poa pratensis)*, big bluegrass, Indian ricegrass, sweetclover, mountain-mahogany, lanceleaf rabbitbrush, and antelope bitterbrush. Good seedling emergence was noted in the spring, 1968, for all species except Indian ricegrass, sweetclover (*Trifolium* spp.), lanceleaf rabbitbrush *(Chrysothamnus lanceolatus)*, and antelope bitterbrush *(Purshia tridentata)*.

Snowfence Treatment

According to Dyksterhuis (1966) the principle factor limiting plant growth in grassland climates is water. Much precipitation in the Kemmerer area occurs as snow and may be lost through wind and sublimation. However, large snowdrifts occurred behind snowfences near the study area and using snowfences as a means of acquiring a moisture supply for plant growth offered possibilities. Snowfences are usually used to keep an area free of deep snow, but the same types of barrier can be used to increase snow depth for crops or winter sports, or to supplement late summer streamflow from mountainous areas (Martinelli, 1964).

The location of the lee drift (when snow fences are used to create maximum snow depths) often can be adjusted by altering the gap between the bottom of the fence and the land surface. Up to 110 cubic feet of water per linear foot of fence can be accumulated behind snowfences in some instances (Martinelli, 1964). Snowfences should be erected in front of areas to be affected and should run at right angles to the prevailing wind (Jagschitz and Bell, 1966).

Five snowfences were constructed on three, nine, and 15 year old spoil banks and grass species were hand broadcast in the immediate vicinity of these sites so that a comparison could be made between snowfence and adjacent areas without snowfence.

Irrigation Treatment

Supplying moisture for plant growth, other than by snowfence, involved pumping water from pits. Water in the Kemmerer coal field pits was tested and found to be safe for livestock and agricultural purposes.

In June, 1966, irrigated plots were initiated on a nine-year old spoil bank. Four species of grass, intermediate wheatgrass, crested wheatgrass, Russian wildrye and smooth bromegrass, and one legume, alsike clover (Trifolium hybridum) were planted by hand broadcasting. Prior to seeding, the area was harrowed to break the crusted surface of the spoil material. The spoil bank was about 30 feet high, 50 feet wide, and 300 yards long with a relatively flat top and east and west facing slopes. Water from a nearby pit was applied by a sprinkler system at the rate of two inches per hour with applications every four to six hours during a two-day period. Irrigation was repeated during June and July.

Erosion Measurement

Erosion is often a deterrent to revegetation of spoil banks and reclamation cannot be accomplished until the banks are stabilized. There was evidence of considerable erosion on many of the Kemmerer spoil banks, especially those supporting no vegetation. To properly stabilize the slopes, it was necessary to determine the amount and nature of erosion and apply control methods that would be effective for the bank age and slope profile.

Three sites were selected, and five steel posts were placed vertically from the slope top to the bottom on each. Each post was driven into the bank to a pre-determined depth so soil movement from erosion or deposition could be measured. The posts were checked after seven months for deposition or displacement.

Jute Net Treatment

Jute netting was tested as a means of spoil bank stabilization. Thirty by four foot strips of jute netting were placed vertically on spoil bank slopes of all three age groups and with treatments located both behind and adjacent to snowfences (Figure 8). Similar strips were placed on non-sloping areas near the sites to test the value of jute as mulch. Barley straw was added to portions of the 30-foot strips to test the advantage of additional mulch.

Prior to placement of the jute or straw mulch, the entire area was hand broadcast with seed of intermediate wheatgrass, crested wheatgrass, Russian wildrye, and smooth bromegrass.

Figure 8. Jute netting is shown installed on the slope of a nine-year old spoil bank.

Mulch and Net Wire Treatment

Due to the high cost of jute netting, a net wire material also was used to hold the mulch in place. This wire was easier to handle, especially on slopes, and greatly reduced the cost. Wire alone would be useless for soil stabilization. Barley straw was placed under the wire mesh as a mulch. This treatment was not tested for soil stabilization, but was compared with the jute netting-barley straw combination for mulching value (Figure 9).

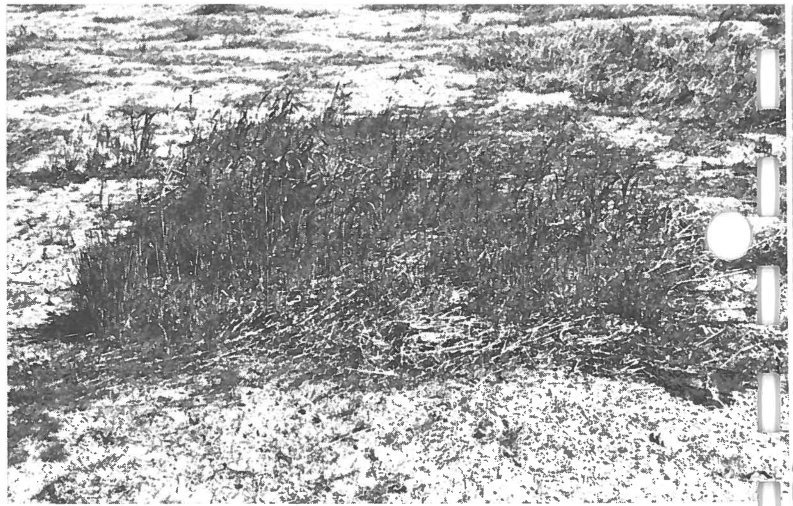


Figure 9. A stand of grass results from a barley-straw mulch held by wire mesh.

Results and Discussion of Grass Seeding Research

A check was made in summer, 1969, of the hand seeded areas, where various species were seeded on three different aged spoil piles. Percentage cover of all species including those which had volunteered is summarized in Table 10.

Snowfence Treatment

During the first winter only three of the six snowfences accumulated a snow pack. The abundance of grass seedlings was greater on plots seeded behind snowfence than on adjacent areas not affected by snowfence (Table 11 and Figures 10 and 11).

Success or failure of snowfence in accumulating snow depended largely on the fence location. Best results were obtained with fences on the leeward side of a sizeable, level, or near level area. On such areas, blowing and drifting snow was sufficient to be trapped behind fences (Figure 12).

Irrigation Treatment

A scattered stand of grass seedlings and small patches of clover were present in August, 1966, on the plot which had been irrigated several times in June. Volunteer species were abundant and seemed to have benefited from the added moisture. Russian thistle, the primary volunteer species, showed good response to irrigation. Being an annual, it was just beginning to initiate growth at the time of irrigation while perennial species were beginning to mature.

TABLE 10. PERCENTAGE COVER OF VARIOUS SPECIES ON THREE DIFFERENT AGED SPOIL PILES WHICH WERE HAND SEEDED IN 1967. DATA PRESENTED WAS COLLECTED IN SUMMER, 1969.

	Spoil age group		
Species	15 years	9 years	3 years
Salsola kali	.33	—	2.66
Agropyron cristatum	3.00	3.00	3.33
A. smithii	13.66	2.66	.66
Hordeum jubatum	1.00	1.33	1.33
Bromus inermis	—	.33	.33
Taraxacum officinale	—	—	1.00
Distichlis spicata var. *stricta*	—	—	.66
Chenopodium album	.33	—	—
Sitanion hystrix	.33	—	—
Trifolium hybridum	—	5.33	—
TOTAL	18.66	12.66	10.00

TABLE 11. AVERAGE SEEDLING NUMBER PER SQUARE FOOT FOR EACH TREATMENT AND AGE GROUP.

	Spoil age group						
	15 years		9 years		3 years		
Treatment	Number of seedlings	Percent of highest number	Number of seedlings	Percent of highest number	Number of seedlings	Percent of highest number	Total seedlings for treatment
Jute-mulch	255	100.00	142	55.68	14	5.49	411
Mulch	240	94.11	105	41.17	—	—	345
Jute	221	86.67	93	36.47	13	5.09	327
Snowfence-jute-mulch	138	54.11	85	32.33	33	12.94	256
Snowfence-jute	110	43.13	83	32.54	18	7.05	211
Snowfence	64	25.09	55	21.56	11	4.31	130
Control	35	13.72	15	5.88	1	0.39	51
Total seedlings for age group	1063		578		90		

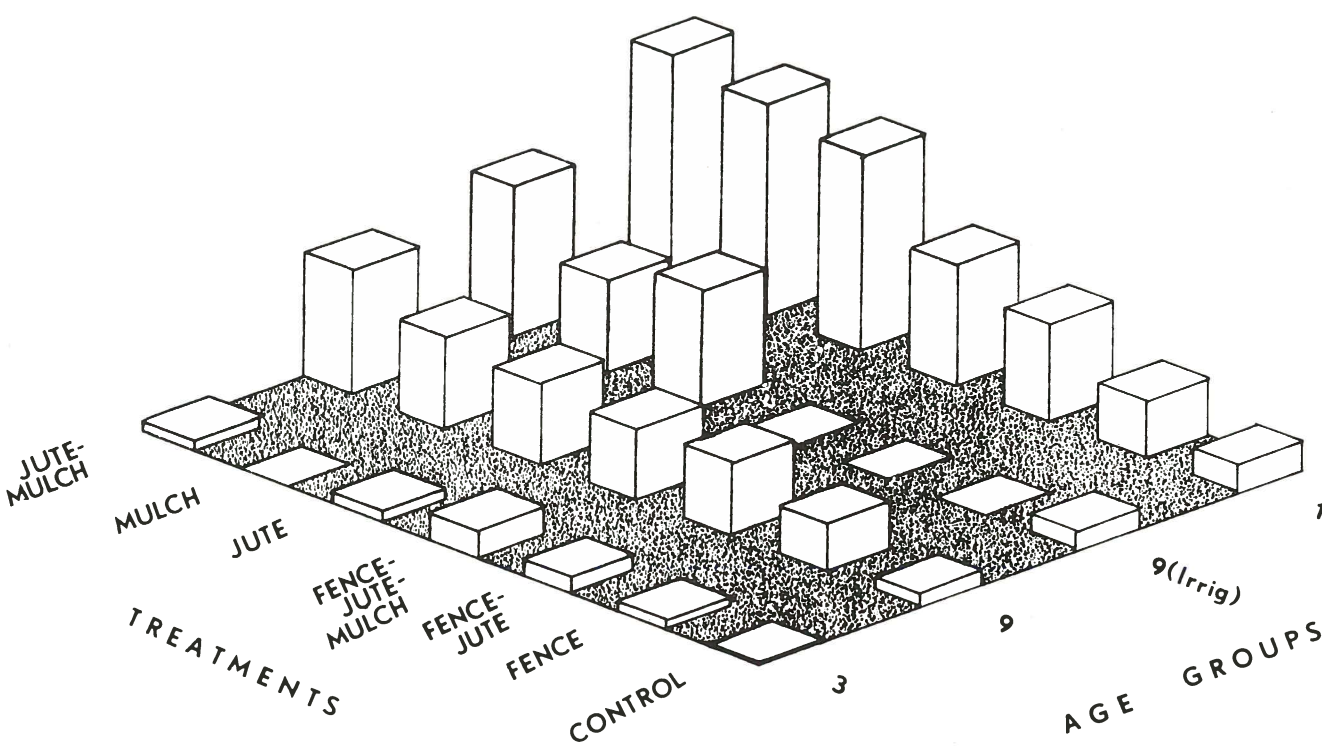


Figure 10. Relative abundance of grass seedlings is shown for different treatments on spoil banks of three ages.

Figure 11. A grass stand was established on the leeward side of a snowfence.

Figure 12. Snow accumulated behind a snowfence during the winter of 1966-67.

By June, 1967, grass seedlings from the preceding summer began to green and by August, 1967, had matured and set seed. Seed from fall, 1966, and early spring, 1967, seedings produced seedlings but did not mature in 1967. Alsike clover produced the best stand of any of the species seeded on the irrigated spoil. Ocular estimates placed this species at 35 percent ground cover in certain areas of the spoil bank.

Irrigation resulted in erosion from running water that would become a major problem if irrigation were used on a large scale. Clay spoil material absorbed water slowly and to a limited depth before it became saturated and runoff occurred. This created special problems for getting adequate moisture penetration on slopes. On the study plot, plant response was limited to the top part of the spoil bank where moisture penetrated deeper than elsewhere on the bank. Little success was obtained from seedings on the slopes.

To obtain conditions suitable for irrigation would require terracing most existing spoil banks. This probably would bring to the surface large amounts of unoxidized spoil material and severely compact the soil setting back revegetation attempts three to five years.

Erosion Measurement

Seven months after installation, steel posts on the three slope sites were checked for spoil bank movement. Results showed that slippage occurred at the top of the spoil bank and deposited material near the base of the slope.

Effects of material displacement on plant establishment were noted near the base of spoil banks where plants often were completely covered by eroded material. This was most noticeable following heavy precipitation. New perennial growth of these plants had to break through a crusted layer of material often as much as five inches deep. Many plants covered with eroded material died. Plant cover never became well developed at the foot of such banks.

Plants on the upper slopes often were killed by having their root systems undercut by water channeling. Whole sections of banks sometimes would cascade downward carrying along plants that might have temporarily stabilized erosion.

From these erosion studies, it became apparent that for revegetation to take place, a spoil bank first needs to be stabilized near the top. This would allow vegetation establishment and the spreading, vegetatively or by seed, down the slope. This also would involve artificially holding the spoil material in place long enough for plants to become well established.

Jute Netting and Mulch Treatments

The use of jute netting was evaluated during the summer, 1967. Unfortunately, the grass seed did not produce large plants and evaluation could be made only from the number of seedlings present.

Jute netting efficiently stabilized erosion on the slopes but was far more effective when supplemented by straw mulch. Without mulch, it allowed some erosion, and on several sites, the jute was partially covered. When jute was placed on the slope crest and extended downslope, it proved effective.

Jute netting, supplemented by barley straw mulch, gave the highest percentage of seedlings on all sites except the three-year old site where snowfence proved superior in influencing seedling number.

Mulch proved to be the most important factor influencing seedling number, even more than snowfence. Snowfence, however, always gave increased seedlings over areas of no treatment. Mulch, jute, and snowfence influenced the amount of soil moisture available for seedling growth.

Economic Consideration of Treatments

Cost considerations are extremely important in reclamation projects and must be considered along with potential results when selecting revegetation treatments. Treatments giving similar results may vary greatly in costs.

When considering costs alone, broadcast seeding without any treatments might be the most sound economical choice. The speed with which the revegetation is to be done, however, may be more important and, therefore, the deciding factor. Actual revegetation costs vary greatly with the amount of area to be treated. Treatments most similar to those used at Kemmerer are seeding and mulching operations conducted by the Wyoming Highway Department. Table 12 shows costs of seeding, jute, and mulch on Wyoming highways during 1966. Per unit costs normally decreased with increased number of units as would be expected.

Table 13 gives the approximate costs of material used in test plots at the Kemmerer

TABLE 12. COSTS OF SEEDING, MULCH, AND JUTE NETTING ON WYOMING HIGHWAYS IN 1966*.

Operation	Highway type	Unit	Total quantity	Average bid price
Dry mulch	Federal interstate	Ton	3,172	38.10
Dry mulch	Federal interstate	Ton	320	48.72
Dry mulch	Combined Federal	Ton	3,492	39.07
Dry mulch	State	Ton	365	42.67
Jute netting	Federal interstate	Sq. yd.	136,400	.53
Jute netting	State	Sq. yd.	2,520	.46
Seeding of	Federal interstate	Acre	2,576	33.15
Agropyron	Federal primary	Acre	507	41.46
cristatum	Federal secondary	Acre	300	28.70
	Combined Federal	Acre	3,383	34.00
	State	Acre	240	32.99

*Based on weighed average bid prices.
Data courtesy of Wyoming Highway Department.

TABLE 13. COMPARATIVE INDIVIDUAL TREATMENT COSTS PER ACRE FOR SEEDING, MATERIAL AND LABOR.

	Cost in dollars			
Treatment	Seed cost	Material	Man hours @ $1.25/hr.	Total (per acre)
Jute-mulch	15	1,488.30	91.25	1,594.55
Mulch	15	181.50	91.25	287.75
Jute netting	15	1,306.80	68.43	1,390.23
Snowfence-jute netting				
Mulch	15	1,628.30	199.68	1,842.98
Fence-jute netting	15	1,446.80	108.43	1,570.23
Snowfence	15	140.00	40.00	195.00
Control	15	0.00	2.50	17.50

research site. The costs are based on retail costs of material, purchased in small lots for small scale tests. Material in larger quantities would probably result in lower costs per unit.

Summary and Conclusions for Grass Seeding Research

Summary

A study area composed of coal strip-mined overburden was selected for revegetation studies. Initial goals were to determine grass and forb species best adapted to conditions existing on spoil banks and to simultaneously test mulching and irrigation treatments to determine their effect on stand.

Grass species tested included crested wheatgrass, intermediate wheatgrass, Russian wildrye, and smooth bromegrass. Alsike clover was used on an irrigated treatment.

Treatments included jute net, barley straw, mulch, snowfence, irrigation, and combinations of these. Treatments were nonreplicated on overburden piles of three ages: three, nine, and 15 years old. It was attempted to determine the best age of a spoil bank on which to initiate seeding. The degree of erosion stabilization and number of established plants formed the basis for evaluation.

Conclusions

(1) Available moisture was a principal limiting factor in plant establishment but this could be supplemented by snowfences and irrigation from nearby permanent ponds. Snowfence was effective only when placed on the leeward side of large, open, level areas.

(2) Mulch, necessary for good seedling establishment, required some means of holding it in place. Annual plants grown for a nurse crop served both as mulch and for erosion control but they in turn depended on ample precipitation for optimum growth.

(3) Jute netting served as a means of erosion control and as a partial mulch. Stabilization of erosion was a pre-requisite for successful revegetation on slopes.

(4) Seedling survival increased with length of weathering period of the spoil pile. Some sites required two years following planting to establish a good perennial grass stand. Annual plants responded more quickly.

(5) With irrigation, alsike clover became well established on a spoil bank nine years old.

(6) For an economically sound revegetation program, spoil banks should be accessible by machinery for seeding and mulching.

(7) Some spoil bank tops revegetated voluntarily within fifteen years. Slopes did not revegetate until stabilized from erosion. Time required for natural revegetation depended entirely on climatic, edaphic, and biotic factors present at the individual sites.

Part IV—GRASS TRANSPLANTING RESEARCH

Methods of Study for Grass Transplanting

Two types of transplanting, sprigging and sodding were studied on the Kemmerer spoil banks. Sprigging involved planting rhizomes (underground stems) and sodding involved planting chunks of sod in which the desired species were rooted. With these techniques mature plants and a solid ground cover should be produced more rapidly than by seeding.

Species Planted

Western wheatgrass and inland saltgrass were used in the transplanting studies.

Western wheatgrass is a perennial, native, cool-season grass which reproduces by rhizomes and seed. It usually initiates growth in early spring, and maximum growth occurs during the cool season. Seed is formed in June or July and the grass goes dormant in late summer. This grass grows one to three feet high and is easily identified by its bluish stems and leaves. The blade has obvious, raised, harsh veins on the upper surface, which feel rough when pulled between the fingers.

Western wheatgrass is widely distributed in North America. It is adapted to a wide range of soils but seems to grow best on alkaline soil. This grass, fairly drought resistant, often forms pure stands in low places and on bottom lands. It is considered a palatable, nutritious grass for both cattle and sheep and furnishes good green pasture for spring, early summer, and fall grazing. It is classed as a decreaser in that, under conditions of overgrazing, it tends to be replaced by less desirable species. Western wheatgrass, maintained in a vigorous condition, is effective for moisture conservation and erosion control (Callantine, 1951).

Inland saltgrass is a perennial, native, warm-season shortgrass with vigorous scaly rhizomes. Growth begins in April and seed is produced from July to September. Saltgrass grows mostly in alkaline or salty soils in all states west of the Mississippi River. It is a rather harsh, rough grass with little palatability for livestock unless grazed early in the season. This grass is classified as an increaser under heavy grazing. Saltgrass has been successfully established from sod chunks.

Planting Procedure

Planting material of Western wheatgrass was collected from a pure stand about a mile north of the strip mine area. The inland saltgrass material was collected from a pure stand three miles north of Sage Junction, about 20 miles west of Kemmerer.

Large chunks of sod from these pure stands were taken to the planting sites. Pieces approximately four inches square were cut from the large chunks of sod and planted level with the surrounding surface.

Individual rhizomes, usually with live blades or shoots above ground, were separated from the large chunks, and planted as soon as possible. A slit four to six inches deep was made in the spoil material and the rhizome placed in it with the shoot or blade above ground. Overburden material was then firmed around the rhizome.

On the top exposures each replication consisted of four rows of five plants spaced approximately one foot apart. On the eastern exposures replications were planted in two rows of ten. These rows were placed horizontally several feet below the crest of the overburden piles.

Treatments

Treatments for the two grass species were as follows: (1) plantings at different times of year, (2) plantings using both the sprigging and sodding technique, (3) plantings on different ages of overburden piles, (4) plantings on top and on east-facing slopes of the piles, and (5) plantings with and without snowfences.

Two planting sites were chosen in June, 1967. One was a nine-year old and the other was a three-year old overburden pile. On each site 20 clumps of sod and 50 rhizomes of each grass were planted (1) on top of the pile without snowfence, (2) on top of the pile behind snowfence, (3) on eastern slopes without snowfence and (4) on eastern slopes behind snowfence. This totaled 320 clumps and 800 rhizomes planted on the two sites.

During the fourth week of August, 1967, two new sites were chosen, a ten-year old and a two-year old overburden pile. The same planting plan used in June was repeated on the two new sites except that rhizome numbers were cut from 50 to 20 making a total of 320 clumps and 320 rhizomes on the two sites.

In April, 1968, the August, 1967, planting was repeated on the same two and ten-year old overburden piles. Again 320 clumps and 320 rhizomes of the two species were planted.

Survival Check

During August in 1968 and 1969, all plantings were checked for survival. Notes also were taken on vegetative spreading and seed set.

Soil Samples

Soil samples taken on the four study sites, on two undisturbed sites, and on the two areas where planting materials were collected were given limited chemical analyses.

Soil Moisture Readings

Soil moisture was determined each month during the summer, 1968, at the four study sites, two undisturbed sites, and the two plant collection areas. Determinations were taken with a neutron probe at six-inch intervals down to a depth of four feet. At the two, three, and ten-year old sites two access tubes were placed on the top, two at the crest of the slope, and two on the eastern slope. In each location one was affected by a snowfence and one was not. On the nine-year site, positioning of the snowfence made it possible to place tubes only on the top and on the east slope for a total of four. Three access tubes were placed at each of the two undisturbed areas. One access tube was placed at each of the two native stands where planting material was collected.

Results and Discussion of Grass Transplanting Studies

Percent Survival

Percent survival was used as the criteria for success in this study. Any plant showing green growth, regardless of its condition, was considered alive.

Table 14 shows percent survival by species and planting site, method, date, and treatment. Living plant counts were made in August, 1968 and 1969.

As can be seen from Table 14, western wheatgrass clumps had a higher survival percentage than inland saltgrass clumps with the exception of the August, 1968, planting. Survival of inland saltgrass from this date of planting was up to 50 percent on the top exposure with snowfence at the two-year old site while western wheatgrass showed no survival under any treatment or site. In general survival was the greatest on the top exposures and behind snowfences. For rhizomes, western wheatgrass showed greater survival than inland saltgrass

TABLE 14. PERCENTAGE SURVIVAL BY SPECIES, SITE, METHOD, TIME AND TREATMENT OF PLANTING DETERMINED THE FIRST WEEK OF AUGUST, 1968 AND AUGUST, 1969.

Age of site (years)	Planting date	Top no snowfence 1968	Top no snowfence 1969	Top snowfence 1968	Top snowfence 1969	East slope no snowfence 1968	East slope no snowfence 1969	East slope snowfence 1968	East slope snowfence 1969
Agropyron smithii rhizomes									
3	June 1967	36	30	42	40	32	25	66	50
9	June 1967	4	2	12	10	0	0	2	0
2	August 1967	0	0	0	0	0	0	0	0
10	August 1967	0	0	0	0	0	0	0	0
2	April 1968	80	70	90	80	35	20	100	95
10	April 1968	45	40	75	75	10	0	75	70
Distichlis spicata rhizomes									
3	June 1967	14	12	40	35	4	4	8	5
9	June 1967	15	15	0	0	0	0	0	0
2	August 1967	0	0	0	0	0	0	0	0
10	August 1967	0	0	0	0	0	0	0	0
2	April 1968	0	0	5	0	0	0	0	0
10	April 1968	0	0	15	10	0	0	5	0
Agropyron smithii clumps									
3	June 1967	100	95	95	95	60	60	95	90
9	June 1967	85	85	90	90	5	0	10	5
2	August 1967	0	0	0	0	0	0	0	0
10	August 1967	0	0	0	0	0	0	0	0
2	April 1968	50	50	90	90	30	30	85	80
10	April 1968	80	80	85	80	35	30	65	65
Distichlis spicata clumps									
3	June 1967	95	90	95	95	75	75	45	45
9	June 1967	25	25	15	15	0	0	0	0
2	August 1967	20	20	50	50	30	30	40	40
10	August 1967	35	30	10	10	0	0	0	0
2	April 1968	25	20	55	50	30	30	30	30
10	April 1968	90	90	45	40	15	15	5	5
Site Average		32	31	38	36	15	13	26	24

Percent survival shown for all treatment columns.

but there was no survival of either species from rhizomes planted August, 1967.

In most cases sodding proved superior to sprigging although it required more planting material. The time spent preparing material for sodding, however, was much less than for sprigging. The most successful site and time was the three-year old site planted in June, 1967, followed by the two-year old site planted April, 1968. The least successful site and time were the two and ten-year old sites planted August, 1967.

The effect of site and snowfence can be seen if the four treatment columns of Table 14 are added and averaged. Tabulation for 1968 showed 32 percent survival on top exposures without snowfence, and 38 percent on top exposures with snowfence. On the eastern slope, survival percentages were 15 without snowfence and 26 with snowfence. The 1969 survival percentages were 31, 36, 13 and 24 for the four sites respectively.

Soil Moisture

A general relationship between soil moisture and survival may be noted from Table 15. The higher the soil moisture the higher the survival percentages. More soil moisture was present on tops of overburden piles than on the slopes. Soil moisture was not always higher behind snowfences but survival percentages usually were higher at these locations. This fact may be accounted for by higher soil moisture in early spring just after the snowbanks melted and when plants were initiating growth, or by snowfences slowing the wind velocity producing milder environments and lowering winterkill.

The nine-year old site which was planted at the same time as the three-year old site had the lowest average soil moisture and showed the lowest survival percentages (Table 15). During the summer of 1966 the top of the nine-year old pile was harrowed and irrigated with a sprinkler, which compacted the soil and lowered the water infiltration rate. Compaction could be noted by walking over the pile and was especially apparent when drilling holes for soil moisture access tubes. Also water stood in the low spots after a rain much longer than at the other sites which had not been harrowed or irrigated.

TABLE 15. MOISTURE CONTENT OF THE FIRST 18 INCHES OF SOIL BY SITE AND TREATMENT AS COMPARED WITH OVERALL PERCENTAGES

Age of site	Planting date	Treatment	Average inches of soil moisture June to August 1968		Percent survival August 1968	
3	June 1967	Top, no snowfence	3.71		60	
3	June 1967	Top, snowfence	4.17		68	
3	June 1967	East slope, no snowfence	4.22		43	
3	June 1967	East slope, snowfence	3.77		54	
	Average—all treatments		3.97		56	
	Average—with snowfence			3.97		61
	Average—without snowfence			3.97		52
9	June 1967	Top, no snowfence	2.68		34	
9	June 1967	Top, snowfence	2.32		31	
9	June 1967	East slope, no snowfence	2.14		1	
9	June 1967	East slope, snowfence	2.07		3	
	Average—all treatments		2.30		17	
	Average—with snowfence			2.20		17
	Average—without snowfence			2.41		17
2	April 1968	Top, no snowfence	2.63		39	
2	April 1968	Top, snowfence	2.71		60	
2	April 1968	East slope, no snowfence	2.49		24	
2	April 1968	East slope, snowfence	2.69		54	
	Average—all treatments		2.63		44	
	Average—with snowfence			2.70		63
	Average—without snowfence			2.56		32
10	April 1968	Top, no snowfence	3.46		54	
10	April 1968	Top, snowfence	2.58		55	
10	April 1968	East slope, no snowfence	2.62		15	
10	April 1968	East slope, snowfence	2.92		38	
	Average—all treatments		2.90		40	
	Average—with snowfence			2.75		47
	Average—without snowfence			2.54		35

Precipitation

The most important factor influencing plant survival was the amount of precipitation at and immediately after planting. Figure 13 shows the precipitation by month for 1967 and 1968 and the 30-year average. During June, 1967, nearly 3.25 inches of rain was recorded. This is reflected in the 56 percent overall plant survival on the three-year old site. Low survival on the nine-year old site has already been explained by compaction and low infiltration rate. The very poor survival rates from the August, 1967, planting can be explained by the fact that there was almost no rain at that time and late summer temperatures were high. Although precipitation was below normal during and immediately after the April, 1968, planting, temperatures were cool and June rainfall was above normal. Some survival rates for this planting date were above 40 percent.

Soil Temperatures

Six soil temperature readings were taken at each of the four study sites within a two-hour period during mid-day in late August, 1968. Readings at each site were averaged and plotted on a graph against percent survival (Figure 14). The graph shows a positive relationship between survival and temperature at the various sites.

The high soil temperature on the three-year site may be attributed to material being dark colored from coal mixed in the spoil. Coal absorbs heat and this coal, in places, was still oxidizing and giving off heat.

Ludwig and Harper (1958), experimenting with maize grown on plots with darkened surfaces, concluded that higher and quicker seedling emergence and accelerated growth in darkened soil was due to the manner in which the soil absorbed and emitted solar radiation.

Soil temperatures were several degrees higher on the eastern slopes than on tops of the spoil piles although this did not affect plant survival. It was noted, however, that inland saltgrass on the eastern exposure of the three-year site flowered nearly two weeks earlier than saltgrass on the top of the spoil pile.

Spread

Only the June, 1968, planting was studied for spreading of the grasses. Most of the four-inch sod cubes had at least doubled in size at the end of one year and were in a vigorous growing condition.

Figure 15 shows a single sod clump of inland saltgrass that had spread over one foot in two directions in a year. This clump was dug and found

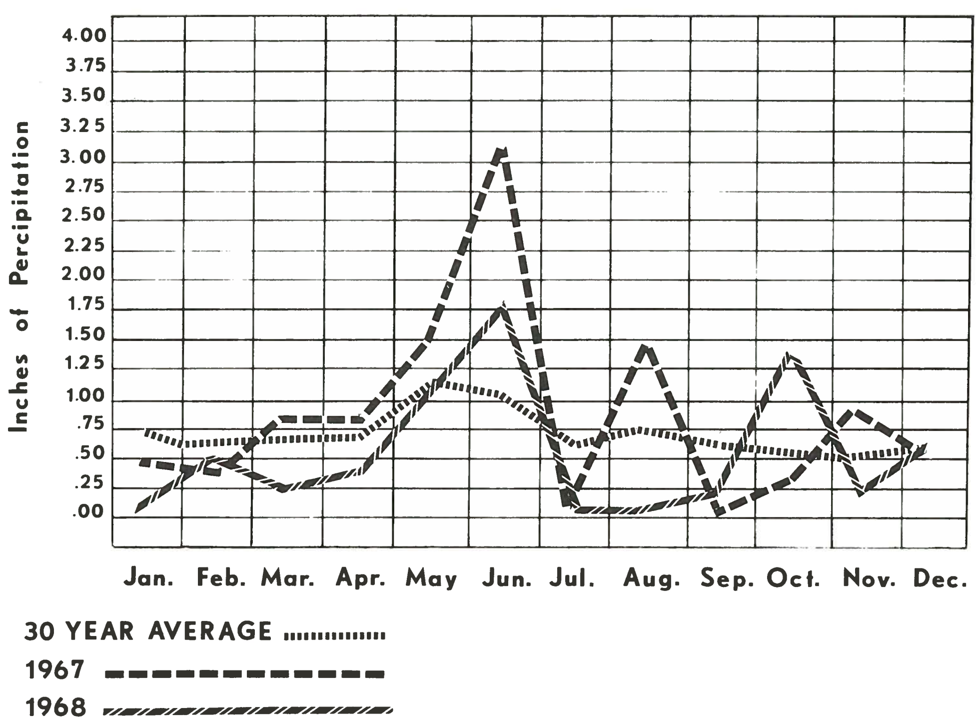


Figure 13. Monthly precipitation for the years, 1967 and 1968, and a 30-year average at Kemmerer, Wyoming, was tabulated.

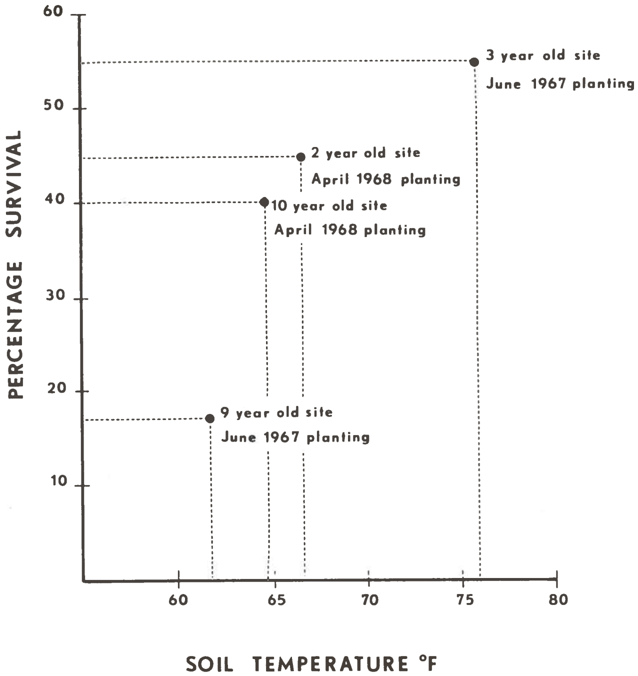


Figure 14. The relationship between soil temperature and percent seedling survival on various sites at the Kemmerer, Wyoming, strip mine spoil banks is shown.

Figure 15. A single clump of inland saltgrass has spread over one foot in two directions in one year.

to have a rhizome over three feet long (Figure 16) which grew to a depth of 18 inches in the overburden material. Grass shoots like those shown in Figure 15 appeared throughout the plot, and it was likely that they would produce a solid stand of inland saltgrass in the next few years.

Associated Species

Several plant species were included in the sod clumps at the time the planting material was collected. These were still growing with the two planted grass species. Bottlebrush squirreltail, plantain (*Plantago* spp.) and meadow barley (*Hordeum brachyantherum*) were the most common species transplanted with the inland saltgrass and western wheatgrass clumps.

Summary and Conclusions for Grass Transplanting Research

Summary

Four study sites on different aged coal strip mine overburden were chosen for revegetation studies. The objective was to test sprigging and sodding techniques for establishing western wheatgrass and inland saltgrass on different aged spoil piles.

Methods used were planting: at different times of year, by sprigging and sodding, on different aged overburden piles, on tops and on east-facing slopes of piles, and behind and not behind snowfences.

Conclusions

(1) Both western wheatgrass and inland saltgrass adapted to vegetative establishment on overburden piles. Western wheatgrass seemed to be the better adapted of the two although inland saltgrass spread more vigorously on favorable sites. Also, inland saltgrass was better adapted to planting during dry weather.

Figure 16. An inland saltgrass rhizome has grown laterally more than three feet and to a depth of 18 inches in one year.

(2) The best time of year to plant was in spring. Early fall planting proved least successful. Late fall planting was not tested.

(3) Sodding produced far better results than did sprigging. Roots within sod clumps stayed moist and were protected by the surrounding soil whereas in sprigging, roots were damaged and moisture was lost from plants being prepared for planting.

(4) Age of overburden material did not affect planting success. The younger piles showed higher survival rates than did older piles which was the reverse of results obtained from other studies conducted on this overburden material.

(5) Planting on top of overburden piles as opposed to the east facing slopes gave better results because infiltration of precipitation and soil moisture were greater on the tops.

(6) Planting behind snowfence resulted in slightly better survival because of early spring snow melt behind the fences and the wind break provided by the snowfence. It is doubtful if the slight advantages caused by the snowfence was worth the added cost.

The most limiting factors influencing vegetative establishment was the amount of precipitation received just before, during, and immediately after planting and the amount of moisture in the spoil material at planting time.

Overall Summary and Conclusions

1. Ample moisture at planting and during establishment was critical for stand success with seeded grasses, planted trees and grass sod or sprigs. Irrigation and/or the use of snowfences to accumulate extra moisture increased the percentage stand establishment of all types of vegetation.

2. Older spoil piles were better sites for establishing seeded grasses than younger ones. Age of the spoil pile, however, had little effect on establishment of grasses by sodding.

3. Russian olive and caragana were the best adapted tree species tested and the top part of east and northeast facing slopes were the best sites for their establishment.

4. Intermediate and crested wheatgrass appeared to be the best adapted of the cool season grass species seeded. The most satisfactory stands of all species were obtained where mulch with some type of netting to hold it in place was used with the seeding or where the seeding received additional moisture benefits from being on the lee side of a snowfence.

5. Sodded grasses were most effectively established on the flat top of the spoil piles whereas tree species and seeded grasses were more effectively established on northeast and east facing slopes.

6. Nitrogen fertilization did not significantly affect establishment of either grasses or trees.

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N. W. Hilston, Dean and Director
Agricultural Experiment Station
University of Wyoming, Laramie 82070

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