REVEGETATION OF COAL STRIPPED LAND NEAR HENRYETTA, OKLAHOMA

SISTER M. MARIAN MALONEY, O. S. B., Catholic College, Guthrie

The ecological study here reported is the result of an investigation of the natural revegetation of a bare area, which was produced by a disturbance of soil when, in strip mining for coal, the raw subsoil was brought to the surface and greatly mixed by the use of a steam shovel.

This coal stripped area, popularly known as the "strip pits", is approximately one and a quarter miles east of Henryetta in Okmulgee County, Oklahoma. In the early part of 1900 Mr. Marler undertook the stripping of the mine using teams of horses and scrapers for the work. He was followed by a Mr. Scott, who continued the work in the same manner. Later, John Paterson took over the mine and, a few years before the first World War, engaged Mr. Crow to complete the work with a steam shovel as large, and similar to, those used in digging the Panama Canal.

In digging the pits, the dirt was shoveled to one side, forming high narrow mounds of shale 50 to 60 feet high. The dirt from each succeeding pit was dumped into the previous one, the last pit alone remaining unfilled. This pit, about 70 feet deep, is today filled with water, which comes from a small creek at the south end of the mine and is very hard.

Previous to the stripping 40 years ago, this land was of the rolling prairie type characteristic of the region around Henryetta. It consisted of a well cultivated farm of 160 acres, only 80 of which were stripped for coal. At the present time the formerly cultivated farm, having been abandoned, has reverted to a mixed grass prairie of short and tall grasses with a few herbs.

No particular study was made of this abandoned area. The present study of the denuded area was begun in September 1940. Weekly or biweekly field trips were taken to this old mine, the weather permitting, until the latter part of November, but were resumed in March and continued through May 1941.

Today, this once rolling prairie presents a somewhat different view with its row after row of dumps, almost geometrical in their regularity, extending for several hundred feet in a northwest-southeasterly direction. Most of these ridges are entirely bare; some are covered with a short stoloniferous grass, which seems completely to have died out and therefore to be impossible to identify; others are sparsely covered with cocklebur, *Xanthium commune*. Here and there almost full grown trees are found growing singly on the top or steep sides of some of the mounds. The greater number of these trees are elms, *Ulmus americana*, with sycamores, *Platanus occidentalis*, cottonwoods, *Populus deltoides*, and persimmons, *Diospyros virginiana*, listed in the order of their frequency. The east sides of a few mounds are covered with dense growths of dewberries, *Rubus villosus;* others are entirely covered with species of sumac, *Rhus glabra* and *Rhus copallina* var. *latifolia*. Near the south end of the strip pits, where the depressions between the ridges are not so deep, the growth of trees and shrubs is more dense. Wild grapes, *Vitis aestivalis* and *Vitis cordifolia*,

FIG. 1. The first mound.

FIG. 2. Central part of the mine.

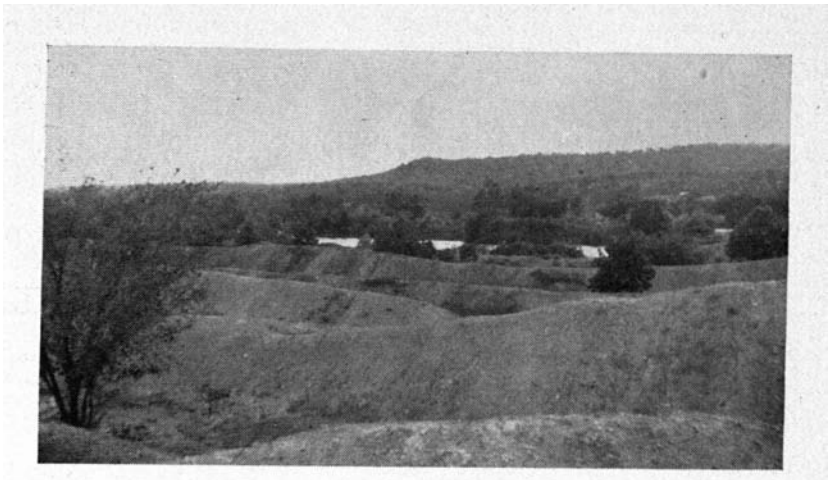

FIG. 3. Region adjoining the one in figure 2; the water is in the last pit.

woodbine, *Psedera quinquefolia*, and poison ivy, *Rhus toxicodendron*, are well established in this place.

The first mound shown in figure 1 appears to be the highest, but the top of it is on a level with the others; the depression between the first two ridges is much wider than between the others.

As may be seen from figure 2 the most dense growth of trees and shrubs is in that part of the mine which is nearest the creek along the end of the first two or three spill banks. In figure 3 young willows, *Salix nigra*, elms, *Ulmus americana*, and cottonwoods, *Populus deltoides*, may be seen growing along the water's edge of the last pit. These trees are much younger than those of the first stripped area. Ridges of the middle region show only a few widely scattered shrubs or small trees.

Since the deposits which were removed in order to obtain the coal are composed chiefly of subsurface materials, and because of the fact that the use of a steam shovel would greatly mix these materials, it was deemed best to have soil samples analyzed. Consequently composite samples from six areas devoid of vegetation were sent to Dr. Horace J. Harper, Professor of Soils, Oklahoma A. & M. College, Stillwater, for analysis. Soil was taken from the surface and from a depth of 12 to 18 inches in each place.

In correspondence with Dr. Harper, the following facts were brought out:

> "These analyses show that the undisturbed shale contained iron sulfide. Weathering has decomposed this material forming sulfuric acid and iron oxide. The sulfuric acid has produced a very acid soil; consequently only an acid-tolerant type of vegetation with low plant nutrient requirement should be found on this area. The results of the nitrogen and organic matter determinations cannot be interpreted in terms of normal soil. Shales associated with coal deposits would be expected to contain organic residues which resist further decay as a result of their long exposure to an anaerobic en-

vironment. The very low quantity of available phosphorus in these samples would indicate that very little growth of commercial plants should be expected. Since a small quantity of soluble sulphate can be extracted with distilled water, all of the iron sulfide (pyrite) may not be completely oxidized. The high organic matter value in the subsoil of 6B is probably an error due to the action of chromic acid on the iron sulfide still remaining in this sample."

The results of the chemical analyses are given in table I.

TABLE I

Chemical studies of soil material from strip pits.

No.	Depth	pH	Total nitrogen	Total organic matter	Easily soluble phosphorus[1]	Water-soluble material[2]	
						Calcium	Sulphates
	in.		%	%	%		
1A	0-12	4.2	0.105	1.25	0	Low	Low
1B	12-18	4.0	.09	1.45	0	Low	Low
2A	0-12	4.2	.105	1.64	0	Low	Low
2B	12-18	3.75	.13	1.64	0	Medium	Medium
3A	0-12	4.1	.084	1.58	0	Low	Low
3B	12-18	3.8	.1	1.56	0	Low	Low
4A	0-12	4.1	.116	1.75	0	Low	Low
4B	12-18	3.85	.093	1.64	0	Medium	Medium
5A	0-12	4.1	.081	1.40	1	Low	Medium
5B	12-18	3.9	.081	1.46	0	Medium	Medium
6A	0-12	4.0	.093	1.81	0	Low	Low
6B	12-18	4.0	.105	3.88	0	Low	Low

[1]Soil leached with 0.1 N acetic acid.
[2]Semi-quantitative test on a 1 to 10 water extract.

In the writer's opinion there is no error in 6B of table I, because this soil sample was taken in the lowest depression (not filled with water) between the first two large mounds, one of which had a good stand of trees and shrubs growing on it. Although there were no plants in the area from which this particular sample was taken, the fact that during a rain the water running down from these dumps into the depression would carry with it some organic matter and deposit it there, probably accounts for the high organic matter value of 6B.

In carrying out the study of the revegetation of this denuded area, an attempt was made to identify all the plants growing there at the present time. All accessible plants, with the exception of the grass mentioned earlier in this paper, were collected. All identifications were verified by Dr. Milton Hopkins, Department of Botany, University of Oklahoma, from the preserved specimens, which at present are in the herbarium of the Catholic College of Oklahoma.

The plants collected have been listed in table II in the order of their frequency as ubiquitous, very common, common, rare, very rare, and escapes. Of those listed under the column "rare" only three or four specimens of each were found, while of those listed "very rare" a single specimen of

Table II

Relative frequency of plants collected from strip pits.

Ubiquitous	Very common	Common	Rare	Very rare	Escapes
Ulmus americana L.	*Platanus occidentalis* L.	*Salix nigra* Marsh.	*Quercus schumardii* var. *schneckii* (Brit.) Sarg.	*Cercis canadensis* L.	*Prunus persica* (L.) Stokes (Peach tree)
Xanthium commune Britton	*Populus deltoides* Marsh.	*Ulmus alata* Michx.	*Prunus serotina* Ehrh.	*Fraxinus pennsylvanica* Marsh.	
	Diospyros virginiana L.	*Crataegus spathulata* Michx.	*Quercus marilandica* Michx.	*Juglans nigra* L.	
	Rhus glabra L.	*Vitis aestivalis* Michx.	*Crataegus invisa* Sarg.	*Carya glabra* (Mill) Spach	
	Rhus copallina L. var. *latifolia*[1]	*Vitis cordifolia* Michx.	*Fraxinus pennsylvanica* var. *lanceolata* Sarg.	*Prunus mexicana*[1] Wats.	
	Rubus villosus Ait.	*Psedera quinquefolia* (L.) Greene	*Amorpha fruticosa* L.[1]	*Carya pecan* (Marsh) Engler & Groebn.	
	Verbena canadensis (L.) Britton	*Smilax rotundifolia* L.	*Rhus toxicodendron* L.	*Typha latifolia* L.	
		Symphocarpos orbiculatus Muench	*Acerates viridiflora* Ell.[1]	*Juncus setaceus* Rostk.	
		Phytolacca decandra L.	*Asclepias variegata* L.	*Rumex hastatulus* Baldw.	
		Oxalis grandis Small.	*Callirhoe alcaeoides* Michx.	*Daucus pusilla*	
		Erigeron ramosus (Walt.) BSP	*Bellis integrifolia* Michx.	*Lithospermum angustifolium* Michx.	
			Polygonum lapathifolium L.		
			Vernonia glauca (L.) Willd.		
			Apocynum cannabinum L. var. *hypercifolium* (Ait.) Gray		
			Cacalia tuberosa Nutt.[1]		
			Eupatorium serotinum Michx.[1]		
			Rudbeckia hirta L.		

[1]Identified by Dr. Milton Hopkins, University of Oklahoma.

each was found, as was also the lone peach tree in the last column, which undoubtedly was introduced into the region as the result of a peach pit's having been dropped there.

From table II it will be seen that the majority of the plants are trees and shrubs. This is to be expected since they grow with less nitrogen than grasses and other types of vegetation which require a higher state of soil fertility. The cat-tails, *Typha latifolia*, were found growing on a submerged ledge of the last pit. There were no other water plants in this pit because the sides are almost perpendicular. The rush, *Juncus setaceus*, was found in a muddy depression between two ridges near the center of the mine.

Most of the trees are nearly full grown; a few are young trees about half grown, but there are no young seedlings to be found. These larger trees may have arisen from plant parts which, in the process of digging the pits, could have been buried and later, if conditions were favorable for growth, taken root, and continued to grow. There is the alternate possibility that these plants were introduced to a particular area as seeds or seedlings when the creek was at flood stage, and probably became well established before the soil became too acid, that is, shortly after the stripping. None of the trees or shrubs appeared to be stunted in any way.

On the other hand all the herbs are undersized and stunted, showing the lack of some of the necessary plant nutrients. With the exception of the cockleburs, *Xanthium commune*, there are no aggregations. Most of the herbs are found growing singly and are widely scattered.

Ulmus americana is the present dominant with *Platanus occidentalis* and *Populus deltoides* as subdominants, and *Diospyros virginiana* is very prolific in comparison with other species. But it will be many years before a climax formation is reached in this particular area, for only plants which grow in soil low in plant nutrients will be able to exist here, and the physical conditions during growth are too severe for most of the migrants over a long period of time in a primary succession of this kind.

SUMMARY

Forty years ago an area of land of typical prairie formation was stripped of the surface soil in order to mine coal. A steam shovel used in the work greatly mixed the soil, depositing deep subsoil materials on the surface. This shale contained a great quantity of iron sulfide, which upon being exposed to the action of air and rainfall produced a very acid soil.

Vegetation at the present time consists mainly of trees and shrubs, which are more numerous near water sources, and a few herbs widely scattered over the area.

It is evident that only a vegetation composed of plants having an extensive root system which are acid-tolerant and which grow with a minimum of nitrogen will reach a climax formation in this region. In making suggestions for the possible rehabilitation of this area a statement from correspondence with Dr. Harper is noteworthy:

> "It will be interesting to add a liberal application of lime to the land in order to observe the changes in vegetative cover which might appear. It will require at least four or five tons per acre to

change the present environment to a condition which would be favorable for calciferous plants."

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