A CHRONOSEQUENCE OF VEGETATION AND MINESOIL DEVELOPMENT ON A TEXAS LIGNITE SURFACE MINE[1]

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Abstract.--Unreclaimed mined sites ranging in age from 1-50 years were sampled to evaluate vegetation and minesoil changes with time, and compared to an adjacent unmined area. One-year-old, unreclaimed mined areas had very sparse vegetation dominated by weedy species. Herbaceous plant cover increased on mined areas that were 5, 10, and 15 years old, and reached a peak on 20-year-old mined sites. On mined sites older than 20 years, shrub and tree canopies began suppressing understory species. Shrub and tree species were observed on mined areas as early as 5 years after mining, but shrub and tree cover did not become substantial until 20 to 30 years after mining. A multi-layered tree and shrub vegetation structure dominated the 50-year-old site. Compared to native soils of the area, minesoil pH increased from 5.9 to 6.9 shortly after mining then dropped to 3.8 during the next 5 years due to weathering and release of acidic ions. Continued weathering and pyrite oxidation caused minesoil pH to remain at this level for approximately 30 years. Minesoil pH of the 50-year-old site was 6.8. Bulk density of minesoils in the surface 12 cm declined with time as vegetation, litter, and organic matter increased on the site. A similarity index revealed the intermediate-aged mined sites (5, 10, 15, and 20) were similar in plant species composition. Vegetation establishment and development on these different-aged mined sites followed several models of ecological succession: initial floristics model (plants reach disturbed areas as a result of chance and remain until other plant species become more competitive for resources), tolerance model (each individual plant species possesses characteristics or mechanisms which make it adapted to the site), and relay floristics (some plants ameliorate the site and fascilitate establishment by other species).

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INTRODUCTION

Natural plant succession and minesoil development on unreclaimed areas after disturbance have been reported in Minnesota (Leisman 1957), Wisconsin (Kimmerer 1984), Montana (Schafer et al. 1980, Schafer and Nielsen 1979, Sindelar 1979), Iowa (Glen-Lewin 1979), Illinois (Croxton 1928), Indiana (Byrnes and Miller 1973), Ohio (Bell and Ungar 1981), Pennsylvania (Bramble and Ashley 1955, Brenner et al.

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1984), West Virginia (Smith et al. 1971), Kentucky (Thompson et al. 1984), Missouri (Game et al. 1982), and Oklahoma (Gibson et al. 1985, Johnson et al. 1982). Most of these studies have attempted to evaluate the plant species and communities that established and developed on the disturbed area, and to assess the influence of soil properties on plant community development.

The Sandow Mine in Milam County, TX, began surface mining for lignite in 1918. The mining operation closed in 1920, reopened in 1924, and closed again in 1948. The mine was reopened by the Aluminum Company of America in 1953 and has continued to mine lignite to the present day. A number of areas on the Sandow Mine were mined during the past several decades prior to the enactment of State (Texas Surface Mining and Reclamation Act of 1977) and Federal (U.S. Surface Mining Reclamation and Control Act of 1977) regulations, and were undergoing natural revegetation.

The plant communities that established and developed on these unreclaimed mined areas provide an example of primary succession in which the major limiting factors are edaphic. Typically, minesoils resulting from lignite mining in the Post Oak Savannah vegetation region in Texas are characterized by a pH of 4.0 to 6.0, a high percentage of silt and clay particles, low amounts of organic matter, low levels of nitrogen and phosphorus, and low populations of microorganisms (Dixon et al. 1980). Minesoil characteristics are often extremely variable, both between and within spoil piles, and consequently the associated vegetation can be quite variable.

To date, no study of plant species composition, community structure, and minesoil properties has been conducted on different-aged, unreclaimed lignite mined areas in Texas. The objectives of this study were to evaluate the minesoils and the vegetation that naturally established on a series of different-aged mined areas and compare them to an adjacent unmined area.

MATERIALS AND METHODS

Study Site

The Sandow Mine is located in the Post Oak Savannah vegetation area of east-central Texas. The climate is moderately humid, subtropical, and continental. Mean annual precipitation is 90 cm irregularly distributed with May and October peaks. Summer drought is common.

Native vegetation in this area is dominated by post oak (*Quercus stellata* Wang.), winged elm (*Ulmus alata* Michx.), eastern redcedar (*Juniperus virginiana* L.), greenbriar (*Smilax bona-nox* L.), yaupon (*Ilex vomitoria* Ait.), and numerous grasses and forbs. Grasses which commonly occur in this area are little bluestem (*Schizachrium scoparium* (Michx.) Nash), switchgrass (*Panicum virgatum* L.), brownseed paspalum (*Paspalum plicatulum* Michx.), Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.), and deertongue (*Dichanthelium clandestinum* (L.) Gould) (Gould 1975).

Native soils in this region are predominantly fine sandy loams or loamy fine sands over clayey subsoils. The soils are generally infertile with low amounts of organic matter. Several soil series are prevalent in this area including Axtell fine sandy loam (Udertic Paleustalfs), Rader fine sandy loam (Aquic Paleustalfs), and Uhland loam (Aquic Ustifluvents). Shales in the overburden associated with lignite seams contain acid-producing (pyritic sulfur) as well as calcareous materials.

Methods of mining lignite on this site over the past 50 years vary considerably. The authors are unsure of the machinery that was available and operating in the 1930's at the site. However, several of the older workers on the site explained that small shovels were used and these shovels could be observed on the site among old machinery. These shovels were small with bucket capacities of 2 to 4 m^3 (3 to 5 cu. yd.) and were probably used during the 1930's and 1940's. Shovels and backhoes with buckets ranging from 6 to 12 m^3 (8 to 16 cu. yd) were used on the site in the 1950's and 1960's. Draglines with 29 m^3 (38 cu. yd.) buckets were used on the site in the 1970's, while much larger draglines (72 m^3 or 95 cu. yd) were employed in the late 1970's, and their use on the site continues to the present. The different equipment used for overburden removal is important because it influenced the size of the spoil piles. These old, mined areas were not graded or seeded and the plants and plant communities establishing on these unreclaimed sites are a result of invasion and primary succession.

Sampling Methods and Analysis

Seven ungraded, unreclaimed areas, which were mined in different years, were chosen based on mining date and proximity to each other. The selected areas were mined in 1933, 1953, 1963, 1968, 1973, 1978, and 1983. Representative portions within each mined area were sampled in May and June 1983. On each area, nine 30-m transects were placed perpendicular to the spoil pile slope: three transects were located at the base, three along the side, and three at the top of the spoil pile. Herbaceous species were identified and assigned cover and density values in a 50-cm wide by 50-cm long (0.25 m^2) quadrat placed at 3-m intervals along the transect line. Herbaceous biomass was clipped at ground level, separated into grass and forb components, and placed into labelled paper bags. The plant material was dried at 60°C for 48 hr and weighed to determine dry weight. Total plant cover, litter cover, and bare ground were also estimated in each 0.25-m^2 quadrat.

Woody plant cover was determined by the line-intercept method along the 30-m transects. Every tree and shrub species that intercepted the transect line was identified and its canopy coverage over the transect line was measured.

Soil samples were taken to a depth of 25 cm at two points along each transect line and composited. Samples were also taken at these same two points to determine bulk density using the core method to a depth of 12 cm (Blake and Hartge 1986). Soil samples were analyzed for pH (2:1 water-soil paste), water soluble salts, and several macronutrients. Phosphorus, potassium, calcium, and magnesium were extracted by NH_4OAc-HCl-H_4EDTA and analyzed by atomic absorption (Welch et al. 1980).

Data were analyzed by the Statistical Analysis System (SAS). Analysis of variance was conducted to determine differences in vegetation and soils across different-aged mined sites and the means were separated by Duncan's multiple range test (Ray 1982).

RESULTS AND DISCUSSION

Vegetation

Sparse vegetation was found on 3-month and 6-month-old mined sites in Texas (table 1). A few invading forb and grass species (*Aster*, *Amaranthus*, *Chenopodium*, *Polygonum*, *Dichanthelium*) were observed. On the 6-month-old site, the number of plant species increased threefold (table 2), even though they were still sparse. These plants established first in patches, possibly due to better minesoil or micro-environmental conditions, or due to the presence of seed and/or rhizome banks in the minesoil. The vegetation patches grew on minesoils that had a lighter color than adjacent darker bare areas. The lighter colored minesoil was probably part of the original oxidized zone in the soil and overburden, and was already partially weathered. The color of the minesoil may also have influenced the amount of solar radiation that was absorbed or reflected, thereby affecting minesoil temperature. Samples were collected from light and dark minesoils and analyzed. The only difference that was evident in our limited analysis was the darker minesoil had a high soluble salt content (550 mg/kg) versus no measureable salt content on the lighter minesoils.

According to Game et al. (1982), unreclaimed surface mines in Missouri were colonized initially by invading plants which grew to form patches and these patches gradually enlarged, coalesced, and covered the surface. We observed a similar trend on mined sites in Texas that were 1, 5, 10, and 15 years old. Even though data are not presented on the cover differences between tops, sides, and bottoms of minesoil piles, a general observation should be made. Sides and tops of the minesoil piles of all ages had lower plant cover than the bottoms. This was likely due to slope steepness, and to the

Table 1--Herbaceous vegetation characteristics of eight different-aged, unreclaimed minesoils and an adjacent unmined area.

Age of Minesoil	Total Herbaceous Plant Cover	Litter Cover	Bare Ground	Average Number of Species in Quadrat: Grasses	Forbs	Grass Biomass	Forb Biomass
	------------	%	------------			------	kg/ha -----
3 months	0.1 d[1]	0.1 f	88.6 a	0.1 d	0.0 d	1 c	0 b
6 months	1.3 d	3.1 ef	69.2 b	0.1 d	0.1 d	4 c	2 b
5 yr	12.0 c	6.2 e	77.5 b	0.5 c	0.8 c	215 ab	139 a
10 yr	10.2 c	6.9 e	73.7 b	0.5 c	0.3 c	182 b	36 b
15 yr	12.1 c	9.2 e	72.2 b	0.6 c	0.5 c	218 ab	116 a
20 yr	25.1 b	23.2 d	48.0 c	1.4 a	1.2 b	329 a	153 a
30 yr	14.8 c	40.1 c	42.6 c	1.1 b	1.2 b	196 b	109 a
50 yr	4.2 d	84.1 a	11.1 d	0.4 c	0.5 c	42 c	21 b
Unmined	31.6 a	55.5 b	12.9 d	1.5 a	2.7 a	248 ab	161 a

[1]Values in columns with the same letter are not significantly different a $p<0.05$.

Table 2--Total number of grass, forb, shrub, and tree species observed on different-aged, unreclaimed minesoils and an adjacent unmined area.

Age of Minesoil	Number of Species Observed						
	Grass		Forb		Vine and Shrub	Tree	TOTAL
	Annual	Perennial	Annual	Perennial			
3 month	-[1]	1	2	2	-	-	5
6 month	2	4	4	5	-	-	15
5 yr	3	6	11	13	1	4	38
10 yr	-	12	8	13	7	5	45
15 yr	-	10	3	10	4	3	30
20 yr	1	11	6	13	4	4	39
30 yr	3	5	3	9	7	9	31
50 yr	1	5	1	5	7	9	28
Unmined	1	12	6	13	6	6	44

[1]No species of this type were observed on the site.

instability and slipping of the minesoil at these positions reducing the ability of plant roots to develop. Another likely reason is improved moisture conditions in the bottom of or between the piles due to water runoff and erosion of fine-textured material to the bottom position. Analysis of some chemical properties (pH, P, K, Ca, Mg, and soluble salts) of the minesoil at these three position on each site showed few significant differences.

Herbaceous plant cover continued to increase until reaching a peak on the 20-year-old site (table 1). Understory cover decreased on 30- and 50-year-old mined sites due to shading from tree and shrub canopies (table 3). The average number of grass and forb species occurring in a quadrat on the mined areas was almost always significantly lower than the average number of species in quadrats from the unmined area (table 1). Intermediate-

Table 3--Characteristics of woody vegetation on eight different-aged, unreclaimed minesoils and an adjacent unmined area.

Age of Minesoil	Tree Canopy Cover (%)	Average Number of Tree Species in Transect	Shrub Canopy Cover (%)	Average Number of Shrub Species in Transect
3 months	0	0	0	0
6 months	0	0	0	0
5	0	0	0	0
10	0	0	3.8	0.7
15	0	0	2.0	0.4
20	0	0	13.7	1.6
30	4.0	0.4	30.4	3.4
50	90.6	5.0	82.1	4.5
Unmined	58.0	2.7	6.9	2.5

aged sites (5 to 20 years old) had the highest total number of species per site on mined areas (table 2), and were similar in herbaceous biomass to the unmined site (table 1).

Cover by woody species increased as these mined sites aged (table 3). Shrubs began establishing on the 5-year-old site and continued to increase with 82% shrub cover on the site that had been mined 50 years ago. Several trees were observed on 5, 10, 15, and 20-year-old sites, but the trees were not large or numerous enough to be intercepted by our sampling techniques. On the 30-year-old site, shrub cover began to dominate the site. On the 50-year-old site, a multi-layered plant community had developed with vines, shrubs, and trees. So thick was the vegetation on this 50-year-old site, that movement in the area was difficult.

Minesoil Properties

In most areas in Texas, minesoils generated from lignite overburden have finer, more-favorable textures, increased water and nutrient-holding capacities, and higher productivity potential than adjacent undisturbed sites (Angel 1973, Dixon et al. 1980, Chichester 1983). Clay content in Texas minesoils is generally higher compared to native soils (Chichester 1983) and this can result in a 25% increase in water-holding capacity (Dixon et al. 1980). Bulk density was 1.28 Mg/m^3 on native soils near the Sandow Mine (table 4). After random overburden placement with draglines, the bulk density remained very similar for the following 10 to 15 years after mining. Reductions in bulk density on older mined areas may be due to several factors. First, mining equipment used 20, 30, and 50 years ago was not as large, nor did it dump such large buckets of overburden which may not have compacted the minesoil so much. On the other hand, litter cover was significantly greater on 20-, 30-, and 50-year-old mined areas compared to sites that were mined more recently. The increase in litter cover undoubtedly increased the amount of organic matter and humus in the minesoil and resulted in a lower bulk density compared to recently mined sites. On the 30- and 50-year-old sites, a bulk density of less than 1.00 Mg/m^3 indicates a surface horizon containing high amounts of organic matter.

Soil pH of the unmined site adjacent to the Sandow Mine was 5.9 (table 4). Disturbing and mixing the soil and overburden overlying the lignite seams created a minesoil with a pH of almost 7.0. However, on mined sites from 5 to 30 years old, the pH was in the 3.2 to 4.5 range, while the 50-year-old site exhibited a surface minesoil pH of 6.8. It is not clear why the pH on the 50-year-old site was so high. Information concerning overburden analysis from the permit (submitted in 1975) revealed that pyritic sulfur asociated with the lignite averaged 0.22%. While this is not a high pyritic sulfur value, it can cause some acid to be formed. The mining permit also reports that an occasional thin layer of limestone occurred with the lignite seam, and overburden analysis again confirms a neutralization potential (% $CaCO_3$) average of 1.5%. Mining for lignite 50 years ago was done near the outcrop and where the lig-

Table 4--Selected minesoil characteristics of eight different-aged, unreclaimed minesoils and an adjacent unmined area.

Age of Minesoil	pH	P	K	Ca (mg/kg)	Mg	Soluble Salts	Bulk Density (Mg/m^3)
3 months	6.9 a[1]	16.0 a	187 b	1968 a	482 ab	335 b	1.35 a
6 months	6.9 a	16.2 a	185 b	1940 a	465 ab	374 b	1.30 ab
5 yr	3.8 cd	12.0 ab	112 c	1867 a	355 b	641 b	1.27 ab
10 yr	3.2 d	7.3 b	85 c	2373 a	445 ab	1410 a	1.35 b
15 yr	3.3 d	13.0 ab	87 c	2707 a	448 ab	1417 a	1.22 b
20 yr	4.2 cd	12.0 ab	180 b	1720 a	433 ab	208 b	1.07 c
30 yr	4.6 c	11.7 ab	209 b	2173 a	470 ab	400 b	0.99 c
50 yr	6.8 a	16.5 a	322 a	3260 a	500 a	0 c	0.93 c
Unmined	5.9 b	4.0 b	190 b	1260 a	340 b	0 c	1.28 ab

[1]Values in columns with the same letter are not significantly different at $p<0.05$.

nite was close to the surface. It is probable that the pyrite associated with the lignite near the outcrop was oxidized before disturbance due to the closeness of the lignite seam to the surface. After disturbance, the pyrite in the overburden did not produce acid and the limestone associated with the seam probably raised the minesoil pH to 6.5 or above. As the lignite seam dipped, the lignite was further from the surface, and pyrite was less oxidized or remained in a reduced state. As bigger equipment was used to mine the lignite from greater depths during successive years, the unoxidized pyrite reacted with air and water thereby releasing acid with time, and decreasing minesoil pH on the intermediate-aged mined sites. Down (1975) reported a rapid drop in pH after mining, and as those minesoils continued to age and weather, pH gradually increased.

Phosphorus concentrations were significantly greater on 1-year-old sites compared to the native, unmined soils. Other nutrients (potassium, calcium, and magnesium) showed no distinct trends in our study. Soluble salts were low to nonexistent on native soils, but increased after mining. During the following 10 to 15 years after mining, soluble salts significantly increased in minesoils. Weathering and oxidation of minerals that had been lying in a reduced state in the overburden before mining probably is the reason for increased soluble salt concentration over time after disturbance. Mineral weathering releases ions which may accumulate at the surface. The increase in soluble salts at the surface may also be due to high surface temperatures and evaporation rates which caused a general movement of water with these mobile ions up to the surface. As the minesoils continued to age and with vegetation establishment, surface moisture and temperature conditions were improved, and these ions were not moved to the surface with water evaporation or may have been taken up by plants.

Whether these different-aged mined sites represent a true minesoil and vegetation chronosequence is hard to determine. The minesoils developed on 5, 10, and 15-year-old mined sites appear from our laboratory analysis to be similar in chemical properties, while the minesoils on the 20 and 30 year-old mined sites are similar to each other. The 50-year-old minesoil is different from all other mined areas, and is also quite different from the native soils of the area. An increase in percent base saturation and leaching of sulfate and acidic cations may help explain why the 50-year-old site has such a high minesoil pH.

Table 5 lists the plant species and the areas where each species occurred. Only one grass (Dichanthelium oligosanthes (Schult.) Gould) was common to all sites sampled, while several grasses, forbs, and

Table 5--Listing of plant species occurring on eight, different-aged, unreclaimed, mined sites (1, 5, 10, 15, 20, 30, 50) and the adjacent unmined area (U).

	Scientific name	Sites Occurring							
Grasses									
p[1]	Andropogon glomeratus			10	15	20	30		
p	Andropogon ternarius			10					
p	Andropogon virginicus			10		20			
a	Aristida oligantha					20			U
p	Bothriochloa saccharoides			10	15	20	30		U
p	Bouteloua rigidiseta								U
a	Bromus japonicus		5						
a	Bromus unioloides	1					30		
p	Carex spp.		5			20	30		U
p	Cynodon dactylon	1	5	10	15	20			
p	Dichanthelium linearifolium				15				U
p	Dichanthelium oligosanthes	1	5	10	15	20	30	50	U
p	Digitaria spp.			10					
p	Elymus virginiana							50	
p	Eragrostis spp.					20		50	U
p	Eragrostis sessilispica								U
a	Hordeum pusillum	1							
p	Leptoloma cognatum						30		
p	Lolium perenne	1	5						
p	Panicum brachyanthum			10					
p	Paspalum dilatatum	1	5	10	15	20		50	
p	Paspalum plicatulum			10					U
p	Paspalum setaceum			10	15	20			U
a	Phalaris caroliniana		5				30		
p	Schizachrium scoparium				15	20			U
p	Setaria geniculata		5		15				
p	Setaria leucopila					20			

a	Setaria viridus		5						
p	Sorghum halepense				15			50	
p	Sporobolus spp.			10					U
p	Stipa leucotricha								U
a	Vulpia octoflora						30	50	

<u>Forbs</u>

p	Asclepias spp.								U
a	Amaranthus retroflexus	1							
p	Ambrosia psilostachya	1	5		15	20	30		U
p	Aster spp.	1	5	10	15	20	30		
p	Apocynum cannabinum		5					50	
p	Baptisia leucophaea			10	15				
a	Brassica spp.								U
p	Cardaria draba								U
a	Cassia spp.			10					
p	Castilleja spp.					20	30		
a	Chenopodium album	1							
p	Circium spp.						30	50	
a	Collinsia violacea					20			
a	Croton capitatus		5			20			U
p	Daucus carota		5			20	30		
p	Desmanthus virgatus		5	10	15				
p	Desmodium spp.			10					U
a	Diotia teres			10					U
a	Erigeron spp.		5	10		20	30		
p	Eupatorium spp.		5	10	15				
a	Euphorbia spp.		5						
p	Gaillardia spp.					20			
a	Gnaphalium spp.			10					
p	Grindelia spp.		5						
a	Helianthus spp.				15				
p	Heterotheca pilosa		5	10		20			U
a	Iva annua		5						
a	Lactuca spp.		5						
a	Lepidium densiflorum	1	5			20	30		
p	Lespedeza virginica	1		10	15				U
p	Liatris spp.		5	10		20	30	50	
a	Linum medium			10					
p	Marrubium vulgare								U
p	Mentha spicata			10					U
p	Oenothera speciosa		5			20			U
a	Oxalis dillenii	1	5	10		20	30	50	U
a	Phytolacca americana			10					
a	Plantago aristata	1	5	10	15				U
p	Polygonum spp.	1		10	15				U
a	Pyrrhopappus spp.		5						
p	Rudbeckia serotina		5			20	30	50	U
p	Rumex acetosella		5	10	15	20	30		
p	Schrankia spp.								U
a	Senecio spp.								U
p	Sesbania drummondii	1							
p	Solanum spp.				15				
p	Solidago rigida					20			
a	Sonchus spp.		5	10		20			U
p	Taraxacum officinale			10	15	20	30		
a	Trifolium subterraneum				15				
p	Verbena halei		5			20		50	U
a	Vicia ludoviciana		5						

<u>Woody Plants</u>

	Ampelopsis arborea			10					
	Baccharis salicina		5	10	15	20	30	50	
	Bumelia lanuginosa								U
	Campsis radicans							50	
	Carya illinoensis							50	
	Callicarpa americana			10					
	Celtis pallida						30	50	U
	Cissus incisa			10					
	Fraxinus pennsylvanica							50	
	Ilex decidua							50	
	Ilex vomitoria			10	15	20	30	50	U
	Juniperus virginiana			10	15	20			U
	Opuntia compressa			10		20			

Passiflora incarnata					30		
Populus deltoides	5	10	15	20	30		
Prosopis glandulosa						50	U
Quercus nigra						50	U
Quercus stellata		10				50	U
Rhus toxicodendron		10			30	50	U
Rubus trivialis	5	10	15	20	30		U
Salix nigra	5			20	30	50	
Smilax bona-nox			15		30	50	U
Symphoricarpus orbiculatus					30	50	U
Tamarix gallica		10					
Ulmus alata	5					50	
Vitus mustangensis			15	20	30	50	U

[1]p=perennial, a=annual

woody plants were found on 5 or more sites. Table 6 shows a similarity index matrix between each pair of sites based on the plant species that are common to the two sites:

$$\frac{2c}{a + b}$$

When comparing 2 different-aged mined sites, a is the total number of plant species on site 1, b is the total species number on site 2, and c is the total number of species that are common to both sites. This index ranges from 0 to 1.0 (Krebs 1978). Plant species were similar among the 5, 10, 15, 20, and 30-year-old sites (index ranges from .34 to .60), with the 20 and 30-year-old sites having the high value between sites relative to plant species composition. Plants observed on the 50-year-old site were species that occurred on other mined sites and were most similar to those found on the 30-year-old site. However, the older mined site supported several tree species not found on other mined areas.

Vegetation Succession

Vegetation establishment and development on these different-aged, unreclaimed, surface-mined sites in Texas followed several models of ecological succession. First, recently disturbed areas were initially colonized by invading herbaceous plants which possess mechanisms for prolific seed production and dispersion, germination during diverse environmental conditions, and establishment on harsh sites. As time passed after disturbance, weathering and oxidation of the material placed on the surface resulted in a release on ions that created acid minesoil conditions. The plants already established on the site must either have the individual capability to tolerate the gradually increasing acidic minesoil conditions or decline. The weathering, acid minesoil has a low capability of supporting most plants which probably inhibited rapid plant invasion and establishment. The species that possessed mechanisms to avoid or tolerate such edaphic conditions established and expanded on the sites thereby further inhi-

Table 6--Species composition similarity index matrix for each pair of different-aged, mined sites (1, 5, 10, 20, 30, 50) and the adjacent unmined site (U).

	Sites							
Sites	**1**	**5**	**10**	**15**	**20**	**30**	**50**	**U**
1	--							
5	.34	--						
10	.23	.39	--					
15	.31	.38	.53	--				
20	.26	.55	.48	.49	--			
30	.26	.46	.34	.43	.60	--		
50	.14	.30	.22	.24	.33	.47	--	
U	.13	.29	.38	.38	.46	.35	.39	--

biting invasion by other species. These plants may have ameliorated the minesoil (increased organic matter content, and improved minesoil temperature and moisture conditions) conceivably fascilitating establishment of less tolerant species on the site. With continued time passage, weathering, and leaching, acidic minesoil conditions gradually diminished allowing native plant species an opportunity to reinhabit the site with initial distribution and abundance. Successional models which appear to operate are the initial floristic composition (inhibition) model (Egler 1954, Grime 1979), the tolerance model (Gleason 1926), and the relay floristics (fascilitation) model (Clements 1916).

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