# Factors affecting vegetation development on mined land at Colstrip, Montana

by Patrick Leo Plantenberg

A thesis submitted in partial fulfillment of the requirements of the degree of Master of Science in Range Science
Montana State University


Abstract:
In 1976 and 1977, six leveled, naturally revegetated 45- to 49-year-old. overburden deposits were studied near Colstrip, MT to determine factors affecting vegetation development on minesoils. Initial observations revealed plant communities on the deposits were different one from another as well as from native rangeland, although the origin, age, parent materials, microtopography, climate, and past management were apparently similar. Study objectives were to review literature on vegetation development patterns on disturbed sites, describe existing plant communities on minesoils and surrounding range-land, and analyze plant species and site differences to identify factors causing the differences in vegetation development.

Information was collected on site origins, grazing use, climatic variability, microtopography, and soil characteristics. Vegetation analyses included community mapping, species lists, canopy coverage, above and below ground productivity, frequency, density, phenology, and age-class distribution of important species. Sampling was conducted on sites, on slopes off sites, and on surrounding grazed rangeland to determine differences in plant species distribution and migrating abilities.

Plant communities on the study sites apparently developed based on responses of individual plant species to: 1) environmental gradients such as differences in season of site abandonment, parent materials, microtopography, past grazing management, and surrounding plant populations, 2) environmental modification produced by the existing vegetation on sites, and 3) the influence of climatic variability on establishment of initial vegetation. Establishment of initial vegetation may be an important process controlling the course a given plant and soil successional sequence will follow.

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MONTANA STATE UNIVERSITY
Bozeman, Montana

June, 1983

APPROVAL

of a thesis submitted by

Patrick Leo Plantenberg

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

5/25/83 — Date

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Date May 27, 1983

ACKNOWLEDGEMENTS

The author acknowledges and thanks the following individuals and organizations who aided the research reported in this thesis:

-U.S. Department of Energy

-Western Energy Co., Colstrip, MT

-Burlington Northern, Inc., St. Paul, MN

-J. Bishop, Burlington Northern, Inc., Miles City, MT

-N. Fandrich, Town Manager, Colstrip, MT

-L. Eastgate, Sarpy Creek, MT

-W.B. Dean family, Forsyth, MT

-Foley Bros. Construction Co., St. Paul, MN

-Montana Department of State Lands, Helena, MT

-Rosebud County Museum, Forsyth, MT

-Minnesota Historical Society, St. Paul, MN

-Montana State University Library archives

-Montana Historical Society, Helena, MT

-Other Montana State University associates:

-B. Sindelar, W. Schafer, G. Nielsen, E. DePuit, F. Munshower, J. Taylor, W. Leininger, R. Thorson, D. Litz, D. Gillam, C. Skilbred, A. Plantenberg, L. Gillam, B. Berg, L. King, and R. Rennick.

Finally, the author thanks his wife and his major professor, B. Sindelar, for their patience and continued support.

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# ABSTRACT

In 1976 and 1977, six leveled, naturally revegetated 45- to 49-year-old overburden deposits were studied near Colstrip, MT to determine factors affecting vegetation development on minesoils. Initial observations revealed plant communities on the deposits were different one from another as well as from native rangeland, although the origin, age, parent materials, microtopography, climate, and past management were apparently similar. Study objectives were to review literature on vegetation development patterns on disturbed sites, describe existing plant communities on minesoils and surrounding rangeland, and analyze plant species and site differences to identify factors causing the differences in vegetation development.

Information was collected on site origins, grazing use, climatic variability, microtopography, and soil characteristics. Vegetation analyses included community mapping, species lists, canopy coverage, above and below ground productivity, frequency, density, phenology, and age-class distribution of important species. Sampling was conducted on sites, on slopes off sites, and on surrounding grazed rangeland to determine differences in plant species distribution and migrating abilities.

Plant communities on the study sites apparently developed based on responses of individual plant species to: 1) environmental gradients such as differences in season of site abandonment, parent materials, microtopography, past grazing management, and surrounding plant populations, 2) environmental modification produced by the existing vegetation on sites, and 3) the influence of climatic variability on establishment of initial vegetation. Establishment of initial vegetation may be an important process controlling the course a given plant and soil successional sequence will follow.

# INTRODUCTION

Development of extensive coal deposits in the semiarid Northern Great Plains to supply energy for generation of electricity has increased discussion about reclamation potential. Doubt exists about the feasibility of reclamation in areas where evaporation exceeds precipitation (NAS 1974). This doubt has stimulated the passage of stringent reclamation laws.

Legislation requires establishment of vegetation cover capable of self-regeneration and succession on surface mined land [30 CFR 515 (b)(19)]. The time required to establish that cover has been repeatedly questioned (Curry 1973, 1975; Packer 1974). The presence of a 45-year-old naturally revegetated overburden deposit that exceeded present standards for reclamation success indicated that potential exists for successful reclamation in the Colstrip, MT area (Sindelar and Plantenberg 1978). However, time alone does not guarantee success, as five 48- to 49-year-old overburden deposits in the same area did not meet the requirements (Skilbred 1979).

Studies of old naturally revegetated deposits could identify and rank importance of factors affecting vegetation development on mined land. These studies are important because the number of old leveled minesoils is limited. In addition, five sites were destroyed by mining in 1977.

In 1976 and 1977, six naturally revegetated overburden deposits were intensively investigated. Study objectives were to review literature on vegetation development patterns on disturbed sites, describe existing plant communities on minesoils and surrounding rangeland, and analyze species and site differences to identify factors causing differences in vegetation development.

The deposits consisted of leveled excess overburden removed before mining in areas where overburden depth exceeded dragline capacity. Overburden was deposited on adjacent native rangeland. Preliminary reconnaissance of the deposits showed that plant communities were dissimilar on the six sites. Plant communities graded from shrub/subshrub-annual grass stands in poor range condition [using Soil Conservation Service (SCS) range condition guidelines] to stands dominated by native perennial species in good range condition. However, site origin, age, parent material, microtopography, climate, and past grazing management were apparently similar on five of six deposits. Plant communities on five of six deposits reflected changes in the relative importance of individual species rather than changes in floristic composition (Skilbred 1979).

This study was part of a study for the U.S. Department of Energy (then Energy Research and Development Administration) (Sindelar and Plantenberg 1977, 1978, 1979, 1980). Another Master of Science study was conducted on five of the six overburden deposits (Skilbred 1979).

# LITERATURE REVIEW

Literature concerning vegetation development patterns on disturbed land is extensive (Haug 1970). Wali (1980) recently reviewed succession theory as it relates to mined land revegetation. He indicated problems ecologists have had relating the "orderly progression to climax" theory to observed vegetation development in areas where evaporation exceeds precipitation. Skilbred (1979) reviewed succession principles that affect natural revegetation of mined land in the Northern Great Plains. The literature review that follows seeks to clarify the role of ecological factors in development of vegetation on mined land.

Development of a climax community is not determined by an inherited design but by characteristics of the environment and of the plant species that are able to establish and maintain populations in the community (Drury and Nisbet 1973; Whittaker 1975; Pickett 1976). Initial establishment of vegetation is important to the natural revegetation process on disturbed sites (Egler 1954). The role of climatic variability in succession is important to initial establishment of vegetation after a disturbance (Lang 1971).

Significant yearly variability in precipitation occurs in the study area (NOAA 1924-1983). The vegetation present in an area may result more from climatic extremes than from average weather patterns (Egler 1977). For example, several studies indicated that drought and precipitation greater than average influenced vegetation development more than grazing (Reed and Peterson 1961; Houston and Woodward 1966; Branson and Miller 1981).

Many vegetation studies in semiarid areas have stressed the importance of yearly precipitation amounts related to long term averages. The variation in precipitation month to month has been shown to be significant as well (Olson 1983). Protential evapotranspiration must also be considered (Toy 1979).

Minesoils are substantially different from native soils in the Colstrip, MT area. Schafer et al. (1979) reviewed differences between native soils and minesoils less than 50 years old at Colstrip. Minesoils were characterized by homogenization of the landscape, parent materials, soil texture, and soil depth, and by high coarse fragment content (Schafer 1982). Minesoils with up to 70% coarse fragments probably have more favorable moisture regimes for deep rooted plants than moderately fine to fine textured soils (Berg and Barrau 1973). Mined land has increased soil depth but often contains impermeable layers that can perch water tables (Larson 1980).

Curry (1973, 1975) speculated that rates of soil genesis may be impossible to measure with the climate that exists in the study area today. However, measurable soil formation processes have been documented on naturally revegetated minesoils under 50 years old (Schafer et al. 1979; Singleton and Barker 1980; Wali 1980).

Vegetation development on mined land is a mixture of primary and secondary succession processes (Wali 1980). Although vegetation and soil development are interdependent, the role of soil development in primary successions probably has been exaggerated (Drury and Nisbet 1973). For example, some plant species characteristically associated with later stages of soil formation, may succeed if introduced initially by seed or vegetative transplant. In South Dakota, cool-season grasses, such as *Agropyron smithii* and *Stipa viridula* replaced warm-season grasses in native plant communities as soil structure and soil fertility (*i.e.* soil development) increased with time (White 1971). But on seeded mined land at Colstrip, cool-season grasses predominated regardless of minesoil age, topsoil treatment, or fertilizer regime (Depuit 1980). Mined land in the Colstrip area typically has sufficient stored soil moisture to increase initial vegetation establishment success if precipitation is normal (Sindelar *et al*. 1973).

Man has introduced many new species into the Northern Great Plains flora. Examples include *Salsola kali* which became widespread in the drought of the 1930's (Van Bruggen 1976). *Melilotus officinalis* is a conspicuous exotic biennial species that has become a naturalized component of disturbed native rangeland in the area (Sindelar and Plantenberg 1978). Introduced perennial species are important in native communities; examples are *Poa pratensis* in *Agropyron smithii-Stipa viridula* grasslands and *Taraxacum officinale*. Improved pastures are seeded with introduced plant species. Various noxious weeds such as *Centaurea maculosa*, *Cirsium arvense*, and *Convolvulus arvensis* occur in the study area on disturbed sites (Sindelar and Plantenberg 1978). Although man's activities have favored introduction of exotic species, the opportunity for exotic species to become established is present even in some existing undisturbed communities (Daubenmire 1968). Disturbance, coupled with the presence of aliens, may result in a plant community different from the antecedent vegetation type (Weaver and Clements 1938). The introduction of competitive new species and varieties alters vegetation development patterns on minesoils (Sindelar and Plantenberg 1978; King 1980).

Man's use of the land may have modified existing vegetation populations in the Northern Great Plains. For example, existing vegetation in an area may not be representative of the potential vegetation because grazing may have altered it (Sedgeley 1974). The bison herds are gone. In contrast to transient bison use (England and De Vos 1969), overgrazing by livestock is extensive in different vegetation communities and occurs in all seasons of the year. The influence of livestock grazing in the past 100 years has significantly changed vegetation development patterns (Ellison 1960). In fact, grazing programs are being used today which recreate the herd effect on land without which plant, soil, and animal succession is altered (Savory 1981).

Vegetation development potentials can be substantially modified by man's choice of mining methodology. Schafer (1982) concluded that new reclamation methods had increased the overall SCS land capability classification at some mines over the capability classes that existed before mining. Different mining methods allow selective handling and placement of overburden (Dollhopf _et al_. 1978). Overburden with man-created improvements may form a better topsoil than the previous natural topsoil (Bradshaw and Chadwick 1980).

Mining methods and economics affect the rate and scale of mining. Size of disturbance is an important factor often overlooked in ecological studies (Burges 1960). Vegetation development patterns change as the size of disturbance changes (Egler 1954; Golley 1965; Platt 1975). The larger the disturbance the less likely the site will return to the antecedent vegetation (Connell and Slatyer 1977).

Revegetation strategies developed to meet the requirements of reclamation laws, alter vegetation development on mined land. For example, climax species depend almost solely on wind for dissemination (Weaver and Clements 1938). Today, legislation requires topsoiling and seeding of land disturbed by mining. With direct-haul topsoiling practices, propagules of relatively immobile climax species are directly transferred to sites, increasing their chance for establishment (King 1980). Establishment irrigation, seed mixture formulation, fertilization, landscape design, and other man-controlled reclamation treatments alter vegetation establishment potentials (DePuit 1980).

Following initial revegetation treatments, plant populations may be manipulated by fertilizers, herbicides, insecticides, and grazing which will influence vegetation development patterns. Reseeding and interseeding are other alternatives to establish additional plant species (Humphries 1979). Direct intervention by man to supply seed may be needed because seed of some species may be unavailable to disturbed sites (Harper 1977).

In summary, climatic variability and minesoil properties are factors that affect the process of initial establishment of vegetation on mined land. Man has introduced new plant species into the local flora and modified existing plant species populations as well. Mining methods and revegetation strategies are other important factors that affect vegetation development on mined land.

# METHODS AND PROCEDURES

## Introduction

Objectives of this study were to describe existing plant communities on mined land and surrounding rangeland near Colstrip, MT and to analyze plant species and site differences. To identify and rank factors causing the differences in vegetation development among the sites, the following methods and procedures were developed.

Six overburden deposits from the same mining period on native rangeland were chosen for study to minimize variations due to mining methods, soil/parent materials, climate, grazing, and fire history in surrounding plant communities. Methods were designed to study each deposit as one site without replicates. Sampling intensity was selected to characterize adequately each site as well as the native rangeland communities surrounding each site.

### Mining Methodology

Historical information concerning mining methods at the time of site formation was searched in many records:

- Western Energy Company records, Colstrip, MT
- W. B. Dean photograph collection - Forsyth, MT and Montana Historical Society, Helena, MT
- Northern Pacific Railway Company records - Minnesota Historical Society, St. Paul, MN
- Northwestern Improvement Company records - St. Paul, MN

-Foley Bros. Construction Company records - St. Paul, MN

-Forsyth Independent newspaper records - Rosebud County Museum, Forsyth, MT

-Personal interview with N. Fandrich, Town Manager, Colstrip, MT

## Grazing History

Information on grazing history of the area was obtained from:

-Burlington Northern, Inc., grazing lease records, J. Bishop, BN, Inc., Miles City, MT

-Personal interview with L. Eastgate, Sarpy Creek, MT, local rancher who leased the study area and who was former purchasing agent, Foley Bros. Construction Co., in Colstrip, MT.

-Environmental impact studies done in the area (Westinghouse Elec. Corp. 1973, Bennett et al. 1976).

Literature about the area was used to supplement information on the mining and grazing history of study sites (Foley 1945, Fulmer 1973).

## Species Identification

Plant lists were made for each site (see Skilbred [1979] and Sindelar and Plantenberg [1978]). Plant collections were made throughout the growing season. Specimens of each species collected were identified, characterized, and catalogued. Duplicate specimens, if available, were submitted to the Montana State University Herbarium. More than 425 vascular plant species in the Colstrip area were collected. A flora including all of the species in the study area does not exist. Scientific nomenclature for plant species was primarily based on Hitchcock and Cronquist (1978). Nomenclature for other species was based on Booth (1950), Booth and Wright (1966), Van Bruggen (1976), and Dorn (1977). Nomenclature is based on USDA-SCS (1982).

### Vegetation Mapping

Color and infrared aerial photographs and topographical maps were used to construct vegetation mosaic maps of five of the sites as well as areas immediately surrounding these sites. Surveying equipment and topographical maps were used to produce microtopographical profiles of these five sites. Regretably, a sixth site and its surrounding rangeland in another management unit, were not mapped. Numerous 35 mm photographs were taken of the sites during the study period.

## On-Site Sampling

### Exclosure Measurements

Exclosures (15 x 25 m) were constructed to protect permanent plots from livestock and vehicle traffic. Exclosure locations were selected on each deposit in the major plant community. The native range site was selected on an upland ridge. The ridge was an extension of the same ridge which was used to form two of the sites. Also, it was selected to match the upland nature of the sites. Vegetation sampling methods matched those of the parent study (Sindelar and Plantenberg 1978, Figure 5, p. 152). All sampling was systematic at regular intervals along transects. Justification for random vs. systematic sampling is a matter of opinion (Daubenmire 1968).

Three permanent 20 m transects were located using galvanized wire stretched at ground level between steel posts and marked at one-meter intervals. On one transect, 10 permanent 0.75 m square quadrats were stereophotographed twice during each growing season. These stereophotographs provided a 35 mm photographic record of the vegetation. A second transect was used for standing crop estimates by the direct harvest method (Lewis 1970). Ten 0.5 m square quadrats were harvested twice during the growing season, once in late May or early June and then again in early July. These dates were chosen to sample the peak standing crop of the major cool-season and warm-season species in the area (Sindelar and Plantenberg 1977). Plant materials including shrubs were clipped to ground level and separated by species. Standing dead material and ground litter were also separated. All samples were oven dried, weighed, and averages determined. Litter samples were not ashed. As a result, litter estimates are maximum values. Shrub and cactus species with above ground perennating cambium layers and leaves were sampled differently. Only the new growth was removed and other perennating material was placed in standing dead samples. As a result, shrub estimates are minimum values.

Two transects were used for ground and canopy coverage analyses. Forty permanently located 20 x 50 cm plots were sampled twice during each growing season. Canopy and ground coverage estimates were made for each species as well as mosses, lichens, fungi, litter, rock, and bare ground with a modification of the Daubenmire (1959) canopy coverage method. Interspaces in the imaginary polygon drawn around a plant canopy were removed to produce actual coverage values. As a result, comparisons with other studies using this method are limited and coverage values should be considered minimal. Canopy coverage estimates provided data for species composition, frequency, and species diversity. Diversity was calculated using the Shannon Index (Pielou 1975). Diversity values are reported to levels as precise as the data that were used to generate them. The indices were not calculated on a plot-by-plot basis. As a result, statistical testing was not conducted.

Summation of the largest standing crop and canopy coverage estimates for individual species from the two sampling dates in a growing season were used to compute a "maximum" value for each site. This computation is standard procedure for productivity estimates (Singh et al. 1975). For the coverage estimates, this represents a modification of the Daubenmire technique. This modification is justified for canopy coverage estimates because this study used permanently located plots with the same plants being estimated each sample date. These maximum values still lack estimates for ephemeral forbs and late developing species.

Plant density estimates were made in 20 permanently located 15 x 15 cm quadrats along one transect (Sindelar and Plantenberg 1978). Density counts of each species were recorded every two weeks during the growing season. Nine sample dates were recorded in 1976 and 15 dates in 1977.

Standing crop, canopy coverage and density differences among sites were tested using analysis of variance procedures (Nie et al. 1975). Mean separation was accomplished using Duncan's Multiple Range test (Steele and Torrie 1960). Statistical analyses were conducted even though sampling on sites was not replicated. Results should be viewed in that context.

Species frequency was used to determine whether exclosure plant communities were comparable with communities on the rest of the study sites. Frequency was sampled by modifying techniques used by Hyder et al. (1963) and Hyder et al. (1965, 1966). Presence of a species was recorded when it was overhanging or rooted in the sampling plot. Over 3,000, 4 x 10 cm plots were sampled on the six minesoil sites. For exclosure comparisons, 60 plots were sampled at one-meter intervals along transects in each exclosure. On the rest of each site, a central point was selected and transects were located in eight cardinal directions radiating from the central point. Frequency plots were sampled at one-meter intervals in eight directions, until 200 plots were recorded on each of the five sites in one management unit. On the sixth site, two central points were selected because of the large size and bilobed appearance of the site (see Figure 14). On the sixth site 1710 plots were inventoried. Frequency samples were subjected to Chi Square ($X^2$) analyses (Snedecor and Cochran 1971).

Slope and Exposure

Plant species on the slopes of five sites were listed and mapped. The relative abundance of each species was estimated using