ABANDONED COAL MINE LANDS RESEARCH PROGRAM

SECOND-SEMI ANNUAL PROJECT REVIEW SEMINAR

GILLETTE, WYOMING

MAY 20, 1992

The seminar series is sponsored jointly by the University of Wyoming, Office of Research and the Abandoned Mine Lands Program of the Wyoming Department of Environmental Quality.

ABANDONED COAL MINE LANDS RESEARCH PROGRAM

TITLE: (FINAL REPORT)
Research Materials on Selenium in the University of Wyoming American Heritage Center
INVESTIGATORS:
Williams, Stephen
Wilsted, Thomas

Amount Funded: $16,156.00
Start Date: 08/01/90
End Date: 08/31/91

TITLE: (FINAL REPORT)
Geophysical Detection of Abandoned Mine Tunnels: A Feasibility Study
INVESTIGATORS:
Smithson, Scott
Fuller, Brian

Amount Funded: $84,960.00
Start Date: 07/01/90
End Date: 07/31/91

TITLE: (INTERIM REPORT)
Strategies for Establishment of Big Sagebrush (Artemisia tridentata ssp. wyomingensis) on Wyoming Lands
INVESTIGATORS:
Schuman, Gerald
Booth, D.T.

Amount Funded: $137,700.00
Start Date: 01/01/91
End Date: 12/31/93

TITLE: (INTERIM REPORT)
The Role of Natural Organic Solutes on the Mobility of Selenium in Abandoned Coal Mine Spoil-Ground Water Systems
INVESTIGATORS:
See, Randolph
Reddy, K.J.
Vance, George

Amount Funded: $157,058.00
Start Date: 05/01/91
End Date: 12/31/93

TITLE: (INTERIM REPORT)
Importance of Solid and Solution Selenium Speciation in Mobility and Plant Uptake of Selenium from Wyoming Coal Mine Land Reclamation
INVESTIGATORS:
Vance, George
Reddy, K.J.
Spackman, Lowell

Amount Funded: $157,980.00
Start Date: 05/01/91
End Date: 04/30/94

TITLE: (INTERIM REPORT)
Relationship Between Soil Selenium Concentrations and Selenium Uptake by Vegetation on Surface Coal Mine Lands in Wyoming
INVESTIGATORS:
Pasch, Roger
Vance, George
Williams, Stephen
Page, Margaret Stacy
Carroll, Peter

Amount Funded: $110,425.00
Start Date: 05/01/91
End Date: 04/30/94

TITLE: (NEW PROJECT)
Long-Term Stability of Designed Channels at Reclaimed Coal Mines in Wyoming
INVESTIGATORS:
Rathburn, Sara L.
Rechard, Paul A.

Amount Funded: $29,474
Start Date: 5/01/92
End Date: 2/28/93

TITLE: (NEW PROJECT)
Toxicologic Evaluation of Chronic Selenosis in Wyoming Herbivores
INVESTIGATORS:
Raisbeck, Meri
O'Toole, Donal
Belden, E. Lee
Waggoner, James
Zinn, Kurt
Thorne, E. Thomas

Amount Funded: $179,150
Start Date: 4/16/92
End Date: 12/31/94

TITLE: (NEW PROJECT)
Methodology for the Geomorphic Classification and Design of Drainage Basins and Stream Channels in the Powder River Coal Field of Wyoming
INVESTIGATORS:
Wesche, Thomas
Lowham, Hugh
Daddow, Richard

Amount Funded: $109,000
Start Date: 07/01/92
End Date: 6/30/94

RESEARCH MATERIALS ON SELENIUM IN THE UNIVERSITY OF WYOMING AMERICAN HERITAGE CENTER

STEPHEN E. WILLIAMS AND THOMAS WILSTED

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RESEARCH MATERIALS ON SELENIUM IN THE UNIVERSITY OF WYOMING AMERICAN HERITAGE CENTER

by Stephen E. Williams[1] and Thomas Wilsted[2]

Work on the toxic nature of selenium was initiated at the University of Wyoming in 1914 by Orville A. Beath. Over the next five decades Beath conducted extensive research on selenium. During this period he worked with many people including Irene Rosenfeld (University of Wyoming), Sam F. Trelease (Columbia University, New York), Carl Gilbert (University of Wyoming), and Harold Eppson (University of Wyoming).

The work of these researchers resulted in a hundred publications on selenium. However, the records and literature collections of these pioneer selenium researchers, were found to be in unusable condition in the University of Wyoming Archives prior to the initiation of this project. Approximately three years ago, S.E. Williams and J. C. Case of the State Geological Survey began to examine the Beath records in order to ascertain the accuracy of published materials. The materials in the Beath Collection were surprisingly scant and limited to a handful of catalogued boxes of material. However, further investigation uncovered seventy eight boxes of uncatalogued records of Beath, Rosenfeld, Eppson and Gilbert which had been stored in the University of Wyoming Archives for some twenty-five years. Examination of this material has yielded records of site locations, experimental designs, thousands of selenium analyses of biological materials (soils, plants, waters and animals), photographs, unpublished summaries as well as hundreds of out-of-print and rare publications and pictorial records. This record may be an important resource for current research, particularly in light of the intense State, Regional and National interest in selenium. Much of the work of these researchers addresses long term studies on disturbed sites and has implications for selenium in abandoned mine lands.

The objectives of this project were essentially to arrange, preserve and describe these materials.

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[1] Professor, Department of Plant, Soil, and Insect Sciences; University of Wyoming.

[2] Associate Director of Operations: American Heritage Center; University of Wyoming.

Work Completed

Much of the materials identifiable as belonging to O. A. Beath and the Beath research group in general were contained in the collections of Irene Rosenfeld and Harold Eppson. The work of processing these two collections was divided into two categories: arrangement and conservation of the items, and describing the materials. The collections together contain about 78 cubic feet of material. These include publications, location of experiment sites, manuscripts, and raw data on plants, soils, and animals.

The material in these collections has been cleaned, refoldered, labeled and placed in acid-neutral folders and acid-neutral boxes. Work has been completed for both collections.

In addition, funds from the project allowed the American Heritage Center staff to reprocess and catalog the papers of O.A. Beath and Carl Gilbert. This resulted in new finding aids and entries into the OCLC bibliographic database. With the compilation of this project all selenium related collections in the American Heritage Center have detailed finding aids and are available on national bibliographic networks.

From a research perspective, work with these collections is in a preliminary stage. As collections were arranged and catalogued, they were superficially examined to determine the value of various items in the collection for continued research or for publication. Material was also noted for its importance to previously published work of the Beath group, especially in regard to specific data, location sites, and selenium concentrations of specific samples.

Future Directions

There are at least three obvious directions this project may take in the future: 1). publication of descriptions and significance of collections in scholarly journals as well as publication of selected items from the collections, 2). synthesis of a library of supporting research and 3). collection of other primary research material.

SHALLOW SEISMIC INVESTIGATION OF ABANDONED MINE LANDS IN ROCK SPRINGS, WYOMING, NOVEMBER 1991

SCOTT B. SMITHSON, PAUL VALASEK, AND MICHAEL C.HUMPHRIES

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REPORT ON SHALLOW SEISMIC INVESTIGATIONS OF ABANDONED MINE LANDS IN ROCK SPRINGS, WYOMING, NOVEMBER 1991

SCOTT B. SMITHSON, PAUL VALASEK, MICHAEL C. HUMPHRIES
UNIVERSITY OF WYOMING GEOLOGY DEPARTMENT

INTRODUCTION: From November 4 to 14, 1991, the University of Wyoming seismic field crew conducted seismic testing in Rock Springs, Wyoming, to determine the utility of the shallow seismic reflection method in locating faults and abandoned underground coal mines. A total of five seismic lines were recorded at four different sites with depths of interest ranging from 60 to 120 feet below the surface. Ground-penetrating radar was also used because of its potential resolution and speed.

RESULTS: Modeling Seismic Response. As expected, logs of a bore hole through coal seams show a large difference in density and velocity between coal seams and surrounding rocks (Fig.1). The density difference is about 0.7 gm/cm^3 and the velocity difference is about 3000 feet per second. This results in very large reflection coefficients and indicates that strong reflections should be associated with coal seams. When mined out, the density and velocity differences become even larger, so that reflections may be stronger unless the mined ore is filled with rubble. In this case, reflections probably become diffuse.

Thompson Street. This area of faulting and subsidence was mapped with high-resolution seismics and processed into a normal CDP stacked section and a true amplitude section (Figs.2 and 3). The seismic section (Fig.2) shows good reflections associated with coal zones, and these reflections are offset, indicating positions of faults including one with an offset of about 60 feet at the north side of the section. Smaller faults are associated with a cracked garage. True-amplitude plots (Fig.3) distinguish between unmined coal, mined voids, and rubble. Synthetic seismics, based on logged boreholes, and superposed on the seismic section show that the seismic interpretation is confirmed by drilling.

Maple Street. The seismic section (Fig.4) shows a fairly distinct reflection dipping to the south from a depth of about 80 feet to 160 feet. This reflection correlates with a partially-mined coal bed. The irregular nature of the reflection indicates that this is cut by a number of faults with displacements of five to fifteen feet. The GPR data suffers from heavy interference from sources of electromagnetic radiation such as power lines. After strong processing, using seismic processing routines, interference is attenuated (Fig.4), faulting is recognized. Ringing may be caused by voids,both grouted and ungrouted.

Belts. GPR provided a striking example for mapping shallow features over a landfill along the Belt Road (Fig.5). Here a low spot had been filled in by fly ash. The base of the landfill was well mapped by the GPR and an underlying coal seam was also imaged (Fig.4). Convex upward events (diffractions) at the base of the coal may indicate strong discontinuities.

Borehole

MC774

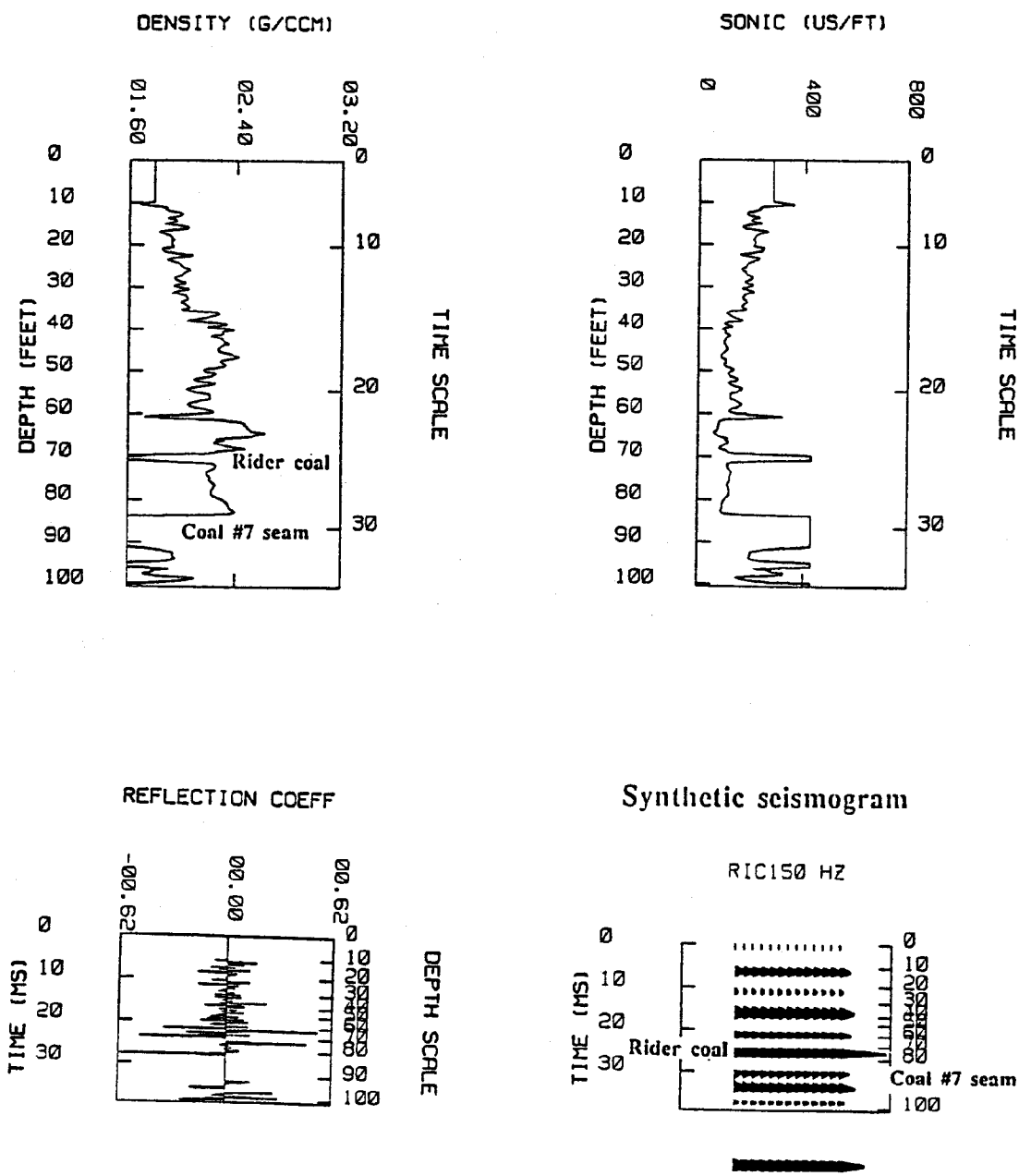
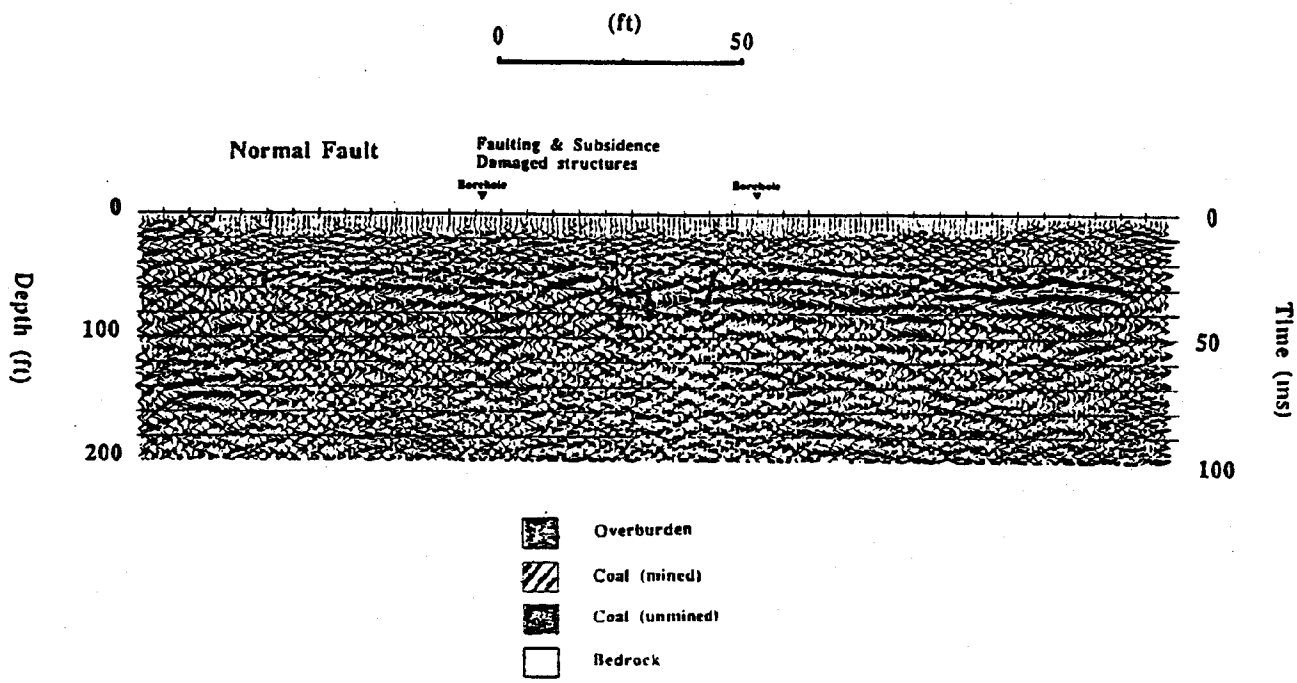


FIGURE 1

High Resolution Seismic (HRS)



True Amplitude Display

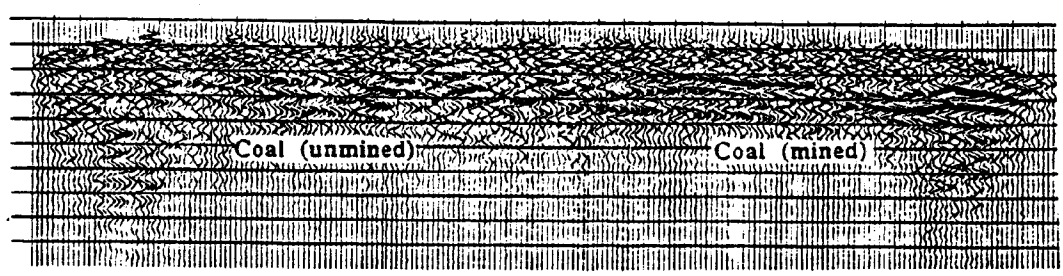


FIGURE 3

Thompson HRS

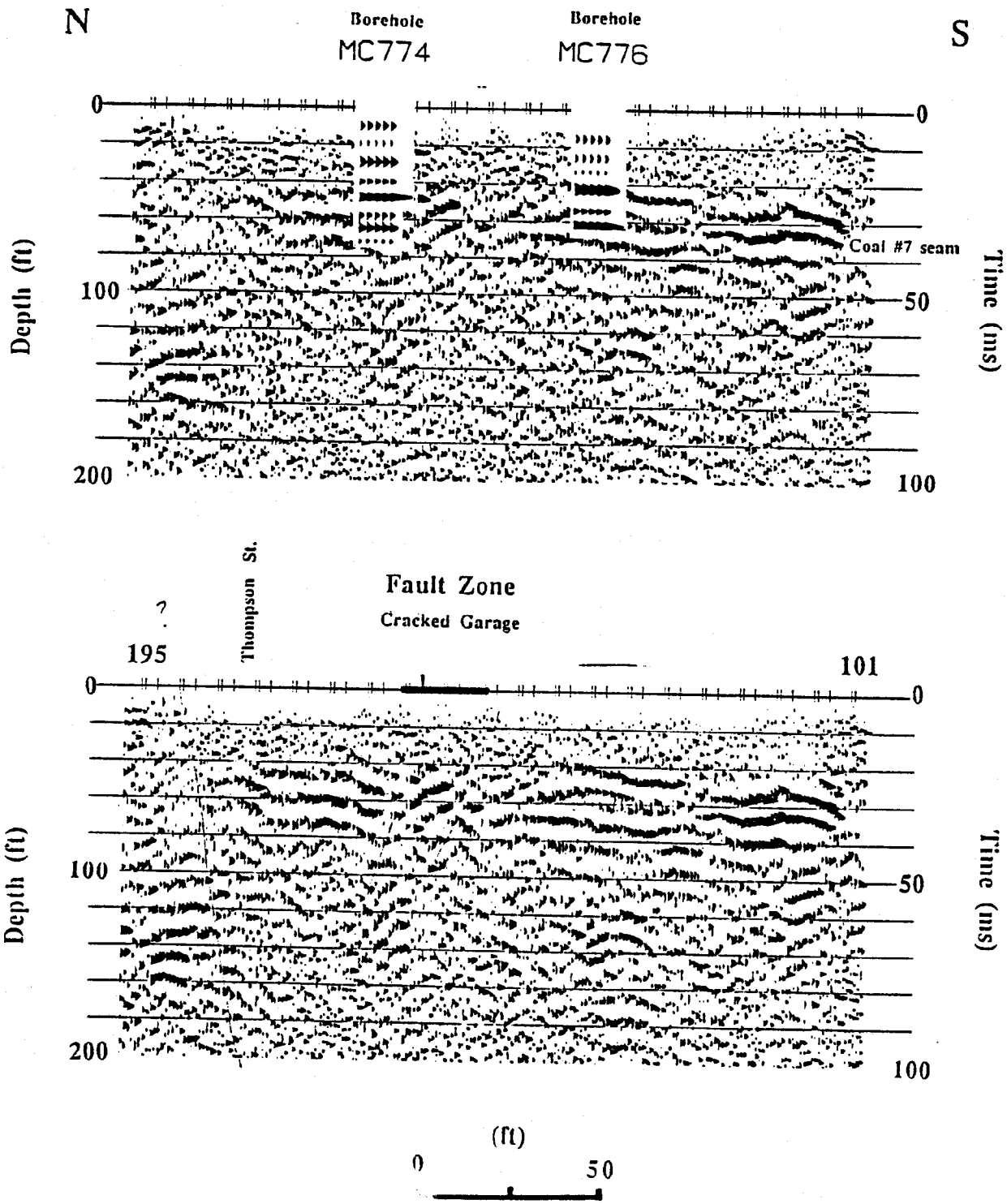
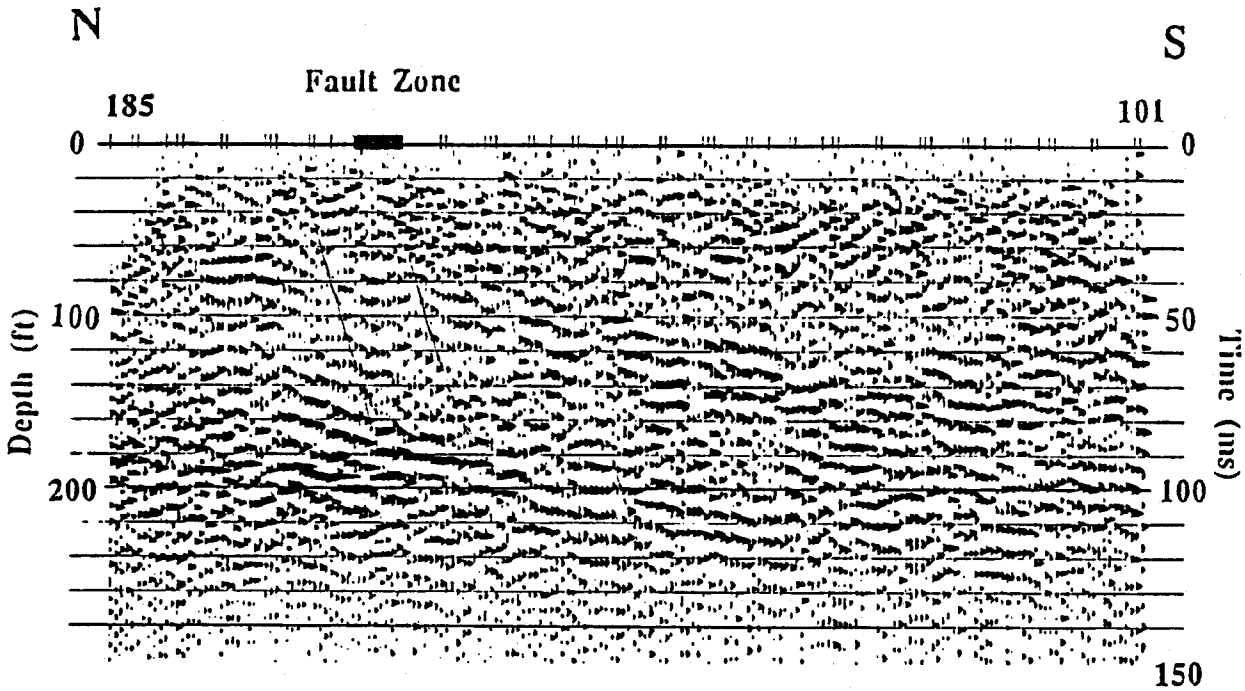


FIGURE 2

Maple HRS



Maple GPR

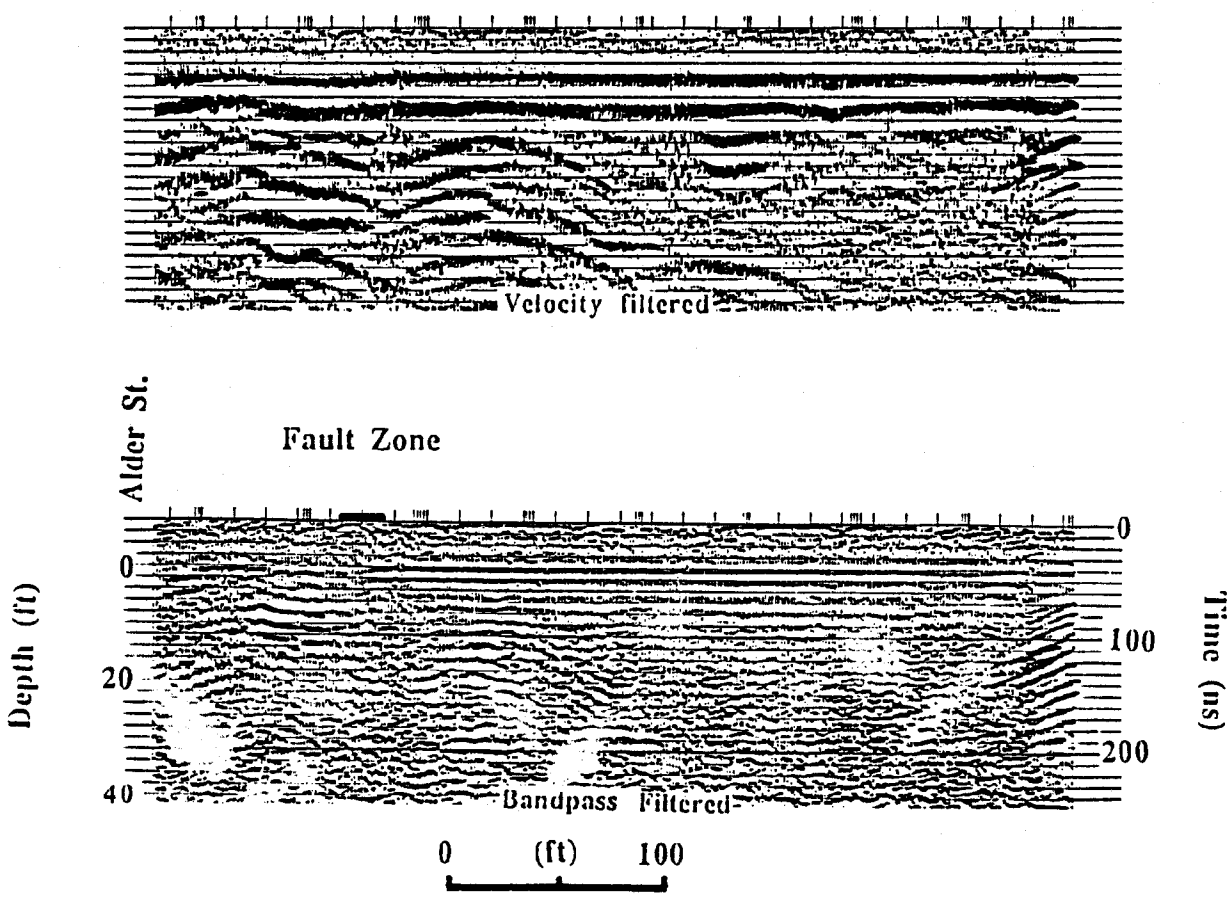


FIGURE 4

Ground Penetrating Radar (GPR)

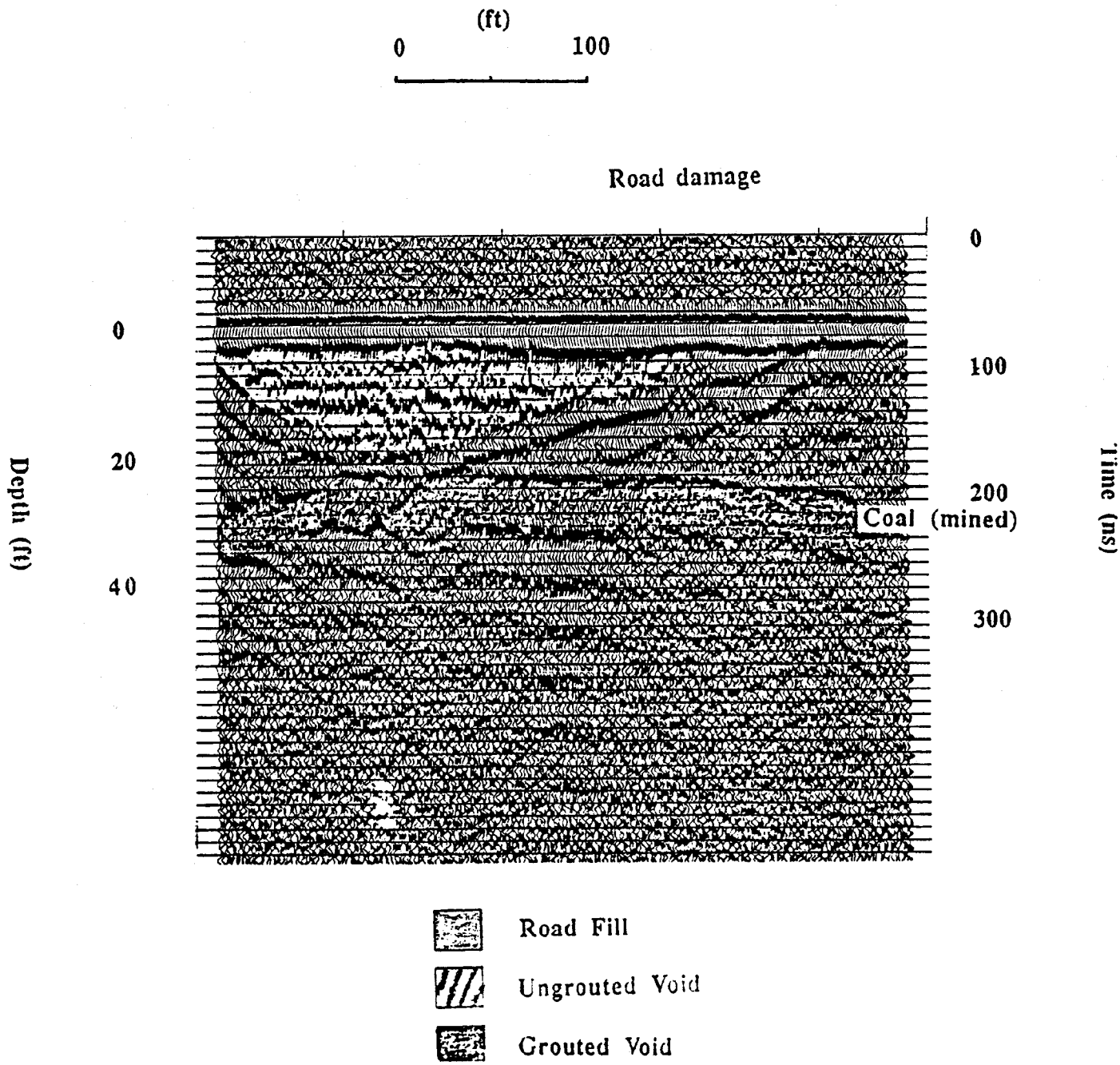


FIGURE 5

STRATEGIES FOR ESTABLISHMENT OF BIG SAGEBRUSH (*Artemisia tridentata* ssp. *wyomingensis*) ON WYOMING MINED LANDS

G.E. SCHUMAN AND D.T. BOOTH

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Strategies for Establishment of Big Sagebrush (*Arternisia tridentata* ssp. *wyomingensis*) on Wyoming Mined Lands

G.E. Schuman and D.T. Booth

Introduction

Wyoming big sagebrush is one of the most widely distributed and adapted shrub species in Wyoming and the region. Although considerable debate has surrounded its value, and the need for re-establishment during mined land reclamation, the fact remains that reclamationists are often advised and sometimes required to restore sagebrush to mined lands at densities that approximate predisturbance conditions. In light of this, methods for establishment of big sagebrush are an important area of revegetation research and technology development. Sagebrush is well adapted and persistent when mature, but establishment from seed has proven difficult. Problems include low seedling vigor, seedling inability to compete with herbaceous species, poor seed quality and/or ecotypic adaptation, inability of agronomic seeding methods to meet seed microsite requirements, and effects of altered soil conditions on establishment of the effective vesicular-arbuscular mycorrhizal (VAM) associations that are important to sagebrush seedling survival.

A research study was initiated in January 1991, to test several cultural approaches so as to define effective strategies for obtaining stands of big sagebrush on mined lands. Specific objectives include:

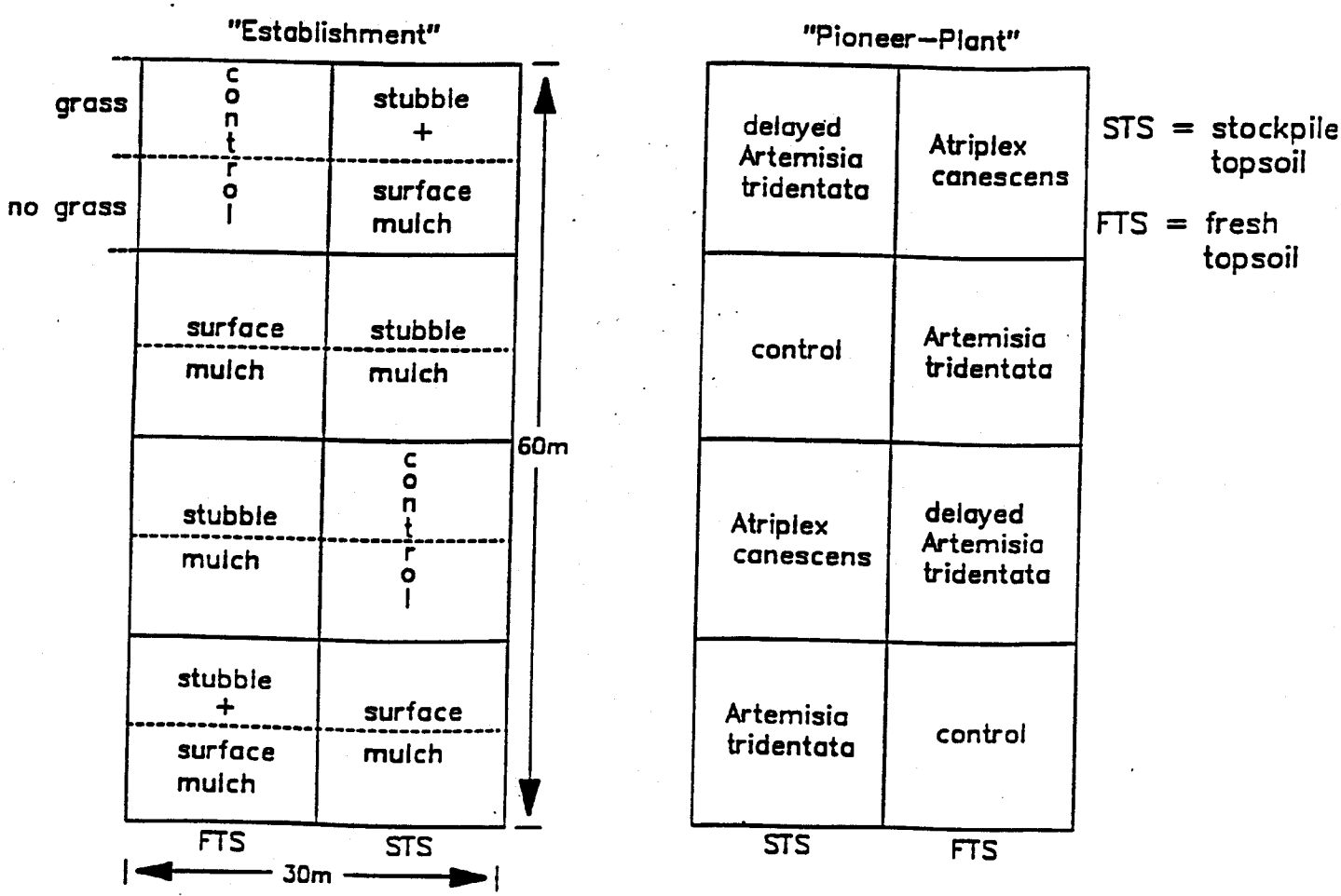
1. Efficacy of direct-applied topsoil for enhanced sagebrush stand establishment through effects of VAM and the topsoil as a seed source,
2. The value of a stubble mulch crop of annual grain for sagebrush establishment through effects on snow catchment and microsite modification,
3. The usefulness of surficially applied hay/straw mulch in improving sagebrush establishment through seed/seedling protection and microsite modification,
4. The effect of competition from concurrently seeded herbaceous species on establishment of sagebrush, and
5. The value of seeding fourwing saltbrush as a pioneer species for enhancing soil biological properties leading to the natural recruitment of sagebrush.

The research will allow evaluation of the primary questions and interactive effects among treatments in a manner to suggest an optimal combination of methods to enhance sagebrush revegetation. It is anticipated that application of technology developed from this project will directly benefit entities involved in western mined land reclamation.

Project Description

This project will be composed of two compatible studies that are being conducted simultaneously. These are identified as the "Establishment Study" and "Pioneer Plant Study" (Figure 1). The Establishment Study will test techniques for sagebrush establishment, and will be fully completed during the three year term of this project. The Pioneer Plant Study will be a longer-term investigation of plant

Figure 1. Field plot diagram of a representative block of the "Establishment" and fourwing saltbush "Pioneer Plant" studies; each block has been replicated three times with main treatments (Table 1) randomly assigned within the split-plot experimental design.



succession manipulation intended to enhance sagebrush establishment. Initial results of the Pioneer Study will be available by year three of the present project, but several additional years of monitoring will be necessary for full evaluation of treatment effects.

Establishment Study

This study will evaluate three sets of main treatment variables (Table 1): topsoil salvage procedures (fresh vs. stored), mulch method (stubble, surface, stubble + surface, and non-mulched), and level of herbaceous species competition (concurrently seeded grasses vs. no seeded grasses). Sagebrush will be seeded similarly within all combinations of the above main treatments using broadcast methods. Figure 1 portrays the field plot design. Each block has been divided into two topsoil treatment plots, each of which will be split into four stubble treatment plots; each stubble treatment plot has been further divided into three grass seeding-rate treatment plots.

The two topsoil treatments are included to evaluate the hypothesis that sagebrush establishment will be enhanced by use of fresh-stripped topsoil instead of stored topsoil (i.e., topsoil that has been stockpiled at least 5 years prior to respreading on mine spoils). It is postulated that freshly stripped topsoil will have a minimum loss of fertility, VAM and, possibly, viability of seed bank sagebrush seeds, and, therefore, a higher potential for natural establishment of sagebrush than stored soil.

The mulch treatments are proposed to test the hypothesis that modifications of seedbed conditions will improve establishment of surficially seeded sagebrush. Mulches are known to modify the seedbed microclimate with regard to temperature and moisture. Two mulches will be tested, alone and in combination: a grain stubble and a surface application of hay/straw mulch. Grain stubble has been found effective in trapping snow, modifying diurnal temperature fluctuation, and increasing water infiltration and storage in the soil. Because of these benefits, researchers found stubble mulching to result in greater grass seedling establishment than that with other mulching practices; the same results would be expected for sagebrush, particularly when surface seeded. The surficially applied hay/straw mulch will likely have little effect on snow accumulation, but may beneficially modify seedbed microclimate through water conservation and temperature moderation; it also may protect sagebrush seeds and seedlings from physical and desiccative effects of wind and/or insolation.

The grass seeding treatments are proposed to evaluate the hypothesis that sagebrush will be more effectively established in absence of competition from concurrently seeded herbaceous species. The three treatments will be absence and two densities of a mixture of vigorous cool-season, native perennial grasses sown at a rate typical for mined land revegetation in the region.

Pioneer Plant Study

This study will involve two sets of main treatment variables (Table 1): topsoiling procedures (fresh vs. stored, for the same purposes described in the Establishment Study), and shrub seeding procedures. Mulch method (grain stubble) and level of seeded herbaceous species competition (no seeded grasses) will be held constant under all main

Table 1. Treatments applied in "Establishment" and fourwing saltbush "Pioneer Plant" studies. All combinations of main treatments will be implemented within each study.

Treatments	Establishment Study	Fourwing Saltbush Pioneer Plant Study
TOPSOIL	1. Fresh Topsoil 2. Stored Topsoil	1. Fresh Topsoil 2. Stored Topsoil
MULCH	1. Stubble Mulch 2. Surface Mulch 3. Stubble + Surface Mulch 4. Control (no mulch)	Not varied (Stubble mulching will be practiced on all treatment combinations)
COMPETITION	1. Seeded Cool-Season Grass Mixture 2. Control (no seeded grasses)	Not varied (No grasses will be seeded)
SHRUB SEEDING	Not varied (sagebrush will be seeded on all treatment combinations)	1. Fourwing saltbush seeded Year 1 and overseeded with sagebrush Years 2 and 3. 2. Sagebrush seeded Year 1 and overseeded with sagebrush in Years 2 & 3. 3. Delayed seeding: no shrubs seeded Year 1, sagebrush initially seeded in Year 2 and overseeded in Year 3. 4. Control (no shrubs seeded)

treatment combinations. The shrub seeding treatments that will be imposed on each topsoil treatment are: a) seeded to sagebrush, b) seeded to fourwing saltbush, c) one year delayed seeding of sagebrush, and d) an unseeded control. After the first growing season for seeded shrubs, treatments a), b) and c) will be over-seeded annually with sagebrush to assure that viable seed is present each spring. The experimental design (Figure 1) divides each block into two topsoil treatment plots, each of which are further split into four shrub seeding treatment plots.

The topsoil and shrub seeding treatments allow testing of two contrasting hypotheses. The first, hereafter referred to as the "exclusion" hypothesis, is that fourwing saltbush seeding rates greater than 2.2 kg/ha (26 seeds/m^2) result in monotypic stands that exclude invasion of other species, particularly climax shrubs such as sagebrush. It has been suggested that if seed mixtures contained more sagebrush and less fourwing saltbush, more sagebrush would establish on reseeded mined lands.

The contrasting view, hereafter referred to as the "pioneer plant" hypothesis, is that planting sagebrush and other climax plants before sufficient soil improvement (biological and physical) has occurred predestines poor survival of climax plant seedlings. It is postulated that fourwing saltbush is a pioneer species that can be used to prepare the site for the later-seral species big sagebrush. Saltbush densities of one plant/m^2 may not exclude sagebrush, but instead may promote the soil improvement necessary for sagebrush to establish and survive. If this hypothetical relationship is valid, the most successful and economical method of obtaining healthy stands of sagebrush may be to initially plant a suitable pioneer species such as fourwing saltbush. The rationale for this view is: a) the perceived need for disturbed soils to regain, through effects of the pioneer species, predisturbance levels of VAM and other developmental attributes required to support sagebrush populations, and b) the beneficial modification of seedbed microclimate that may occur with the establishment of a pioneer shrub species. Fourwing saltbush has been previously proposed and justified as an effective pioneer species that will promote the desired soil and microclimate changes.

Comparisons of vegetation responses among the various treatment combinations will allow us to evaluate sagebrush establishment, survival and plant succession with and without fourwing saltbush as a pioneer species. If the exclusion hypothesis is true, there will be little interaction between topsoil and shrub seeding treatments. Plots seeded to sagebrush only will have the greatest, and plots seeded to fourwing saltbush will have the least, sagebrush development. Conversely, there will be significant topsoil and shrub seeding treatment interactions if the pioneer plant hypothesis is true. In that case, sagebrush development on stored topsoil should be greater where fourwing saltbush was established than where it was not. Sagebrush should also have greater development on the fresh topsoil than on stored topsoil. In all treatments, survival of sagebrush seedlings should increase as soils and plant communities develop. Proper evaluation of the pioneer plant theory will require additional years beyond the period covered by this proposal.

Progress Report

This project was initiated January 1, 1991 and is being carried out in cooperation with North Antelope Coal Company, north of Douglas. Mr. Scott Belden, Environmental Supervisor with North Antelope Coal Co., is our site coordinator. The project site has been selected, the spoil regraded and ripped, and the respective topsoil sources spread on the plots. The stockpiled topsoil used in the study had been stockpiled for 5 1/2 years and the other topsoil was "fresh", stripped and direct placed. Initial soil and spoil samples have been collected and evaluation is underway. The plots have been delineated, the stubble mulch treatments seeded, and the resulting stubble mulch evaluated (biomass and density). The small grain crop was mowed in July to remove seed heads to prevent seed development and subsequent volunteering that would result in future seedling/plant competition.

Microbiological analysis of the soil and spoil included an assessment of mycorrhizal inoculum potential (MIP) and Rhizobium inoculum potential (RIP). These assessments were conducted by growing yellow blossom sweetclover in pots containing a 3:1 mixture of sand to soil/spoil. After 10 weeks of growth, the roots were washed and any nodules present scored for Rhizobium infections (Williams, personal communication). They were then sectioned, stained, and examined under the microscope for the presence of mycorrhizal structures (Kormanik and McGraw, 1982). MIP is the percent mycorrhizal infection and was determined by counting the number of infected root segments per 100 segments observed.

MIP, but not RIP, exhibited a difference between soil and spoil. The spoil MIP was, as expected, much lower than for soil (only one spoil sample showed any mycorrhizal infection). In contrast to expectations, RIP was higher for stored topsoil than for freshly stripped topsoil. Less than a third of all soil (fresh and stored) samples showed any mycorrhizal infection. Thirty-three percent of yellow blossom sweetclover roots grown on fresh topsoil were infected, compared to 24% of those grown on stored topsoil. However, this difference was not statistically significant. Percent infection of any one sample was generally less than 30%, although two soil samples resulted in 55 and 93% infection of the sweetclover roots.

We did find a significant difference in RIP which appears related to the sequence in which the soils were laid down. This may require future comparisons to be adjusted to account for this baseline difference. A similar effect was not evident in the MIP data.

The soil and spoil samples are being analyzed for a number of chemical and physical parameters, however, analysis and data summarization are not completed.

Grass and fourwing saltbrush will be seeded this month and surface mulches applied. Sagebrush will be seeded in February or March.

Literature Cited

Kormanik, P.P. and A.C. McGraw. 1982. Qualification of the vesicular-arbuscular mycorrhizae in plant roots. pp. 37-45. In: N.C. Schenck. Methods and Principal of Micorrhizal Research. American Phytopathological Society. Saint Paul, MN.

THE ROLE OF NATURAL ORGANIC SOLUTES ON THE MOBILITY OF SELENIUM IN COAL MINE SPOIL-GROUND-WATER SYSTEMS

RANDOLPH B. SEE, K.J. REDDY, GEORGE F. VANCE
DAVID L. NAFTZ, AND AMR A. FADLEMAWLA

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SEMI-ANNUAL REPORT #2

THE ROLE OF NATURAL ORGANIC SOLUTES IN THE MOBILITY OF SELENIUM IN COAL MINE SPOIL-GROUND-WATER SYSTEMS

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David L. Naftz, U.S. Geological Survey
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SUBMITTED TO
THE ABANDONED COAL MINE LAND RESEARCH PROGRAM

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INTRODUCTION

Natural organic solutes may play an important role in the mobility of selenium in coal mine spoil and associated ground water. A better understanding of the processes involving organic solute-selenium interactions could provide information for improving coal mining reclamation techniques. The specific objectives of this research are:

1. To characterize inorganic and organic selenium species in coal mine spoil and associated ground water,
2. To determine the role of natural organic solutes on selenium adsorption/desorption and precipitation/dissolution processes, and
3. To quantify the effects of organic solutes on the mobility of selenium from coal mine spoil to ground water.

The information obtained from this research will increase our understanding of processes that influence the mobility of selenium in coal mine spoil and associated ground water.

STATEMENT OF WORK

The project is currently on schedule as planned in the project proposal. Site selection, sample collection, and preliminary analyses have been completed. Amr Fadlemawla has been selected as a Ph.D graduate student and will be an integral contributor to this research project. Additional assistance has been provided by student assistants and technicians.

SITE SELECTION

Field sites were selected after consultation with hydrologists and other scientists from the Wyoming Department of Environmental Quality, U.S. Geological Survey, and mining industry in Wyoming. All available data records were searched including annual mining reports, Gillette Area Groundwater Monitoring Organization annual reports, Wyoming Department of Environmental Quality data files, Wyoming Geological Survey data files, and the U.S. Geological Survey National Water Information System. After a thorough review of the available data on selenium concentrations, ground-water levels, and other factors, a limited number of potential field sites were identified. Field sites were selected from active coal mines in order to provide the maximum amount of background data for the study.

Three field sites were located in reclaimed areas at two large surface coal mines in the Powder River Basin. The mines will be referred to by letter designation (A and B) throughout this project because of agreements with the companies not to identify the mines by name. Two sites were investigated at mine A (A-1 and A-2) and one site was investigated at mine B (B-1).

FIELD SAMPLE COLLECTION

Quality Assurance

Quality assurance practices are essential to provide accurate interpretation and utilization of analytical data. Standard U.S. Geological Survey guidelines and quality-control procedures for collection and processing of spoil cores and ground-water samples were used.

Spoil Cores

Two spoil cores were obtained from within approximately a 15-foot radius of the well at each site. Core holes ranged from 22.5 to 27.5 feet deep and were at least as deep as the associated well. Drilling logs recorded sampling procedures and sample descriptions.

Spoil cores were collected by U.S. Geological Survey personnel using a rotary driven, split spoon auger. The auger head measured 8.6 inches in diameter and collected cores 3.25 inches in diameter. The core barrel extends approximately 3 inches beyond the auger head and rests on a bearing assembly which prevents the core barrel sampler from rotating. The device permits collection of a relatively undisturbed core sample.

Acrylic liners were used inside the core barrel to collect and subsequently store the spoil cores. The liners were purged with pre-purified argon gas and then sealed with plastic caps and tape to prevent oxidation of the spoil cores. Spoil cores were chilled in the field and stored under refrigeration at the University of Wyoming for subsequent laboratory experiments. Spoil core recoveries, spoil core subsamples, and depth to ground water are shown in figure 1.

Ground-Water Samples

Ground-water samples were collected at each associated well after the spoil cores were collected. Wells were pumped at approximately 1.2 gallons per minute with a positive displacement pump until pH, specific conductance and temperature were stable. Usually this was about 3 to 5 casing volumes of water. Analyses of water samples are presented in Table 1.

Ground-water samples were collected in 4-liter, high-density polyethylene bottles for laboratory analyses. Samples were filtered through 25 and 0.3 micron in-line filters; however, 0.3 micron filters burst under the filtering pressure. Sample bottles were purged with argon gas and filled under a stream of argon gas to avoid oxidation of the samples. Samples were chilled in the field with ice and subsequently stored at 4° C at the University of Wyoming. Because of the failure of the 0.3 micron filters, it may be necessary to collect additional ground-water samples. The ground water samples that have been collected will be used for preliminary laboratory experiments.

LABORATORY ANALYSES

Quality Assurance

Laboratory quality assurance will include the use of blanks, standard reference samples and spike recovery analyses. A total of 10 to 15 percent of the total analyses will be dedicated to quality control. A spoil reference sample will be developed from excess spoil material collected during the sample collection. An additional soil standard reference material has been developed by the U.S. Geological Survey using soils from the San Joaquin Valley, California. Water standard reference samples prepared by the U.S. Geological Survey Standard Reference Water Sample Project will also be included in analyses.

Spoil

Spoil core samples were removed from the acrylic collection tubes and divided into subsamples. Chemical and mineralogical analyses of spoil subsamples has not yet begun. These analyses will be performed in the laboratories of the University of Wyoming using methods described in the project proposal.

Ground Water

Ground-water samples were analyzed for dissolved organic carbon (DOC) and total selenium within one week of sampling (Table 1). Two of the ground-water samples (A-1 and B-1) contained adequate concentrations of DOC for isolation and fractionation studies. The DOC concentration of sample (A-2) was not sufficient for isolation, but can be fractionated. Isolation

and fractionation of the DOC will be conducted according to the methods described below.

Total selenium concentrations were found to parallel the DOC concentrations. Ground-water samples A-1 and B-1, which had high DOC concentrations, had selenium concentrations of 165 µg/L (A-1) and 63 µg/L (B-1). Ground-water sample A-2, which had a low DOC concentration, had a selenium concentration of 3 µg/L. Although sample A-2 had low DOC and selenium concentrations, the sample will be useful for studies of adsorption/desorption and precipitation/dissolution properties of the different spoil materials.

Adsorption/Desorption and Precipitation/Dissolution Studies

To examine the adsorption/desorption and precipitation/dissolution reactions in mine spoils and associated ground water we have designed a reaction cell in which pH and redox potential can be controlled. This unit consists of a sample chamber with platinum, pH and reference electrodes connected to a pH/millivolt meter. The meter is connected to a relay, which controls redox potential (±10 milliVolts) and pH (±0.1 unit) in the reaction cell. After the cell is purged with argon, samples will be placed in the reaction cell with a specified solid to solution ratio. Ground-water samples will not be diluted. Samples will be mixed at regular, timed intervals. The field pH and redox potential of the solutions will be used as initial control points. After reaction periods of 1, 3, 7, 14, 21, and 28 days, suspensions will be collected from the unit using a syringe assembly containing a 0.45 µm millipore filter. The filtrate will be stabilized immediately with acid and analyzed for total selenium, selenate, selenite, selenide, cations, and anions. Similarly, adsorption experiments will be conducted using the unit. The information obtained from these experiments will indicate the form of selenium present and its mobility in coal mining spoils and associated ground water.

Dissolved Organic Carbon

Ground-water samples will be analyzed for DOC fractions by using macroporous ionic and nonionic resin chromatography. The six DOC fractions include: hydrophobic acids, bases, and neutrals; and hydrophilic acids, bases, and neutrals. The dominant DOC fractions will also be isolated for use in studies to determine the influence of DOC on selenium adsorption/desorption properties of the spoil samples. Construction of the DOC fractionation columns is complete.

DOC was fractionated according to the method developed by Leenheer and Huffman (1979) that separates 6 DOC fractions: hydrophobic acids, bases and neutrals, and hydrophilic acids, bases, and neutrals. The results of the DOC fractionation analysis (Table 2) indicate DOC in the ground-water samples was dominated by organic acids (69 to 74 percent), organic neutrals ranged from 21 to 25 percent, and organic bases ranged from 4 to 11 percent. Because hydrophobic bases were a small percentage (0 to 2 percent), this analysis will be omitted in future analyses.

SUMMARY

Three field sites were selected and sampled at two surface coal mines. Two spoil cores and ground-water samples have been collected from each field site. Preliminary analyses of ground-water samples indicate that total selenium concentrations ranged from 3 to 165 µg/L and DOC concentrations ranged from 12 to 88 mg/L. Equipment and supplies for laboratory studies are available and the studies are progressing as planned.

REFERENCE

Leenheer, J.A. and Huffman, E.W.D., 1979, Analytical method for dissolved organic carbon fractionation:U.S. Geological Survey Water-Resources Investigation 79-4.

Table 1.-- Analytical results of ground-water samples.

Sample number	Field analyses					Laboratory analyses	
	Date	pH	Specific conductance (micro-Siemens/ centimeter)	Electrical potential (milliVolts)	Temper-ature (degrees Celsius)	Dissolved organic carbon (milligrams/ liter)	Total selenium micrograms/ liter)
A-1	9/17/91	7.1	10,000	350	11	88	165
A-2	9/17/91	5.5	5,000	450	10	12	3
B-1	9/18/91	6.3	3,650	400	10	87	63

Table 2. -- Dissolved organic carbon fractionation of ground-water samples.

Sample number	Hydrophobic solutes (percent)				Hydrophilic solutes (percent)			
	Total	Bases	Acids	Neutral	Total	Bases	Acids	Neutral
A-1	58.1	1.8	41.7	14.6	41.9	2.1	32.4	7.5
A-2	49.0	0.3	43.1	5.6	51.0	10.4	25.6	14.9
B-1	70.4	0.4	53.4	16.6	29.6	6.1	15.2	8.3

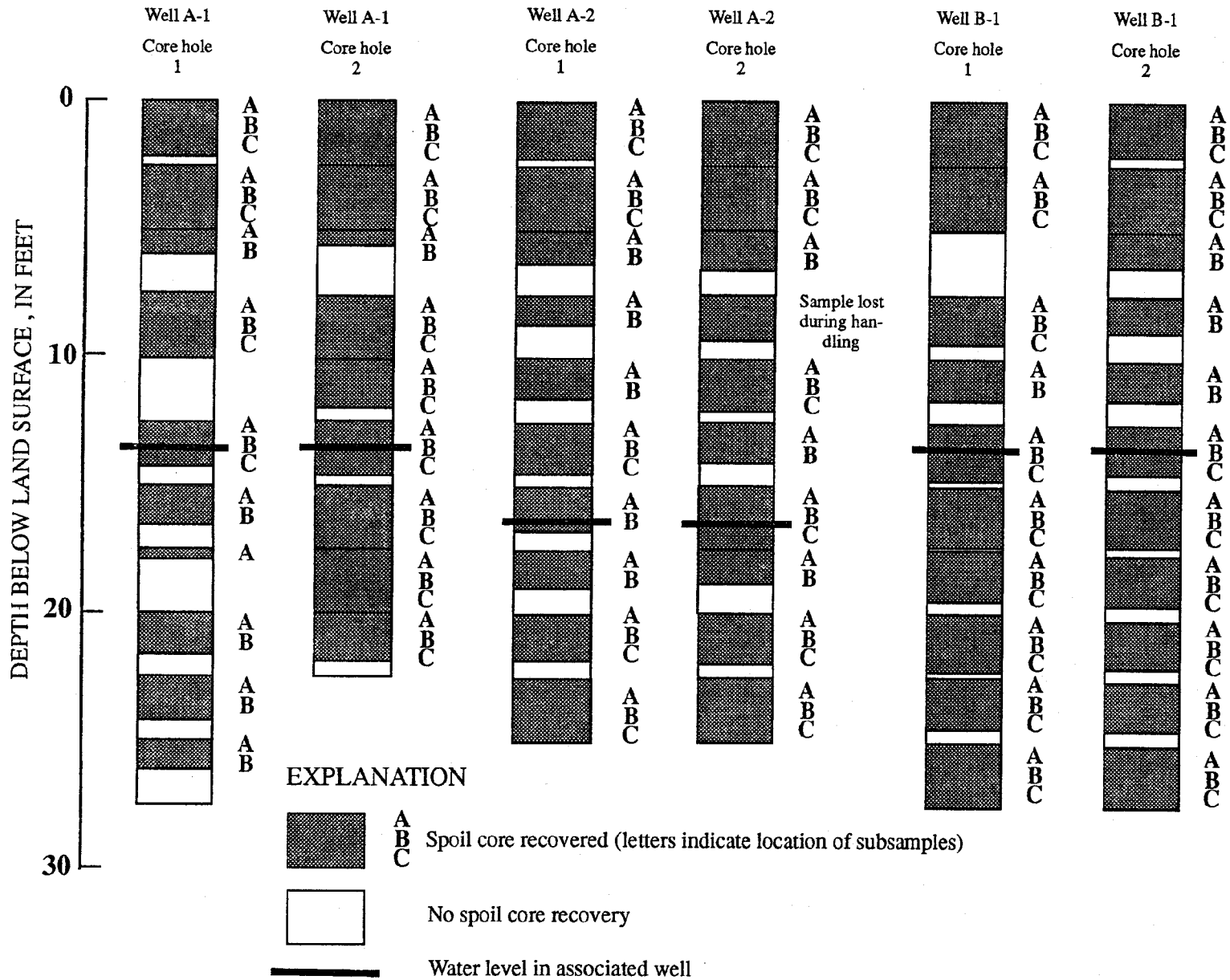

Figure 1. Spoil core recoveries, core subsamples and depth to ground water.

THE IMPORTANCE OF SOLID AND SOLUTION SELENIUM SPECIATION IN MOBILITY AND PLANT UPTAKE OF SELENIUM FROM WYOMING COAL MINE LAND RECLAMATION

GEORGE F. VANCE, KATTA J. REDDY, LOWELL K. SPACKMAN AND GORDON M. STURGEON

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Semi-Annual Project Report

for the

Abandoned Coal Mine Land Research Project

THE IMPORTANCE OF SOLID AND SOLUTION SELENIUM SPECIATION IN MOBILITY AND PLANT UPTAKE OF SELENIUM FROM WYOMING COAL MINE LAND RECLAMATION

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May 1, 1992

The Importance of Solid and Solution Selenium Speciation in Mobility and Plant Uptake of Selenium from Wyoming Coal Mine Land Reclamation

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INTRODUCTION

Environmental concern over selenium (Se) in abandoned and reclaimed mine land sites is due to the potential of Se becoming increasingly soluble with time. This would in turn influence the fate and behavior of Se in spoil, backfilled and reclaimed mine landscapes. During surface mining activities, materials previously in reducing environments are exposed to oxidizing conditions. The oxidation of Se can result in elevated levels of Se becoming available to plants, which might induce greater plant Se uptake and enhance the possibility of Se toxicity to animals. Increased solubility and mobility of Se in disturbed areas may result in higher levels of Se in surface waters, groundwaters and in resaturated backfill.

At present, we do not know the consequences coal mining activities will eventually have on wildlife and livestock. A majority of abandoned and reclaimed coal mine lands will ultimately be used for grazing, pastureland and wildlife habitat. Because Se bioaccumulation has been associated with certain aquatic environments, surface and ground waters with elevated Se concentrations are of concern. If the elevated concentration of Se do not attenuate, these abandoned and reclaimed areas may not be suitable for post-mining land use or may require special resource management considerations. Therefore, without appropriate Se research to ascertain the relationship between soil, spoil and overburden characteristics to Se uptake by plants and enhanced mobility, these questions cannot be reliably answered.

Selenium has been identified in native lands, reclaimed mine sites, and abandoned spoil materials throughout the Powder River Basin (PRB). The PRB is the focus of this study because of the occurrence of Se in these different environments.

OBJECTIVES

The objective of this research project is to examine the biogeochemistry of Se in abandoned and reclaimed coal mine sites and native lands. The project is divided into four research tasks:

1) development of a rapid and cost effective method for determining Se species in overburden, spoil and soil materials of abandoned and active coal mine sites,
2) examination of solid-phase and solution speciation of Se in the rooting-zone of mine soils for correlation to plant uptake,
3) characterization of Se adsorption/desorption and precipitation/dissolution processes controlling Se mobility in overburden, spoil, and soil environments,
4) determination of plant uptake of Se at coal mine lands and other affected sites that can be correlated to Se solid-phase and solution-phase speciation.

Selenium occurs naturally in several chemical forms. We propose that the analysis of the factors that control Se speciation and the direct analysis of Se species can be used to characterize and predict the processes that control Se solubility, mobility, availability, and plant

uptake. This information will assist in designing preventative and/or remediation schemes for abandoned, reclaimed and active coal mine lands.

Survey of Abandoned Coal Mine Lands in the Powder River Basin (PRB)

Sources of information used for locating research sites on abandoned and active coal mine lands included: 1) Abandoned Coal Mine Land Records, Department of Environmental Quality, Gary Beach; 2) Coal Map of the Powder River Basin and Adjacent Areas, Map Series 33, Geological Survey of Wyoming - contains the location of approximately fifty (50) abandoned surface coal mines or pits and fifty (50) active or proposed surface coal mine land sites; 3) Coal Mine permit records, Land Quality Division, Department of Environmental Quality; and 4) Western Water Consultants, Report of AML Project 15-I Investigation. A comprehensive description of our survey of potential abandoned coal mine sites is available in an interim report submitted to the Office of Research, University of Wyoming.

Site Selection

Site selection was based on access, permit information, records of reclamation by AML, land manager or owner willingness to help, and location. Data from the different sources listed above suggested that study sites were available in north, central and southern PRB. Initial study sites were selected and sampled during summer, 1991.

Field Work

Plant, soil, and spoil samples were collected from abandoned, reclaimed and native sites located in northern, central and southern regions of the PRB. Over 200 soil/spoil samples were taken from 37 research plots located in 10 transects from five mine sites. Three to four research plots were setup on each of the three abandoned, three native, and four reclaimed transects. Soil/spoil samples were collected at each research site based on the morphological differences observed in the field. Sufficient volume of soil was sampled at each depth so enough material would be available for analyses.

Non-woody portion of the plants sampled were clipped to obtain approximately 5-10 g of sample. Approximately five plant samples were collected from each of the research plots. A total of 189 plant samples of 59 different species were clipped, placed in ziplock plastic bags and immediately put on ice.

Photographs were taken at each research plot and site, location, topography, transect characteristics, and unique features were recorded. Upon completion of the field work, a document was produced that provided a general description of each transect, along with a listing of associated soil and plant samples and their respective Se contents, to summarize the project results to date. Plants were identified with the assistance of the Rocky Mountain Herbarium, University of Wyoming.

Laboratory Analyses

All the soil/spoil and plant samples have been logged in and prepared for complete chemical analysis. The plant samples were oven-dried at 50-60°C for 24 hours and

then ground to 60 mesh using a Wiley Mill. The soil/spoil samples were divided in two, using a Riffle Splitter, and one part was crushed with a hammer covered with cheese cloth and sieved to 10 mesh and the other sealed and stored. The samples collected from the abandoned research sites were given the highest priority.

Soil/Spoil and Plant Analysis

The chemical form of an element in an aqueous environment is important in determining its solubility, mobility, availability and environmental impact. Thus, the analytical determination of the concentrations of aqueous Se species in soil and spoil solutions is required to adequately predict its fate and behavior. Soil/spoil samples have been analyzed for total Se. Additional analyses currently being performed are: pH, texture, mineralogy, carbon, cation exchange capacity, base cations, and extractable Se. Soil and spoil samples from the abandoned mine research sites are being used for selective sequential extractions to determine the Se solid-phase speciation. Plant samples have been analyzed for total Se by digesting in nitric/perchloric acid mixture followed by Se analysis using an atomic adsorption/hydride generator technique.

Solid Phase Se Speciation: Mobility and plant uptake of Se are related to the rate and extent of soil and overburden material solubilization, and the resulting chemical speciation once in solution. Sequential extraction will determine soil and overburden solid-phase Se fractions by examining: 1) Soluble (0.25 M KCl), 2) Exchangeable (1 M KH_2PO_4), 3) Acid soluble (4 M HCl), 4) Sulfide and organic matter complexed (conc. HCl and microwave heating), and 5) silicaceous materials (HNO_3-$HCLO_4$-HF digestion). The first three extraction steps provide the most important information concerning soil-plant relationships. Step one will determine the water soluble fraction which is the fraction that best represents the soil solution. The KH_2PO_4 extraction defines the Se concentration that should be highly correlated with plant uptake and mobility. In addition, Se determined in step three provides the amount of Se that may be accessible over time and which may be solubilized readily by plant root interactions.

Precipitation/Dissolution Studies: Few studies have investigated precipitation/dissolution reactions of Se in soil/spoil materials due in part to the lack of adequate information on the Se species and solid phases expected to be present. Results of the precipitation/dissolution studies will be analyzed using the chemical speciation model MINTEQA2. The information obtained from these experiments will define the form of Se and its solubility and mobility in soil/spoil materials.

Adsorption/Precipitation Studies: Adsorption and precipitation reactions play an important role in controlling solution concentrations of Se in soil and overburden solutions. Selenium adsorption will be correlated to the chemical, mineralogical, and pedological properties of the geologic materials. Adsorption/desorption studies are currently being conducted. Both the adsorption/desorption and precipitation/dissolution studies will provide information useful for understanding Se solubility, mobility, and availability.

Selenium Extraction Methods: Results obtained through the application of a chemical extraction techniques will be used to test the relationship of Se in soil/spoils and plant contents. The extraction techniques applied in this study include hot-water, AB-DTPA, saturated paste and phosphate methods. The saturation paste extracts will be analyzed for Se species to determine which species correlates with Plant Se content.

Personnel Involved with Project

Doug Bonett, Associate Professor of Statistics, has been consulted for statistical analysis of this project. Shankar Sharmasarkar, Soil Chemistry masters degree candidate, will be joining the project. Additional personnel who are contributing to this project include a Research Associate and three undergraduate laboratory assistants.

Project Outcome

We anticipate the results of this research will provide the information necessary to predict the availability of Se to plants and the migration of Se to sensitive aqueous environments. This information can be used to aid in the development of suitability limits for regraded zone materials. The information may also be useful in designing remediation schemes by identifying materials which are locally available and that can fix mobile Se species. The identification of solid and solution phase Se species that plants accumulate can result in the development of methodologies to fix Se in plant unavailable forms. The results of this study should also provide a better indicator of where elevated Se spoil materials can be placed in the backfill (i.e. reduced, oxidized, or degree of saturation).

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RELATIONSHIP BETWEEN SOIL SELENIUM CONCENTRATIONS AND SELENIUM UPTAKE BY VEGETATION ON SURFACE COAL MINE LANDS IN WYOMING

ROGER N. PASCH, GEORGE F. VANCE, STEPHEN E. WILLIAMS
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RELATIONSHIP BETWEEN SOIL SELENIUM CONCENTRATIONS AND SELENIUM UPTAKE BY VEGETATION ON SURFACE COAL MINE LANDS IN WYOMING

Roger N. Pasch, George F. Vance, Stephen E. Williams, Margaret Stacy Page, Peter K. Carroll and Brenda K. Schladweiler

Introduction

Selenium is an important issue in regards to abandoned as well as active surface mine lands. Surface mining can affect soil/backfill selenium chemistry, which may influence soil-plant selenium relationships. Much of the backfill material that is brought to the surface during mining has AB-DTPA extractable selenium levels of 0.1 ug Se/g or more. This project will determine how relevant the surface mine land selenium issue is as well as the importance of selenium to current and future reclamation endeavors.

Objectives

The main objective of this project is to evaluate plant and soil/backfill selenium relationships. Project sites are located on an abandoned coal mine and two active coal mines located in the Powder River Basin, Wyoming. The abandoned coal mine site is located north of Sheridan and the two active coal mines are located south of Gillette. The specific objectives of this study are to determine:

1) What analytical procedures should be used to determine "soluble" (plant available) soil selenium and resulting plant selenium;

2) What forms of selenium are present in seleniferous soil, overburden and backfill materials and how these are related to plant uptake of selenium;

3) What impact chemical, physical and biological soil characteristics have on plant uptake of selenium;

4) How selenium content of native and revegetation species vary across a growing season;

5) What effect soil depth has on plant uptake of selenium;

6) What suitability limits should be set on selenium concentrations in backfill materials to be revegetated.

One abandoned and two active coal mine sites in the Powder River Basin were selected as the principle sites for this study. The advantage of involving active coal mines is that extensive soil sampling, overburden and backfill selenium data already exists.

The correlation between soil/backfill selenium levels determined from four different extraction methods and total selenium, and plant selenium levels (three different life forms) is being examined. Information from experimental sites located in native and reclaimed areas on active coal mines will be extrapolated to abandoned coal mine backfill and plants. The

information obtained from this study will be used to better understand those conditions that influence selenium uptake in plants. This is an important issue to both abandoned and active coal mine lands because it may indicate how backfill materials should be handled.

Methods of Analysis

The four methods of selenium extraction (AB-DTPA, hot water, phosphate extraction, and saturated paste) and total selenium are being evaluated to determine which would be the most reproducible and accurate for determining the effects of selenium uptake by plants. Examination of abandoned and active coal mine materials by these four methods will allow us to determine if a relationship exists between a specific extractant and plant selenium level. Soil/backfill depths and plant selenium concentrations are also being evaluated to determine if an identifiable and quantifiable relationship exists.

Vegetation and Soil/Backfill Sampling

Plant selenium levels on reclaimed abandoned coal mine sites near Sheridan and native and reclaimed sites at the Black Thunder and Coal Creek mines have been determined and are currently being analyzed to determine if there is a statistical correlation with soil/backfill selenium concentrations. In the first year of this project the following has been accomplished:

In June of 1991, four sites at the AML Project 8, Hidden Water, were sampled. The reclaimed area was seeded in 1985. Seeding was made directly into backfill material; no topsoil was present. Grasses and forbs, when available, were collected, sealed in plastic bags and kept frozen until processing. The vegetation samples contained between 0.10 ppm and 0.30 ppm selenium. No plant analysis contained higher than 5 ppm selenium. At the time of sampling, plants were at the flowering stage.

In early May, 1991, four vegetation and corresponding soil samples were gathered on each of four native sites at the Black Thunder Mine. At the same time, vegetation and soil information was gathered on nine reclaimed area sites. The reclaimed area samples were gathered in the North Pit at Black Thunder (reclaimed between 1982 and 1986). Three to four dominant plant species were collected from the native sites, while vegetation on the reclaimed areas were gathered as a composite sample. At the time of sampling, overall spring greenup was in its early stages due to below average precipitation in April and cooler than normal conditions.

In early June, 1991, an additional nine native vegetation sites were sampled at the Black Thunder Mine. Methodology was similar to that used during the May sampling for the native sites. Due to project constraints we were unable to sample vegetation during a single sampling period. This year we will sample the vegetation twice to determine the seasonal variability in plant selenium concentration.

In late June, 1991, ten native sites and eight reclaimed vegetation sites were sampled at the Coal Creek Mine. One reclaimed site was located in the reclaimed Section 16 scoria pit (reclaimed in 1981), three in the area known at the "east ballpark" (reclaimed in 1988), two in the area known as the "west ballpark" (reclaimed in 1990), and two west of the existing pit area (reclaimed in 1990). Due to the mine configuration and relatively small size, available reclaimed

area at Coal Creek is limited. Vegetation for both native and reclaimed sites was separated by the 3-4 dominant species. Samples were collected from within a 4 meter radius from the point of soil sampling.

In early July, 1991, 47 reclaimed sites at the Black Thunder mine were systematically placed and sampled by transect. These transects dissected reclaimed areas of various ages. In addition, 23 reclaimed sites were selected, based on past selenium analyses indicating high soil selenium. Vegetation for reclaimed areas sites was separated by the 3-4 dominant species in the vicinity of the soil sampling location.

Preliminary Findings

Several statistically significant (alpha = 0.05) relationships were noted from a preliminary analysis of 888 AB-DTPA extractable soil/backfill selenium results. First, there appears to be no significant difference in the AB-DTPA selenium concentration for each depth of the three holes sampled.

Preliminary analysis of plant and soil/backfill selenium correlations suggests there is a significant relationship between grasses, shrubs and forbs at a depth of approximately 30 cm or greater at the Coal Creek mine native sites. Correlations of results from Black Thunder mine native sites were only significant for the 0-30 cm depth for grasses and forbs, and 120-150 depth for shrubs.

On Coal Creek reclaimed sites, a significant correlation was noted between grasses and soil/backfill selenium at the 0-30 cm depth. A significant inverse trend was found for forb and soil/backfill selenium at the Coal Creek mine site. As soil/backfill selenium concentrations increased, the selenium content of the forbs decreased. An insufficient sampling of shrubs precluded a statistical analysis of this vegetation life form type.

On Black Thunder reclaimed sites, significant correlations were found between: soil/backfill and grasses at all depths; shrubs and the regraded backfill; and forbs only at the lower backfill depth (60-120 cm). Although the grass and forb relationships were statistically significant, they may not be biologically significant (i.e., statistically significant correlation ranged from 0.15 to 0.24).

The quality control/quality assurance program for this project indicates there is excellent agreement between results from Inter-Mountain Laboratories and the Soil Chemistry laboratory at University of Wyoming. For AB-DTPA, hot water, and phosphate extractable selenium, linear regression results indicated correlation coefficients were greater than 0.95.

Research Plan for 1992

Vegetation will be sampled from select native and reclaimed sites that were established in 1991. Vegetation will be collected twice this year to evaluate the seasonal effects on plant selenium concentrations. Based on 1991 methodology, sites will also be characterized to determine if there were major changes in vegetation patterns.

Last years data is being statistically analyzed to determine if other correlations exist. Plant species, cumulative depth, and correlations between the various extractants and plant selenium are a few of the evaluations to be done. In addition, we will also be evaluating the significance of sampling soil/backfill at three holes at each sampling location. This information will be used in developing the 1993 soil/backfill sampling procedure.

Two abstracts have been submitted for presentation of the initial project results.

1) Relationship Between Soil Selenium Concentrations and Selenium Uptake by Vegetation on Surface Coal Mine Lands in Wyoming - 1993 Billings Reclamation Conference.

2) Evaluation of Various Selenium Extraction Methods for Correlating Soil/Backfill Levels to Plant Concentrations - 1992 Soil Science Society of America Annual Meeting.

LONG-TERM STABILITY OF DESIGNED CHANNELS AT RECLAIMED COAL MINES IN WYOMING

SARA RATHBURN AND PAUL RECHARD

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Long-Term Stability of Designed Channels at Reclaimed Coal Mines in Wyoming

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Abandoned Coal Mine Land Research Program
Semi-Annual Project Review Seminar
Gillette, WY
May 20, 1992

Long-Term Stability of Designed Channels at Reclaimed Coal Mines in Wyoming

Abstract

Restoring the landscape to a stable configuration is central to the reclamation of abandoned coal mines in Wyoming. The success of reclaimed channels is dependent on balancing the forces of flowing water and the resistances of channel bed and banks. Channel design parameters most influential in stabilizing against long-term erosional processes include channel slope, channel dimensions (width, depth), and drainage density. Natural system analogs provide critical information on the balance between physical processes typical of a geographical area and the resultant channel forms. Long-term stability is indicated by natural, ephemeral channels because they evolve over extensive time periods under constant exposure to prevailing climatic conditions. Field study of three regions in Wyoming, where a majority of abandoned coals mines with channel reclamation cluster, will provide site-specific information on the relationships between channel and basin parameters that most influence design channel success. Undisturbed channel characteristics will be compared to design criteria and techniques employed at reclaimed coal sites with channel restoration work using statistically-based regression relations. A stability index for each reclaimed project site will be developed from deviations about the regression relation for undisturbed sites. Two known sites of gully initiation at reclaimed mine sites will verify the stability index. The indices will flag sites with the potential for instabilities, possibly averting future problems, and facilitating decisions of certifying AML sites complete. Recommended channel design criteria which provide for the greatest long-term stability will be presented.

INTRODUCTION

Approximately 125 coal mine sites have been reclaimed in Wyoming under the Abandoned Mine Land (AML) program, which oversees areas disrupted prior to the Surface Mine Reclamation Control Act of 1977. Of these 125 coal sites, 18 involved channel reconstruction work and generally cluster within three geographical areas near the towns of Rock Springs/Superior, Hanna, and Sheridan (Figure 1).

Designed channels at reclaimed coal mines in Wyoming have endured, at maximum, six years of surficial exposure; the first AML coal sites reclaimed were completed in 1985. Although six years is probably sufficient to test designed channels under low to moderate magnitude events, some sites may be certified complete without experiencing high magnitude events capable of inducing channel modification. As such, the long-term performance of reclaimed drainages remains largely unknown, presenting many uncertainties to reclamation specialists. A means of quantifying long-term erosional stability of reclaimed channels is needed.

A rigorous investigation of the physical controls on stable channel designs for ephemeral streams at reclaimed coal sites in Wyoming will be conducted. The approach and objectives of our proposed research includes:

1. An inventory of geomorphic and channel design criteria at reclaimed abandoned coal mines with channel rehabilitation work to understand previous reclamation practices. The compiled information will provide an easily accessible, useful reference document.
2. A field investigation of representative, unmined drainage basins and channel systems to define geographically-dependent criteria that provide for a dynamic equilibrium or stable condition.
3. Development of a stability index for reclaimed channels by statistically comparing design criteria employed at reclaimed AML coal sites with data obtained from geographically similar, unmined drainage systems. In this way, a measure of the relative potential for future instabilities at AML sites will be developed to guide management decisions. Documented gully development

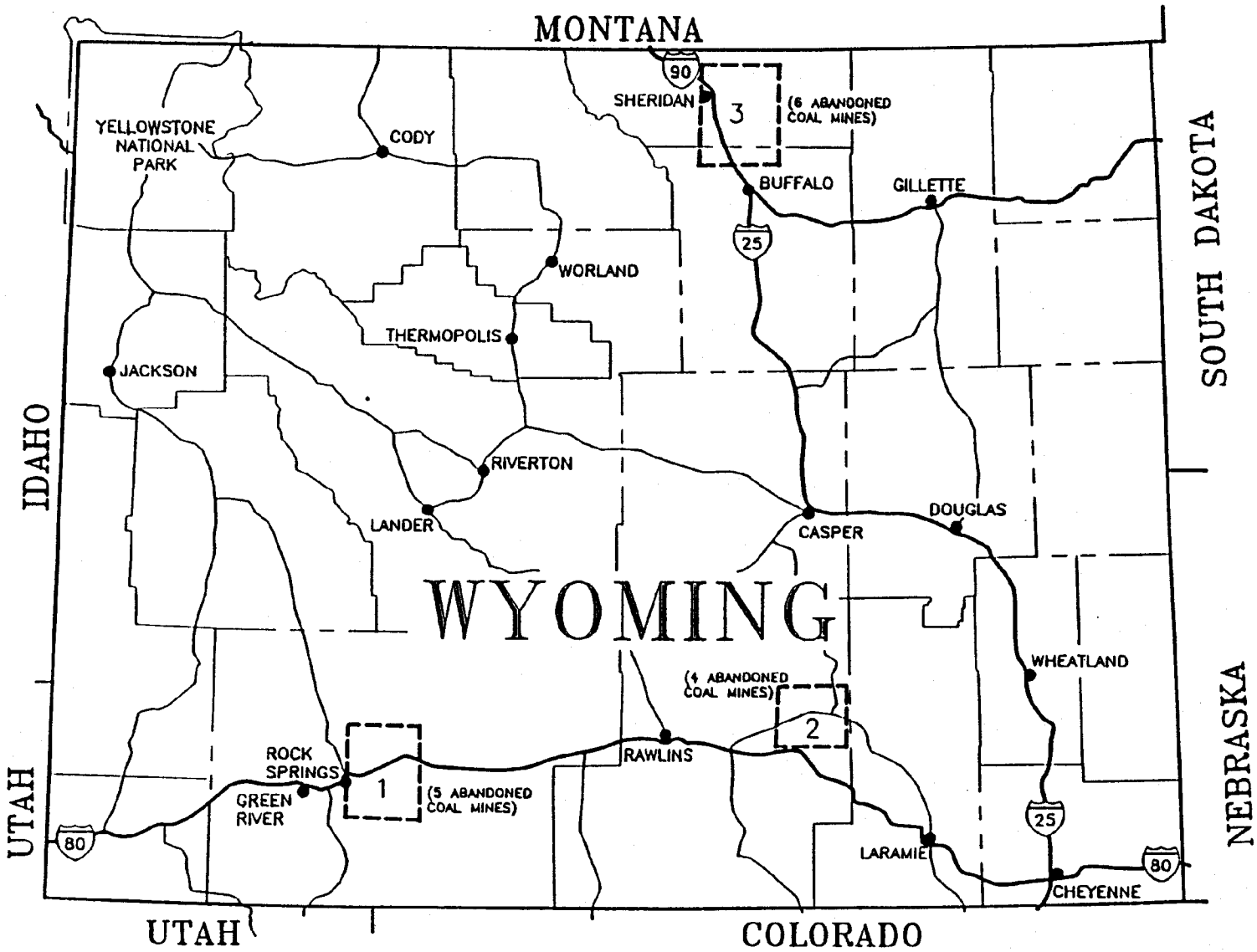

FIGURE 1. NATURAL ANALOG STUDY SITES BASED ON LOCATIONS OF RECLAIMED COAL MINES WITH CHANNEL RESTORATION

at two reclaimed coal sites will be useful in verifying and testing stability indices.

METHODOLOGY

Inventory Geomorphic and Channel Designs

A thorough review of geomorphic and channel design criteria will be conducted for the 18 reclaimed coal sites in Wyoming with channel reconstruction. At the present time, no comprehensive summary of channel reclamation techniques is available for these reclaimed sites. The inventory will elucidate consistencies or inconsistencies in channel design, and may indicate that a wide range of approaches have so far provided for relatively stable landform configurations.

The inventory will utilize existing documents in the AML library and site files maintained by AML personnel. We anticipate the need to calculate many geomorphic parameters from available maps.

Field Study of Natural Analogs

An aerial photographic and field assessment will be conducted on natural ephemeral channels within the vicinity of the reclaimed coal mines with channel restoration work. Natural, undisturbed drainage networks are representative of long-term stability, or geomorphic systems in dynamic equilibrium with imposed water and sediment loads. In the absence of baseline hydrologic conditions, such as at abandoned coal mines, adjacent, undisturbed channels provide natural analogs of pre-disturbance conditions. Valuable geomorphologic information such as drainage basin shape, drainage density, and stream order will be compiled from maps and aerial photographs of selected unmined sites.

A field inspection of each study site will follow to survey approximately 20-30 channel longitudinal profiles and cross section from natural ephemeral channels. A sizeable data set is desired to accurately identify important relationships between channel and basin variables that influence long-term stability.

Stability Index

The inventory and field data will allow linear regression analysis of documented relationships that best indicate stability of channels in natural systems. Confidence envelopes of 90 percent or greater will be developed around plots of natural channel relationships to define a range of stability that typifies Wyoming's semiarid environment.

By summing vertical deviations for each of the sites and comparing these to values determined for natural, undisturbed channels a quantitative index of long-term channel stability will be developed. The index will serve to quantify the disparities between design criteria inherent to natural drainage systems at the three study areas. The stability indices will be tested on two reclaimed sites that have undergone known gullying.

APPLICATION OF RESEARCH

Results of this research will provide a needed summary of information on channel design techniques and criteria at reclaimed coal mines. Channel design criteria which provide for the greatest long-term stability will be elucidated. In the event of future erosion or deposition that threatens channel integrity at reclaimed coal mines, a basis for understanding the cause of the problem and directing remedial action will be available. Also, Land Quality Division personnel confronted with bond release issues can utilize stability indices to evaluate long-term design channel performance.

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TOXICOLOGIC EVALUATION OF CHRONIC SELENOSIS IN WYOMING HERBIVORES

M.F. RAISBECK, D. O'TOOLE, E.L. BELDEN, J.W. WAGGONER, K. ZINN, AND E.T. THORNE

TOXICOLOGIC EVALUATION OF CHRONIC SELENOSIS IN WYOMING HERBIVORES

ACMLRP 5-39516

M. F. Raisbeck, D. O'Toole, E. L. Belden, J. W. Waggoner, K. Zinn, E. T. Thorne.

Semiannual Report, 5/20/92

Much of the extractable coal in the Northern Great Plains is closely associated with seleniferous shales. Disruption of these layers by surface mining and reclamation may result in elevated Se concentrations in surface waters and vegetation, and thus theoretically poses a long-term hazard to livestock and wildlife. Testing and special handling of "excessively" seleniferous materials has been mandated by the state to minimize this potential hazard.

The paucity of reliable data on the *chronic* effects of Se in mammalian livestock and wildlife is a major stumbling block to predicting selenium hazard from soil concentrations. Most of what is "known" about chronic selenosis is the result of uncritical repetitive citation of a few early reports. Much is possibly inaccurate.

The toxicology of seleno-amino acids (the predominate form of selenium in forage plants) has not been evaluated in ruminant livestock nor in wild mammals. Recently published data in other species suggests that selenomethionine and inorganic salts such as selenite are not equally toxic, qualitatively nor quantitatively. If the same holds true for major grazing grassland species such as antelope and cattle, it may be possible to devise a more rational paradigm to predict the hazard of

abandoned coal mine lands than is currently available. Additionally, this information *may* significantly impact the future reclamation of existing mines.

The overall objective of our intended research is to facilitate the prediction of selenosis in economically important herbivores in Wyoming. This overall objective is subdivided into several, interrelated short-term objectives:

a. Describe effect(s) of naturally occurring forms of Se on rumen function and the effect of rumen flora on the chemical form of ingested Se.

b. Describe the toxicity of selenomethionine in cattle and antelope.

c. Define the pathophysiology of chronic selenosis in two important species of primary consumers of seleniferous feeds.

d. Correlate findings of experimental studies with animals on seleniferous reclaimed pastures.

The toxicology literature contains numerous examples of unique sensitivity (or resistance) to naturally occurring toxicants conferred by rumen metabolism. In some instances, ruminal microflora convert a highly toxic substance such as aflatoxin to relatively less toxic metabolites. Conversely, rumen metabolism can convert relatively innocuous substances such as nitrate or urea to highly toxic products. We intend to discover the fate of Se in the rumen environment by following radiolabelled Se compounds through an artificial rumen model developed by the UW Departments of Animal Science and Veterinary

Science.

The predominant forms of Se in forage plant species (as opposed to "accumulator" plants) are as the seleno analogs of sulfur containing amino acids (especially selenomethionine). We have devised a series of experiments to determine the chronic health effects of dietary exposure to this compound in yearling steers and antelope. In addition to the relatively crude endpoints reported in the older literature, we will monitor several subclinical health indices such as immune function.

The major objective of this project is to better define the relationship between forage grown on seleniferous soils and animal health. Thus, the results of the second year's study will be validated with naturally seleniferous forage.

Although this project has been designed around reclaimed coal mine lands, a better understanding of chronic selenosis is directly applicable to other major segments of Wyoming's economy, notably agriculture and recreation.

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METHODOLOGY FOR THE GEOMORPHIC CLASSIFICATION AND DESIGN OF DRAINAGE BASINS AND STREAM CHANNELS IN THE POWDER RIVER COAL FIELD OF WYOMING

THOMAS WESCHE, HUGH LOWHAM, RICHARD DADDOW, AND MARK SMITH

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PROJECT SUMMARY

Prepared for

SEMI-ANNUAL PROJECT REVIEW SEMINAR

ABANDONED COAL MINE LANDS RESEARCH PROGRAM

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Gillette, Wyoming

Project Title

"Methodology for the Geomorphic Classification and Design of Drainage Basins and Stream Channels in the Powder River Coal Field of Wyoming"

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Project Duration

May 1, 1992 to June 30, 1994

PROJECT SUMMARY

The goal of drainage basin and stream channel reconstruction is to produce a drainage basin and stream network that is hydrologically similar to its natural, premining state; provides long-term stability; and requires minimal use and maintenance of erosion and sediment control structures. Procedures for designing drainage basins and stream channels have been developed for local areas but standardized methods have not been developed for regional application. The science of drainage basin and stream channel design is in the developmental stage.

The specific objectives of our study will be to:

1. Inventory, review, and summarize design procedures being used for reconstruction and reclamation of drainage basins and stream channels in the Powder River coal field of Wyoming, focusing especially on the type and extent of geomorphic approaches currently being used for reconstruction design;

2. Develop a classification system for drainage basins and stream channels in the Powder River coal field of Wyoming based on the natural, physical characteristics of selected groups of small drainage basins;

3. Analyze and summarize the geomorphic characteristics of different classes or types of drainage basins and stream channels, thereby developing geomorphic methodology and criteria for the design of reconstructed drainage basins and stream channels.

The results of this study will be published in a Final Executive Summary and as a U.S. Geological Survey - University of Wyoming technical report. This latter report will be prepared in a userguide manual format primarily geared for reclamation specialists and regulatory and land management agencies involved in mine land reclamation. Portions of these results will also be presented in two Master of Science theses at the University of Wyoming and several technical papers submitted to appropriate scientific journals for publication. The Project Schedule is presented on the following page.

PROJECT SCHEDULE

Activity	1992								1993												1994					
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Planning meetings	X		X			X		X			X			X			X			X			X			
Project reviews								X						X						X						X
Develop detailed work plan		X	X																							
Review existing data			X																							
Compile existing data			X	X																						
Select additional drainage basins					X	X																				
Classification analyses						X	X	X	X																	
Site visits			X	X										X	X	X										
Geomorphic analyses									X	X	X	X	X				X	X								
Develop relations/methods												X	X				X	X								
Prepare final report																			X	X	X	X				
Complete final report																										X

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