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A study of the diagenesis of the overburden between the Badger and School Coal Seams, Dave Johnston Coal Field, Converse County, Wyoming

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Title: A Study of the Diagenesis of the Overburden Between the Badger and School Coal Seams, Dave Johnston Coal Field, Converse County, Wyoming.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

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Marvin H. Beeson

Low pH zones in portions of the overburden at the Dave Johnston Coal Field, Converse County, Wyoming are the subject of this study. The low pH zones are restricted to limonite stained sandstones which grade downdip into normal pH gray sandstones. Changes in color, clay mineralogy, cementation and feldspar surface textures are noted between the two sandstone units. These changes appear to be the result of post depositional alteration that was responsible for oxidation of pyrite and chlorite, dissolu-

tion of calcite, and the etching of feldspar grains. The parameters for the diagenesis fit those of uranium roll front models proposed for the Powder River Basin. The alteration appears responsible for the low pH values reported in the yellow sandstone. Research by the North Dakota Geological Survey on similar problems associated with lignite mines in North Dakota suggests reclamation procedures for dealing with these potentially hazardous overburden spoils.

A STUDY OF THE DIAGENESIS OF THE OVERBURDEN BETWEEN THE BADGER AND SCHOOL COAL SEAMS, DAVE JOHNSTON COAL FIELD, CONVERSE COUNTY, WYOMING

by

REBECCA K. JAFFER

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University

1983

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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There were five people without whom this thesis would not have been completed. Their support, both financial and moral, ideas, suggestions, criticisms, and assistance made the last two years possible. It is with much gratitude I dedicate this study to Stevie D. (Steven Davis), Mom (Nina Haas), Velocity (Susan Hartford), derF (Fred Gullixson) and that funny looking blond kid (Richard Marty).

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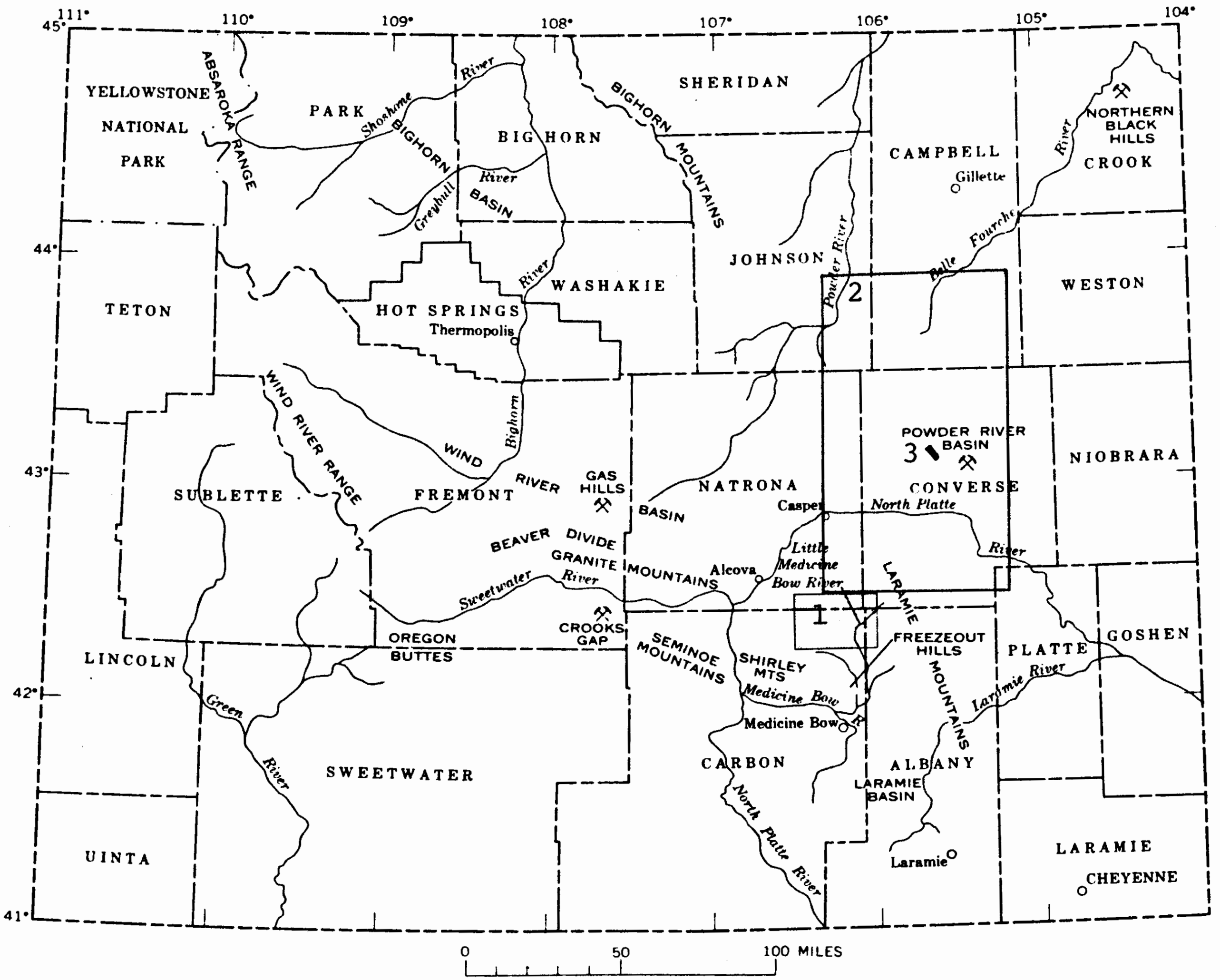
INTRODUCTION

PURPOSE

The purpose of this study was to identify the causes of low pH values in the overburden at the Dave Johnston Coal Field. To this end, the study concentrated on identifying possible sources for the apparent alteration of some of the overburden sandstones in which the low pH values appear to be centered. The study sought to identify parameters defined by the alteration in the sandstones and the possible affects the alteration system could have had on the mineralogy, Eh, pH and ion distribution in the sandstones. A detailed diagenetic study was not possible due to the inability to obtain whole rock samples which would have facilitated the study of relationships between porosity, authigenic clays and alteration.

LOCATION AND STRATIGRAPHIC BACKGROUND

The Dave Johnston Coal Field is located in east central Wyoming, near the southwestern edge of the Powder River Basin (see Figure 1). The Powder River Basin is a broad, asymmetric syncline, which occupies the northeastern corner of Wyoming and adjacent parts of Montana and South



1. Davis 1969
   Study Area

2. Harshman 1972
   Study Area

3. Dave Johnston
   Coal Field

Figure 1. Map of Wyoming showing the locations of studies cited in this thesis.

Dakota. The basin is bounded by the Bighorn Mountains on the west, the Black Hills to the east, and the Casper Arch, Laramie Mountains, and Hartville Uplift to the south. Northward the basin is separated from the Williston Basin by the Miles City Arch.

The Dave Johnston Coal Field is located approximately twelve miles north of Glenrock, Wyoming (see Figure 2). The mine is operated under the auspices of the NERCO Mining Company, and extracts coal from the Badger and School coal seams (see Plate I). The mine area is in Converse County, crossing Townships 35 and 36 N, and Ranges 74 and 75 W.

The two coal seams occur in the lower Eocene Wasatch Formation (Denson, Dover, and Osmonson, 1980). The Wasatch, 1000 to 2000 feet thick, comprises loosely consolidated sandstones, siltstones, claystones and coal of continental origin (Project Report 1980; Glass, 1981). The sediments are considered to have been deposited on low lying flood plains, estuaries, sloughs and swamps. Lenticular cross bedded sandstones with interbedded siltstones, claystones and coal beds make up the stratigraphic section in the Dave Johnston Coal Field. Lithologic logs from drill holes within the mine area describe the sandstones as poorly sorted and interbedded with layers of fine-grained sandstones and siltstones. Pyrite is noted as small cubes and "globs" in lithologic logs of reduced (gray) sediments.

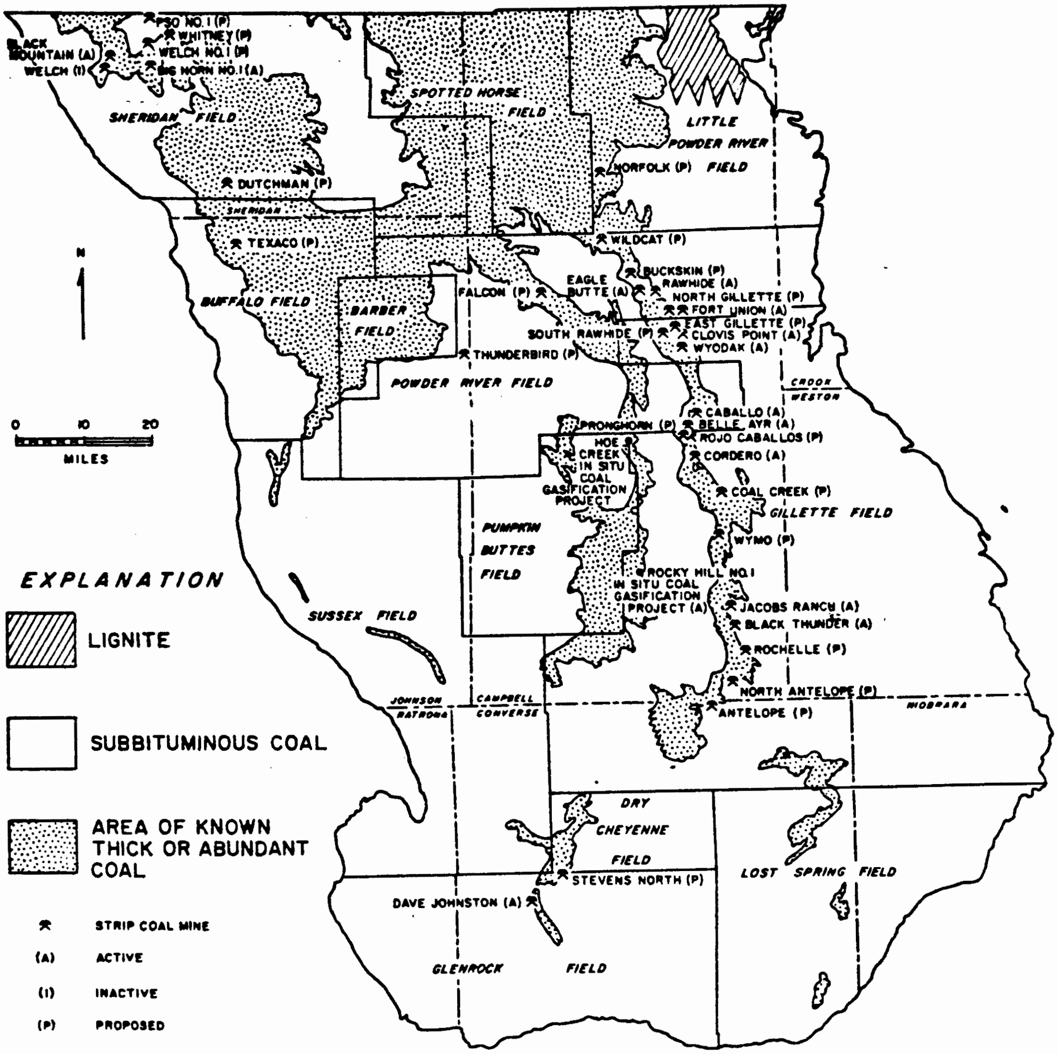


Figure 2. Map of the Powder River Basin showing the location of known coal reserves (from Glass 1981).

The overburden between the Badger and School coal seams is composed of coarse- to fine-grained sandstones, siltstones and claystones. The depositional environment has been described as a fluvial meander belt system, and the coals are considered to have formed in back swamps of flood basins adjacent to meandering river channels (Ethridge, Jackson, and Youngberg, 1981; Flores and Ethridge, 1981).

OVERVIEW OF SURFACE MINING

The Badger coal seam is at or near the surface in the mine area. The dip of the coal bed and enclosing strata is very gentle (1 to 4 degrees) eastward, toward the axis of the Powder River Basin. Dave Johnston is a surface coal mine and is mined in a box-cut manner. Surface mining entails digging a trench, or cut, through the overburden to the depth of the coal seam which is then removed. Since two seams are economically mineable at Dave Johnston, the process is repeated after the removal of the Badger coal to expose the lower School seam. With each successive cut, the overburden debris (spoil) from the new cut is deposited in the cut previously excavated. Thus the overburden is broken up, transported and dumped for later recontouring and reclamation.

In preparation for mining, exploratory wells are drilled to sample the coal quality and seam thickness in advance of the trench cut. Also sampled is the overburden above and between the coal seams. The sample drill cores of the overburden are analyzed for toxic or hazardous materials. Portions of the analyses are done to help pinpoint potential problems in mine reclamation.

PROBLEM AND PROCEDURE

At the Dave Johnston mine, overburden drill core analyses have shown low pH values in significant portions of the overburden between the Badger and School coal seams. The acidic nature of the overburden (pH values of 3.2 to 5.0) could cause problems during reclamation and may require special handling of the material (Michael Woods, pers. comm., 1981). Vegetation is difficult to re-establish in acidic soils, and there is a potential of ground water contamination during and after the mining process.

The acidic zones of the overburden were shown to be restricted to sandstone units in an in-house study at NERCO during the summer of 1981 (see Plate II). These units are usually orangish yellow, medium- to coarse-grained, limonite stained, poorly to moderately indurated, angular to subrounded sandstones. To the north a gray, well indurated sandstone is found. The gray sandstones consistently have a "normal" pH range of 5.0 to 8.0. If these two sandstones are laterally and stratigraphically continuous, presumably they are the same unit. If they are the same, the changes in color and cementation could have been caused by some type of weathering, groundwater percolation or mineralizing event.

Several cross sections show the interfingering nature of the yellow and gray sandstones, with the gray sandstone occupying a downdip relationship to the yellow (see Plate III and Figures 3 and 4). During the course of the overburden study at NERCO, several hypotheses to explain the presence of limonite and low pH zones in the yellow sandstones were discussed. The presence of uranium prospects to the west of the mine area and the known occurrence of uranium mineralization in the Powder River Basin and in the Wasatch Formation, suggested a study of the characteristics of uranium roll front mineralization.

A determination of the stratigraphic relationship between the yellow and gray sandstone was made in this study. Along with the stratigraphic and petrologic examination of drill core data, the chemical and clay mineralogical characteristics were studied. The information obtained through these studies was then examined in an effort to identify the parameters of alteration in the overburden sandstones. A model for alteration was developed and tested against the results of the study. Finally, an effort was made to assess the possible effects of the chemical and physical changes in the overburden on reclamation at the Dave Johnston Coal Field.

The samples used in this study were untreated

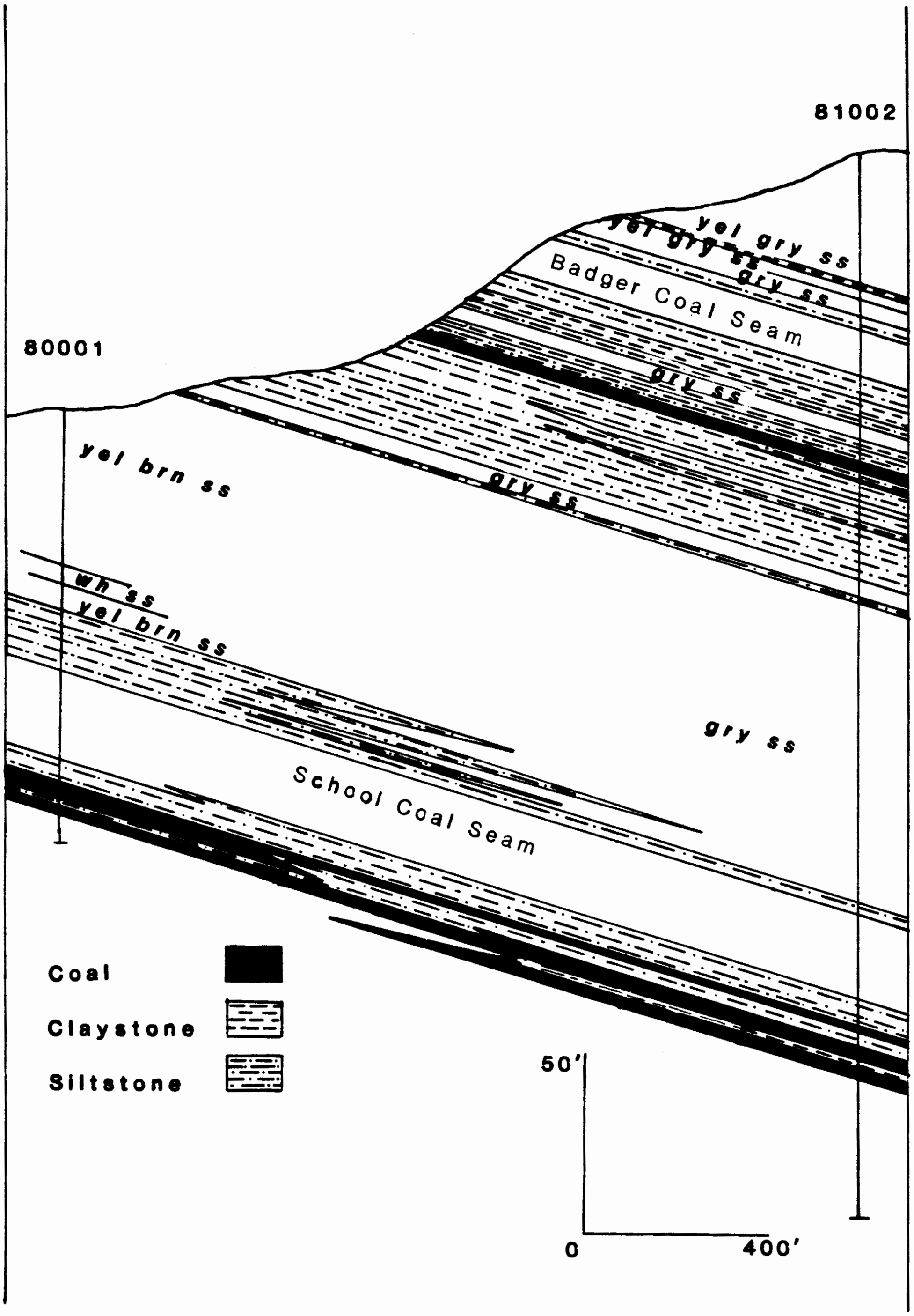


Figure 3. Cross section between drill holes 80001 and 81002 showing the relationship of the strata and the yellow and gray sandstone.

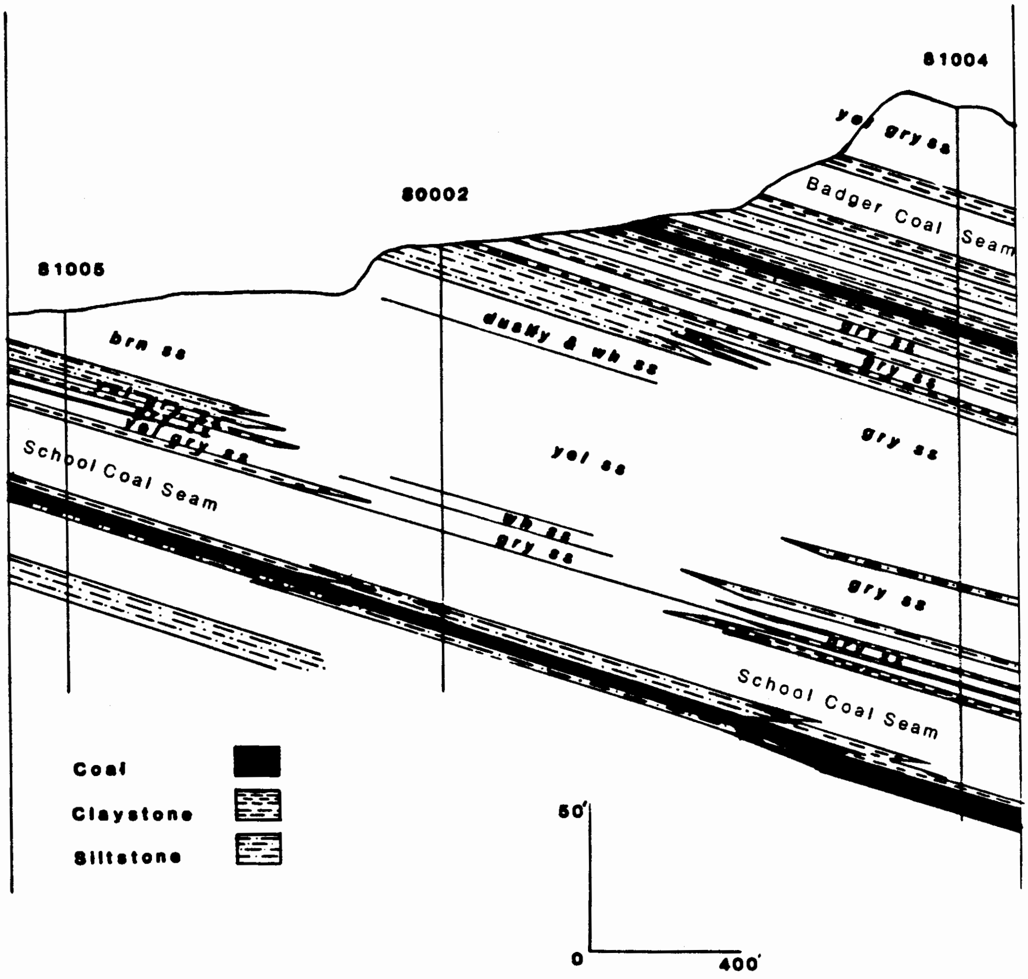


Figure 4. Cross section between drill holes 81005, 80002 and 81004 showing the relationship of the strata and the yellow and gray sandstone.

disaggregated portions of the drill core from ten overburden core holes (for locations see Plate I). They were obtained from Energy Laboratories of Billings, Montana. The procedures for overburden sampling is outlined in the Wyoming Department of Environmental Quality, Land Quality Division, Guideline No. 1, and the pertinent portions are presented in Appendix 1. The fifty-six samples used in this study were chosen to provide sample coverage in each drill hole of low and normal pH zones, and yellow and gray sandstone units.

Procedures used in this study did not require any initial treatment of the disaggregated samples. Specific methods of preparation for a particular study are outlined in the chapter pertaining to the study. Chemical values, including the pH and ion concentrations, were obtained from the chemical analyses prepared by Energy Laboratories according to the procedures recommended by the Wyoming D.E.Q. (see Appendix 1).

Methods used in this study included x-ray diffraction studies of the overburden clays and clay minerals from samples of overburden drill cores. An attempt was made to track metal ion movement in relation to a mineralizing front using data from the overburden analyses of each drill core. Petrographic study of grain mounts from the core samples was used in conjunction with cross sections to try to establish stratigraphic sequence and continuity of the overburden units. Scanning electron microscopy was used to study textures on feldspar grains in the yellow and gray sandstones, as well as in identifying clay types.

CHAPTER 2

STRATIGRAPHIC CORRELATION

Stratigraphic control in the Dave Johnston Coal Field is based on logs and cores from wells drilled on two hundred foot centers. The continuity of the Badger and School coal seams, their thicknesses and variations have been mapped with great care. Coal quality is assessed as well, and all of this information is brought together in determining the amount and grade of coal to be mined each year. The "mine plan" is thus the result of an extensive drilling program.

The Wasatch Formation is the result of fluvial sedimentation (Ethridge and others, 1981; Flores and Ethridge, 1981), and the Dave Johnston Coal Field represents a small portion of a very large fluvial system (see Figure 5). The drainage patterns during the Eocene were quite similar to those developed during the Paleocene (Ethridge and others, 1981) as shown in Figure 6. Within a fluvial sedimentary system several facies can exist in a relatively small area, leading to complex intertonguing of sand, silt, clay and carbonaceous layers (see Figure 7). Depositional models developed by Ethridge and others (1981) and by Groenewold, Rehm, and Cherry (1981) illustrate how meandering and

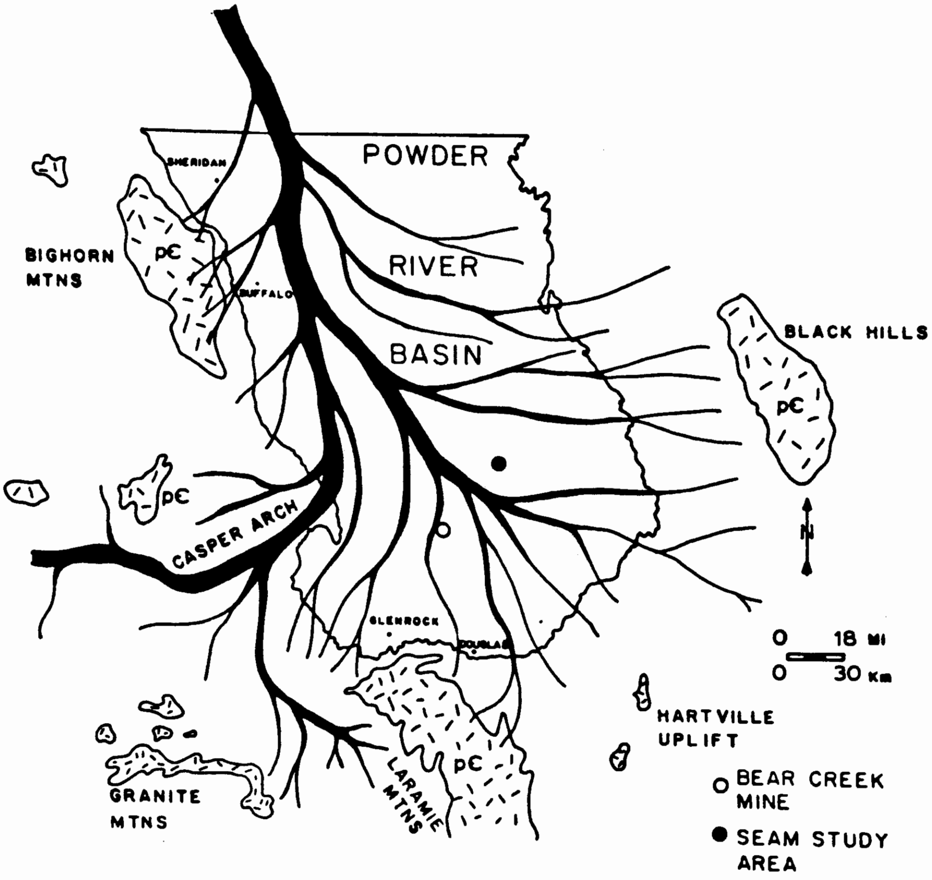


Figure 5. Interpretive map of Eocene paleogeography of northeastern Wyoming suggesting a general drainage pattern for Wasatch streams. The southeastern portion of the Powder River Basin is dominated by floodbasin deposits (crevasse splay, swamp, and lake) and meandering channels of tributary streams (from Ethridge and others 1981).

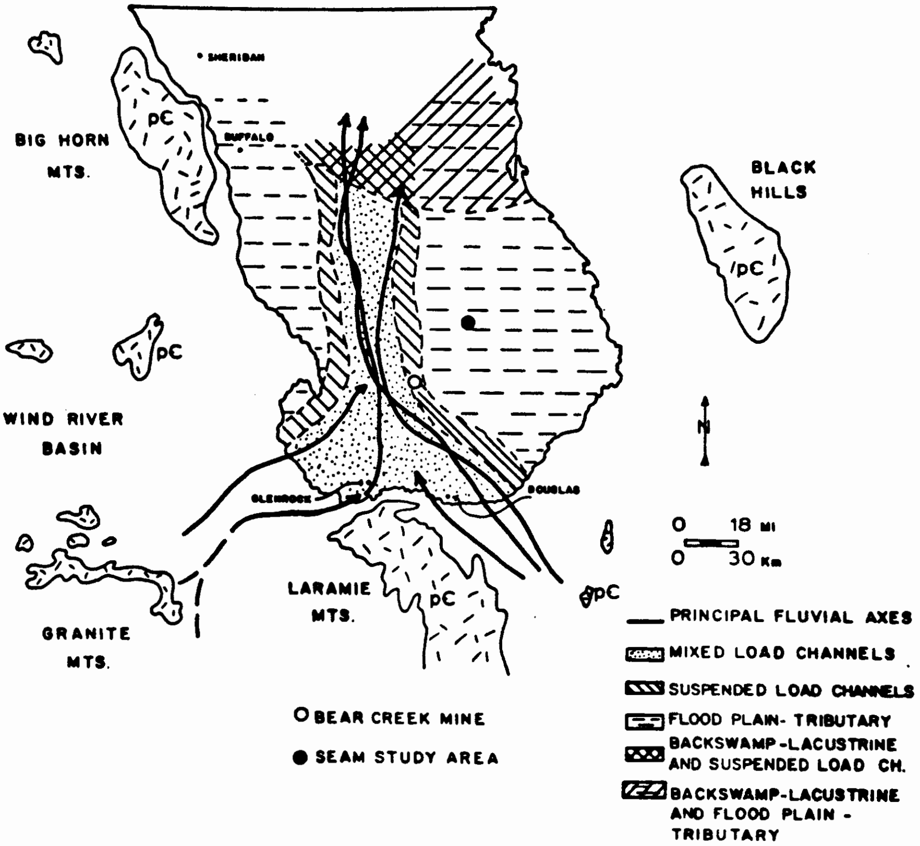


Figure 6. Inferred depositional system and subsystems for the upper part of the Fort Union Formation (Paleocene). The depositional setting of the Eocene Wasatch is thought by Ethridge and others (1981) to have been quite similar to the flood-plain-tributary system shown here (from Ethridge and others 1981).

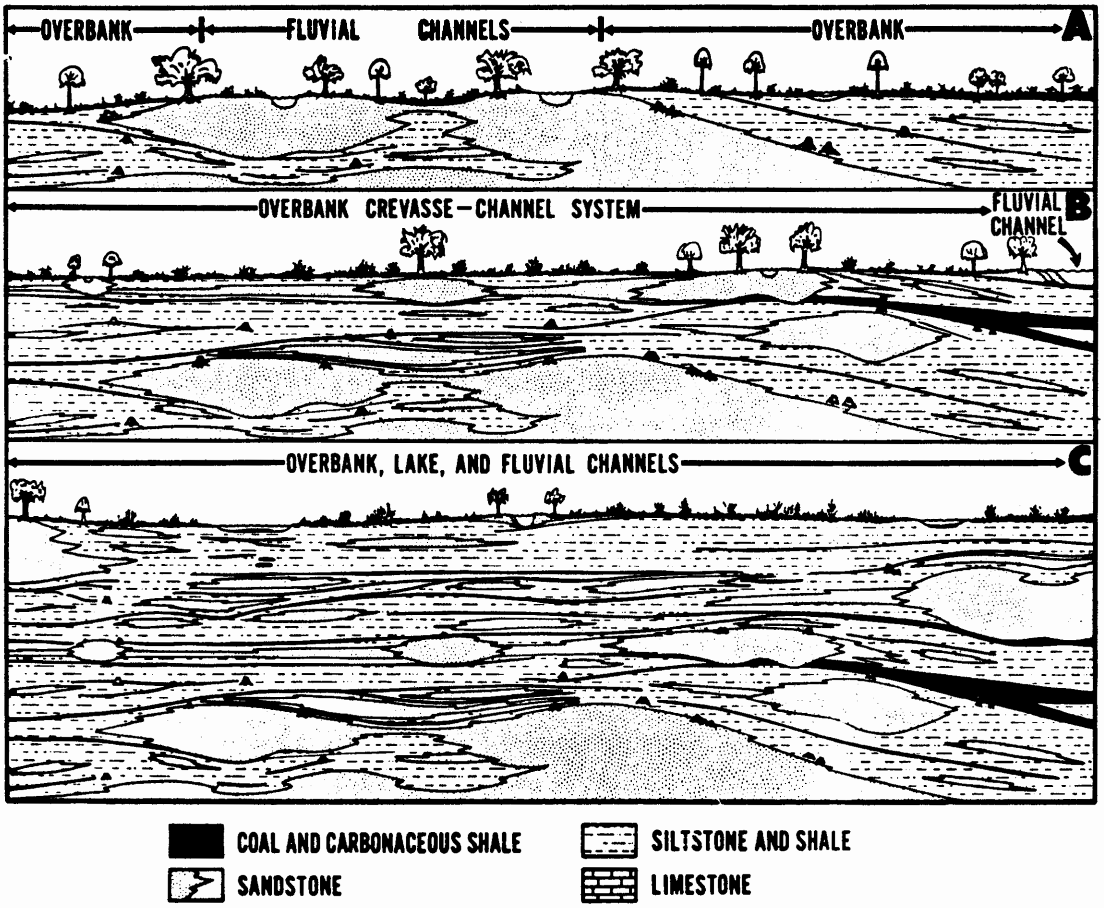


Figure 7. Complex lithogenetic model developed for a fluvial-channel-dominated facies in a portion of the Tongue River Member of the Fort Union Formation (from Flores 1981).

channeling by a stream, coupled with poorly drained swamp areas, can produce an intricate stratigraphic section of sandstone, siltstone, claystone and coal. Their models are shown in Figures 8 and 9. Cross sectional views within the Dave Johnston Coal Field show remarkable agreement with those envisioned by Ethridge and others (1981) and with their depositional model. The longitudinal cross section (Plates II and III) as well as Figures 3 and 4, record the meandering of a stream system between the deposition of the School and Badger coal seams. The silt and claystone units represent the filling in of meanders, while the absence of fine-grained units in Overburden Drill Hole 80002 corresponds to a crevasse splay deposit.

To establish the continuity of the sandstones in this study, the data from ten overburden drill holes were used to draw cross section views, both parallel and perpendicular to strike, establishing spatial relationships. Two transverse cross sections readily show the stratigraphic relationships of the yellow and gray sandstones. The gray sandstone is downdip, to the east, from the yellow. The relationships are not as clear on the longitudinal section (Plate II), but a sandstone layer can be followed throughout the section at approximately fifty feet above the top of the School seam. Plate II was drawn using the top of the School seam as the datum plane and better illustrates the continuity of the sandstone above the coal seam. The

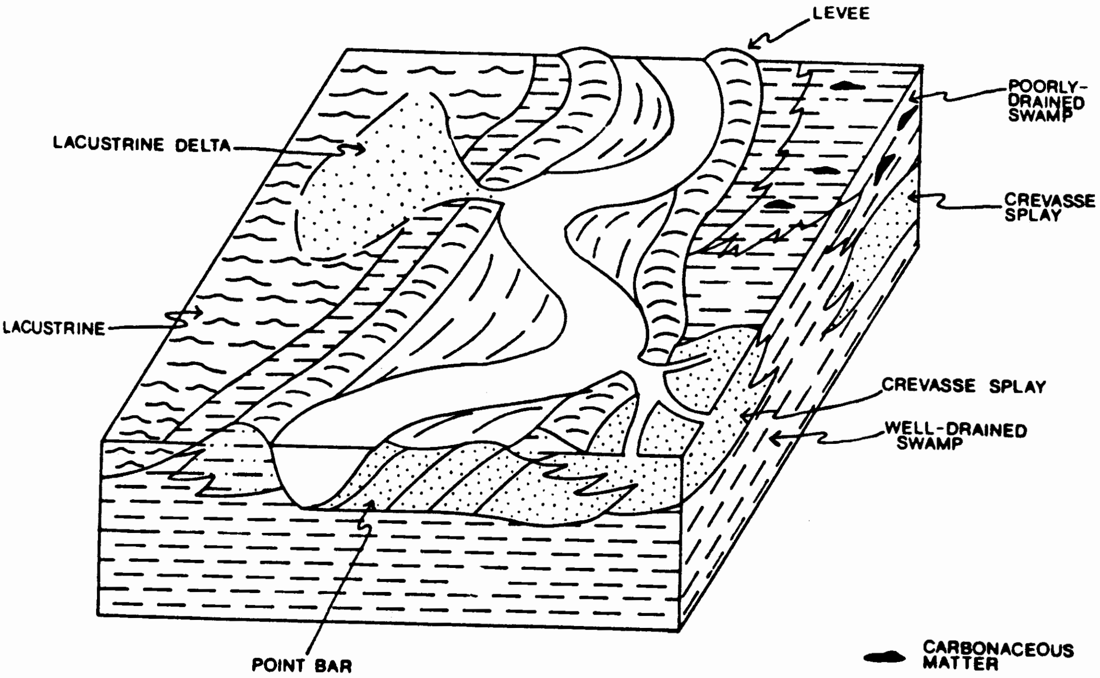


Figure 8. Schematic reconstruction of inferred depositional environments in the tributary subsystem, lower Wasatch Formation, in the SEAM Study Area of Wthridge and others (1981), northeast of the Dave Johnston Coal Field. Sketch shows the intricate relationships of sand, silt, clay and carbonaceous material that develop in a fluvial-channel environment (from Ethridge and others 1981).

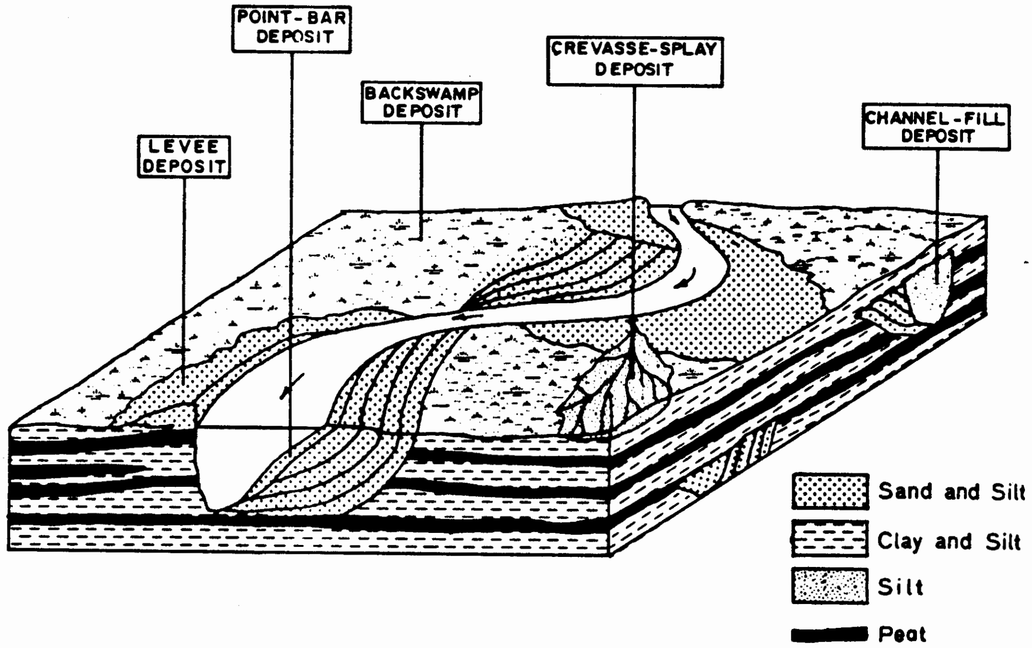


Figure 9. Depositional model developed for low-gradient meandering streams in alluvial flood plain environments (from Groenewold and others 1981).

change in sandstone color in the longitudinal sections probably is the result of both downdip movements of oxidizing solutions and weathering (oxidation) of the sandstones due to erosion of the fine-grained capping layers (see Harshman, 1972).

PETROGRAPHY

Sixteen samples were chosen for preparation of grain mounts, in hopes that a petrographic examination would further establish the uniformity and continuity of the sandstone beds between the School and Badger coal seams. Each sample was sieved and divided into 1-2 phi and 2-4 phi size classes. The sands are predominantly quartz and feldspar, with a few opaques. The quartz grains were chosen as easily identifiable and were counted as rutilated quartz, recrystallized quartz and chert, and other quartz. Results of the grain mount study are included in Table 1. Pyrite cubes were identified under reflected light in several of the grain mounts of the gray sandstones, but not in the mounts from the yellow samples.

Microscopic examination of the grain mounts did show rutilated quartz in all samples, with an average proportion of 13%. Recrystallized quartz and chert also gave a fairly steady value of about 10% in all samples. The feldspar counts varied considerably, with a corresponding inverse variation in the amount of limonite and limonite coated fragments in a given sample.

Table 1 Grain Mount Results

	81006		81005			81004		81003	81002	81001	80006	80004	80002		80001	
	OB 9	OB 10	OB 4	OB 5	OB 6	OB 15	OB 19	OB 10	OB 12	OB 8	OB 6	OB 8	OB 6	OB 10	OB 4	OB 5
Rutilated Quartz	22 13	18 9	15 13	13 16	18 13	17 9	11 14	22 10	3 9	17 4	19 13	15 10	9 3	9 18	17 11	12 10
Recrystallized Qtz	5 10	6 9	22 15	14 11	9 7	13 17	16 7	5 10	14 11	7 11	9 10	7 10	16 12	7 7	13 13	7 7
Other Quartz	28 44	26 42	21 39	21 36	21 27	23 37	26 36	28 33	34 51	33 50	22 44	23 37	17 20	29 26	34 48	26 35
Feldspar	35 21	22 17	8 7	5 7	26 22	25 19	29 22	35 29	7 9	20 14	26 21	26 22	12 10	19 26	14 14	25 25
Limonite	1 3	1 1	10 11	7 9	9 9	1 7	3 4	1 7	11 7	3 5	0 3	7 5	13 13	14 6	6 2	12 12
Limonite Clots	4 1	15 2	15 9	34 15	9 15	5 2	2 1	4 3	26 5	15 7	13 1	16 6	24 31	11 9	11 5	11 3
Opaques	2 3	1 3	5 4	5 5	3 3	6 5	10 11	2 3	1 5	2 3	6 3	3 5	4 7	1 3	3 4	1 6
Other	3 5	12 17	4 2	1 1	5 4	10 4	3 5	3 5	4 2	3 6	5 5	3 5	5 4	9 5	2 3	6 2
pH	6.6	7.2	3.9	3.3	3.5	7.2	7.3	4.1	7.4	3.5	6.4	4.4	6.9	6.5	4.5	4.2
Color	gry	gry	yel	yel	yel	gry	gry	yel	gry	yel	yel	yel	wh	wh	yel	yel
Phi size	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4	1-2 2-4

The grain mounts indicate very similar, if not the same, provenance for the sandstones. Since whole rock samples were not available for this study, it was not possible to do more detailed petrographic studies of the sandstones which might have served to better illustrate the petrologic equivalence of the various samples.

However, the stratigraphic control and lateral continuity of the affected sandstones can be easily seen in the cross sections perpendicular to strike. In the 1400 feet separating Overburden Drill Hole 80002 and 81004 (see Figure 4), the drillhole data does not show any abrupt changes in lithology, but rather lithologies that correspond very closely. The major changes in the sandstone unit between the coal seams are in the color and pH values. The same changes are found in the same sandstone unit between holes 80001 and 81002 as seen in Figure 3.

The decrease in feldspars in some of the samples shows the effect of an acidic environment. The feldspar grains that are recognizable in these grain mounts are corroded and heavily coated with limonite and clay. Several clots were probably feldspar grains, but are now indistinguishable clumps of limonite and clay. Recognizable feldspar grains from these samples also show etching along cleavage traces. Samples taken from yellow sandstones show a decrease in feldspars and an increase in the number of grains identified as limonite and limonite clots. The samples taken from gray sandstones have a greater percentage of feldspars, as well as fresher, less corroded feldspar grains (see Figure 10). The gray sandstones were not subjected to acidic or oxidizing changes in environment.

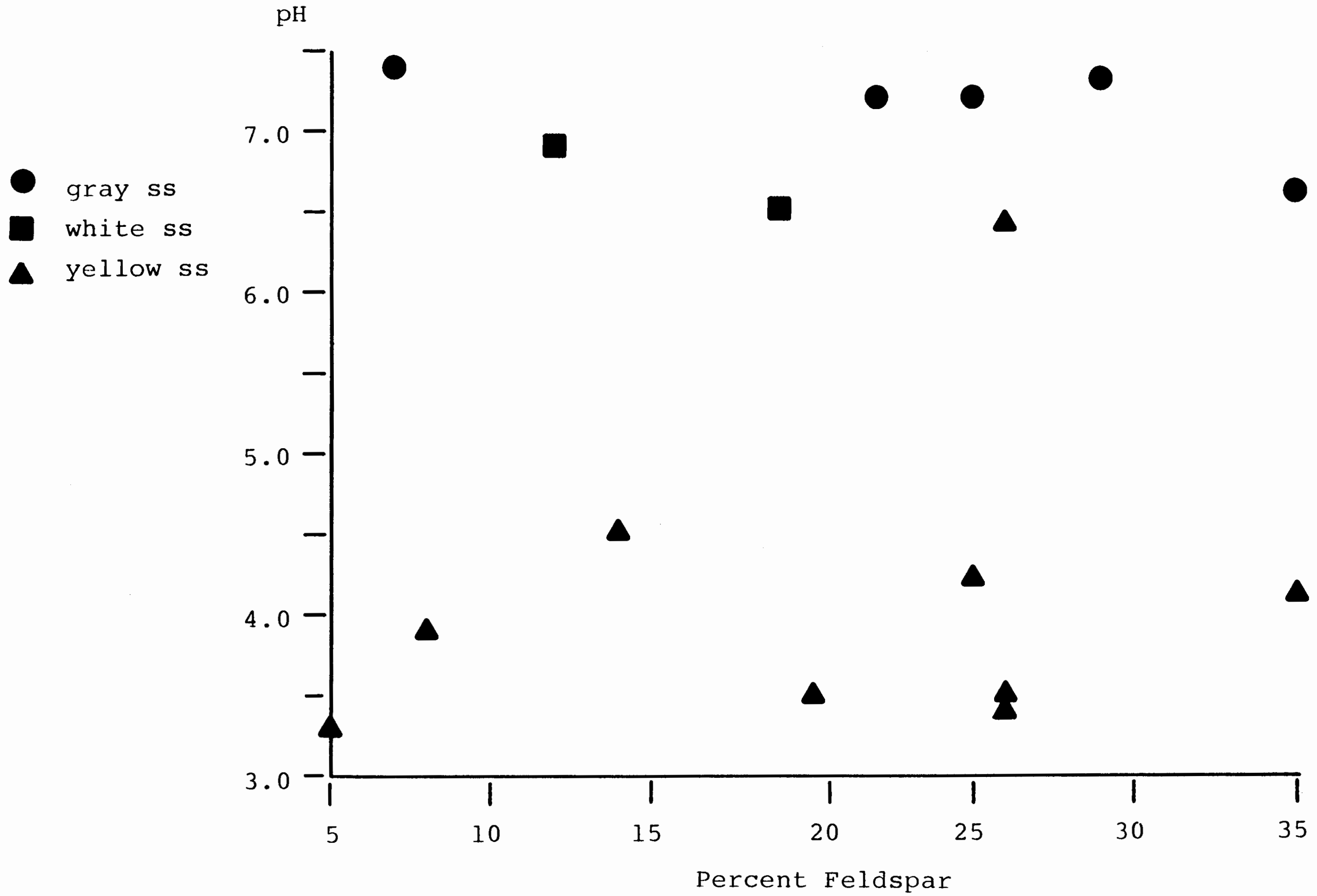


Figure 10. Plot of 1-2 phi size grain mount data, pH versus percent feldspar.

CHAPTER 3

CLAY MINERALOGY

Analysis of the clays in the overburden at Dave Johnston Coal Field was made by x-ray diffraction studies of fifty-six samples from ten different overburden drill holes. The samples, which were received from Energy Laboratories of Billings, Montana, were portions of disaggregated untreated overburden drill cores.

The purpose of the clay analysis was to determine whether or not any changes in clay mineralogy could be found that could be correlated to the oxidized and reduced sandstones. A change in clay minerals could be a response to the pH and the Eh environment produced by the mineralizing solution as it moved through the sandstones.

Preparation of the samples for x-ray diffraction was simple and straightforward. The samples were not subjected to any pre-treatments, such as iron removal or calcium saturation, since the samples gave quite satisfactory peaks without such treatments. The samples were agitated in distilled water using a sonic probe and centrifuged at 750 rpm to settle out the greater than 2 micron size fraction. The supernatant was then treated with DMSO as a check for swelling clays, and for these samples the supernatant was dropped onto clay tiles positioned over evaporating funnels. The DMSO was then dropped onto the clays.

The x-ray diffraction patterns for the samples on the glass slides were run from 2 to 28 degrees 2θ, which gives an effective range of 20 to 3 Angstrom spacing in the crystal lattices. The slides were then baked at 600 degrees C for one hour and x-rayed again. After the initial x-ray studies were analyzed, twenty samples were chosen for DMSO treatment to better categorize the clay minerals. Two mounts were made of each of the twenty, one on glass as a control, and one on clay tile which was DMSO saturated. The second set of diffractograms were run from 30 A to 5.90 A, since the clay tiles begin to give interference peaks at 4.9 A, and the smectite and chlorite peaks occur between 29.4 A and 6.80 A. The second set of clay mounts were also baked at 600 degrees C for one hour and x-rayed after cooling.

Tabulation of the peaks recorded on the diffractograms is presented in Appendix 2. Identification of the clays by x-ray peak and d-spacing were done using data from Brown (1961), Carroll (1970), Grim (1962), and Thorez (1976).

The x-ray studies do show a different clay mineralogy between those samples with a normal pH range between 5 and 9, and those samples with a pH value of less than 5. To check these results, twenty samples were remounted and saturated with DMSO. The results were consistent and yielded even better resolution of some of the clay peaks. Smectite (montmorillonite), kaolinite, illite, alpha quartz, and feldspar peaks were identified in all fifty-six samples. The illite peaks were intensified after baking by the collapse of the smectites from a 14 Å spacing to a 10 Å spacing. The kaolinite peaks were lost after baking, while the alpha quartz and feldspar peaks remained stable.

The appearance of a 13.5 Å to 14 Å peak after baking confirms the presence of chlorite in several of the samples. Thirty samples show a 14 Å peak after baking, but three of those are probably due to incomplete collapse of the montmorillonite (samples 80002-OB 6, 81002-OB 5, and 81004-OB 6). All three samples were x-rayed a second time with DMSO treatment and two did not show a 14 Å peak after baking, while 80001-Ob 6 had a poorly developed 14 Å peak. However, the other twenty-seven samples did show a good 14 Å peak after baking. (After baking the 14 Å peak of chlorite is intensified while its 7 Å peak is lost, as is the 14 Å peak of the smectite clays (Thorez, 1976). Twelve of those samples showing good 14 Å peaks after baking were remounted and treated with DMSO and re-x-rayed.

The overburden core hole samples which show chlorite peaks all have a normal pH range as determined by the analysis done on the cores by Energy Laboratories. Those samples with a pH value below 5.0 do not show a 14 Å peak after baking. Samples 81002-OB 5 and 81003-OB 6 have a low pH value and show 14 Å peaks after baking in the initial x-ray study. Subsequent remounting and x-raying does not show a chlorite peak, either on the glass slide or on the DMSO treated clay tiles. The remaining samples, those with a pH value in the normal range but without a chlorite peak are either samples of siltstone, samples of white sandstone, or they represent mixtures of gray and yellow sandstone in the core sample.

The absence of chlorite in the siltstone samples may be due to the fact that chlorite did not form in those sediments during diagenesis. Triplehorn (1970) argues persuasively that chlorite probably does not form authigenicly in siltstone and claystone due to the decreased permeability of these sediments. The decrease in permeability may prevent circulation of waters carrying excess silica and free ions that would promote the formation of chlorite (see also Wilson and Pittman, 1977).

The mixed sandstone samples probably would have shown the chlorite-pH association had the cores been split on lithology or color changes rather than on ten foot core lengths. When samples were taken in ten foot lengths, the boundaries between the altered and unaltered sandstones were not observed. As a result, the samples tend to yield moderate pH values due to the mixing of the zones, as seen in the values for 81006 (see Plate II). The white sandstones present an anomalous situation. The most reasonable answer is that the low pH values are tied to the presence of limonite in the samples, and absence of limonite, even in altered sandstones, accounts for both the lack of yellow color and the normal pH range in those samples.

Chlorite forms authigenicly under slightly alkaline conditions (Millot, 1970) developed during diagenesis (Wilson and Pittman, 1977). A change from basic to acidic in the circulating groundwaters can lead to the destruction of chlorite (Millot, 1970; Triplehorn, 1970). The Eh of solutions also influences the formation or degradation of ferrous iron, and thus of ferriferous clays such as chlorite (Millot, 1970). The oxidation of ferrous iron would disrupt the crystal lattice, facilitating the loss of oxygen and of the central cation in the octahedral layers in the chlorite structure. Millot (1970) and Birkland (1974) call this process degradation and it can result in the eventual formation of montmorillonite from chlorite (see Figure 11).

All fifty-six samples did have good smectite (montmorillonite) peaks. Montmorillonite clays often have charge deficits due to the partial replacement of aluminum in the octahedral layers. The charge deficits are balanced by exchangeable interlayer ions, with sodium and calcium being the most frequent cations (Millot, 1970). Differentiation between sodium and calcium rich montmorillonite clays is made by examining the sharpness of the 14 Å peak

Degradation

$\longrightarrow$

Illite ⇌ I-Vmixed layer ⇌ vermiculite ⇌ V-M mixed layer ⇌ montmorillonite
Biotite ⇌ hydrobiotite ⇌ (Tri)vermiculite ⇌ (Tri)montmorillonite
Biotite ⇌ chlorite ⇌ C-V mixed layer ⇌ (Di)vermiculite ⇌ (Di)montmorillonite

$\longleftarrow$

Aggradation

Figure 11. Degradation scheme for montmorillonite clay (from Millot 1970).

on x-ray diffractograms (Brown, 1961). Further determination of the presence of Na^+ or Ca^+ can be made by calcium saturation of samples thought to be Na^+ rich and comparing treated and untreated diffraction patterns. If a sample is Na^+ rich a calcium saturation should sharpen the 14 Å peak (Robert Van Atta, pers. comm., 1983).

Of the fifteen low pH samples, twelve of them show very sharp, well-defined 14 Å peaks, corresponding to a Ca^{++} rich interlayer (see Figure 12). The same proportion (80%) of the normal pH, or gray sandstone samples show diffuse, broad shouldered 14 Å peaks (see Figure 13). Two gray sandstone samples were calcium saturated to see if the broad peaks could be tightened. As Figures 14 and 15 show, the calcium treatment did change the patterns, tightening the 14 Å peak.

The x-ray analysis shows the presence of sodium rich montmorillonite in the downdip, unaltered sandstones. In the altered, yellow sandstone samples the sodium has been replaced by calcium, giving a sharper 14 Å peak. The replacement of sodium implies that calcium is more available in the oxidized sandstones. Dissolution of calcite in the acidic environment of the yellow sandstone provides Ca^{++} for substitution in the interlayer positions of the montmorillonite clays.

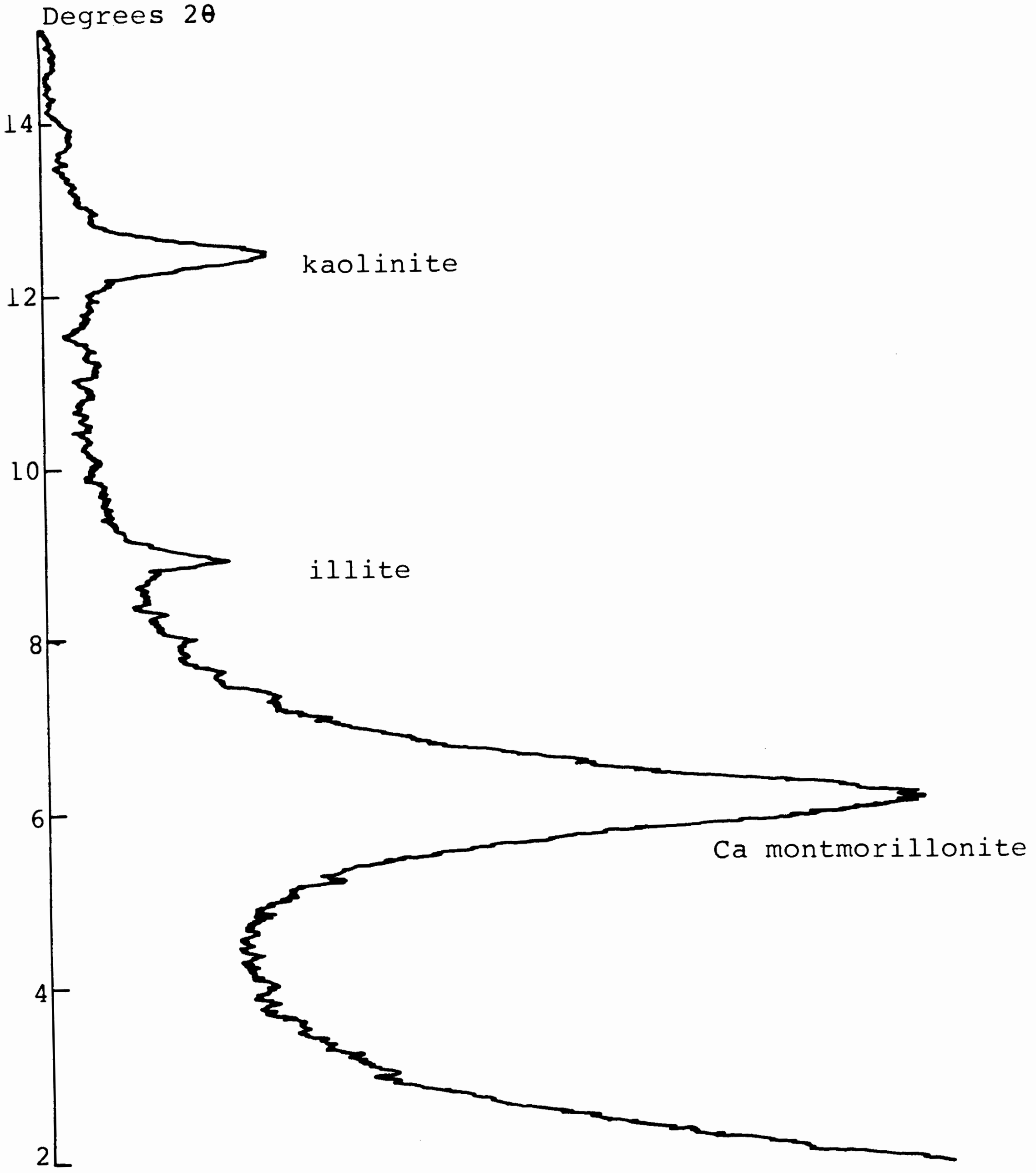


Figure 12. Diffraction pattern for sample 81001-OB 8 showing a sharp montmortillonite peak.

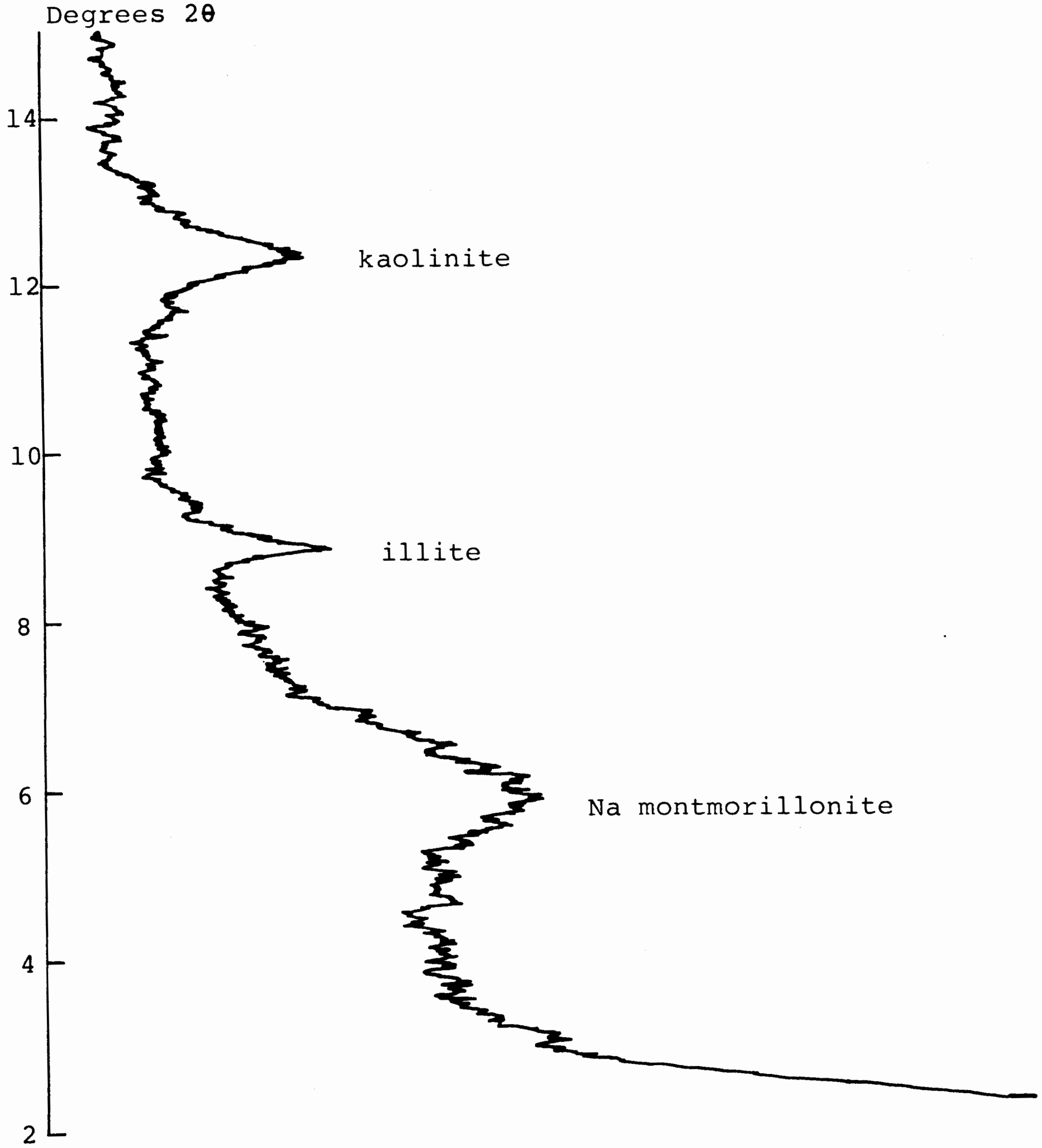


Figure 13. Diffraction pattern for sample 81006-OB 14 showing a broad montmorillonite peak.

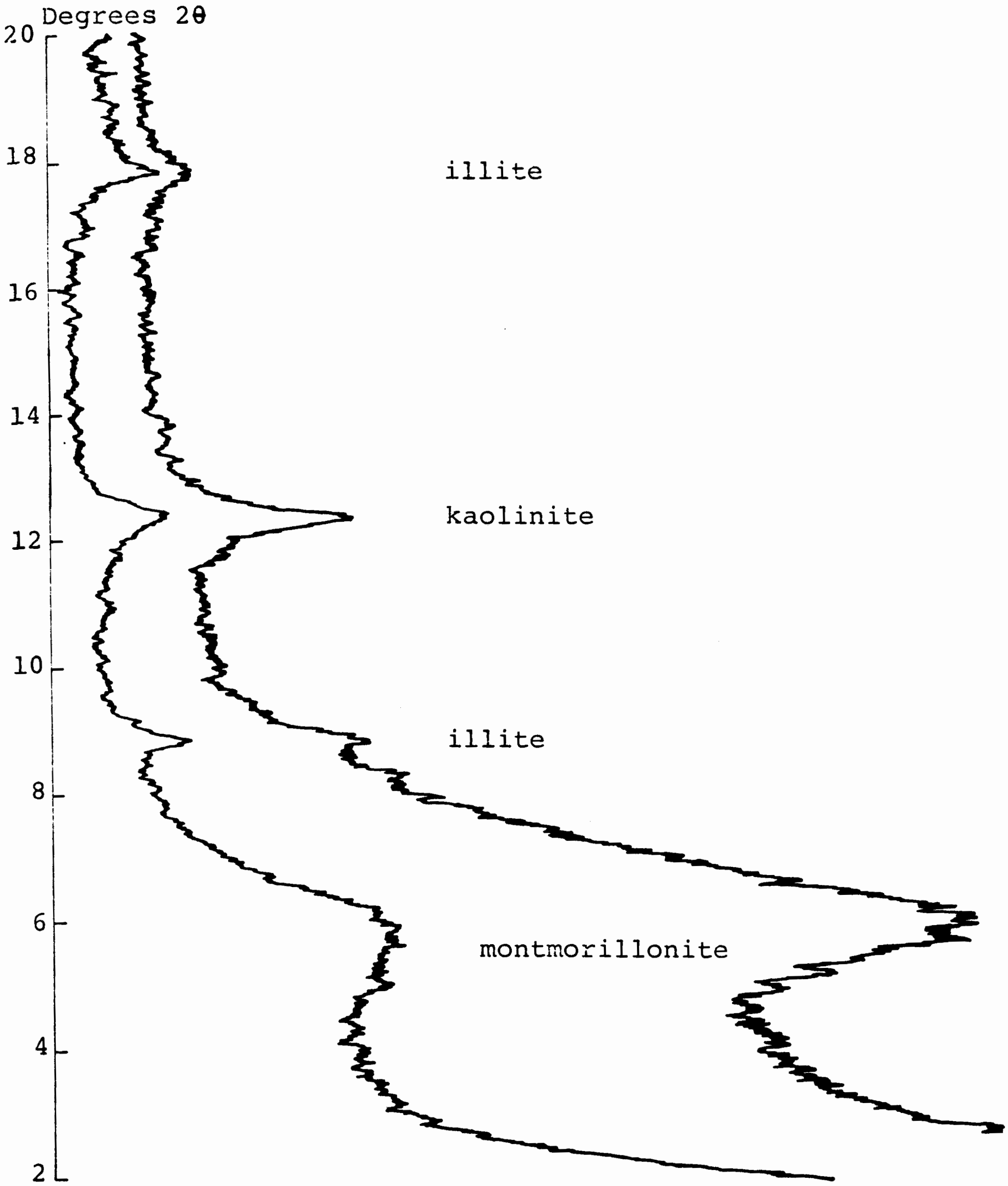


Figure 14. Comparison of untreated and Ca^{++} saturated diffraction patterns for sample 81006-OB 5, the Ca^{++} treated pattern is on the right.

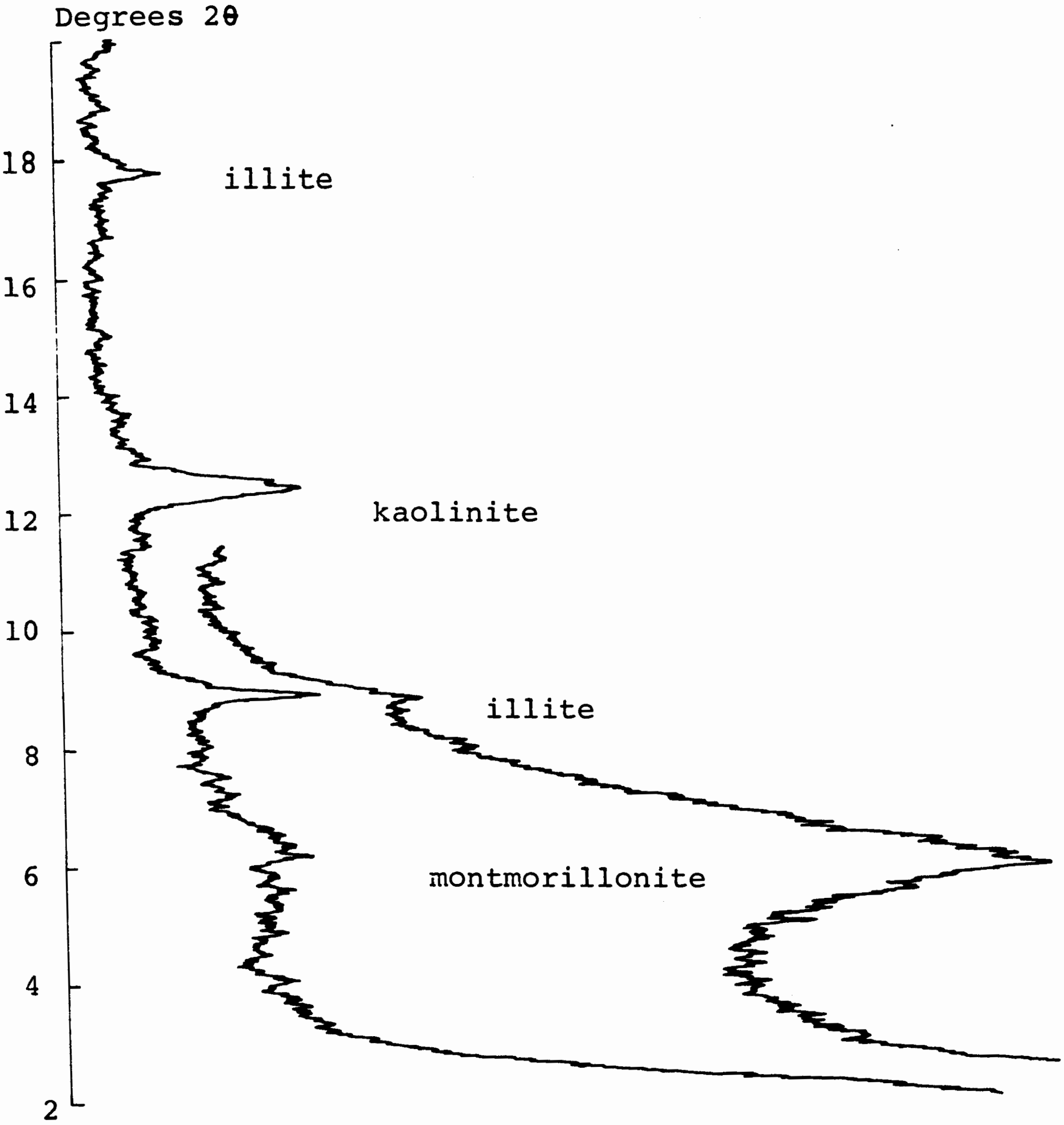


Figure 15. Comparison of untreated and Ca^{++} saturated diffraction patterns for sample 80004-OB 10, the Ca treated pattern is to the right.

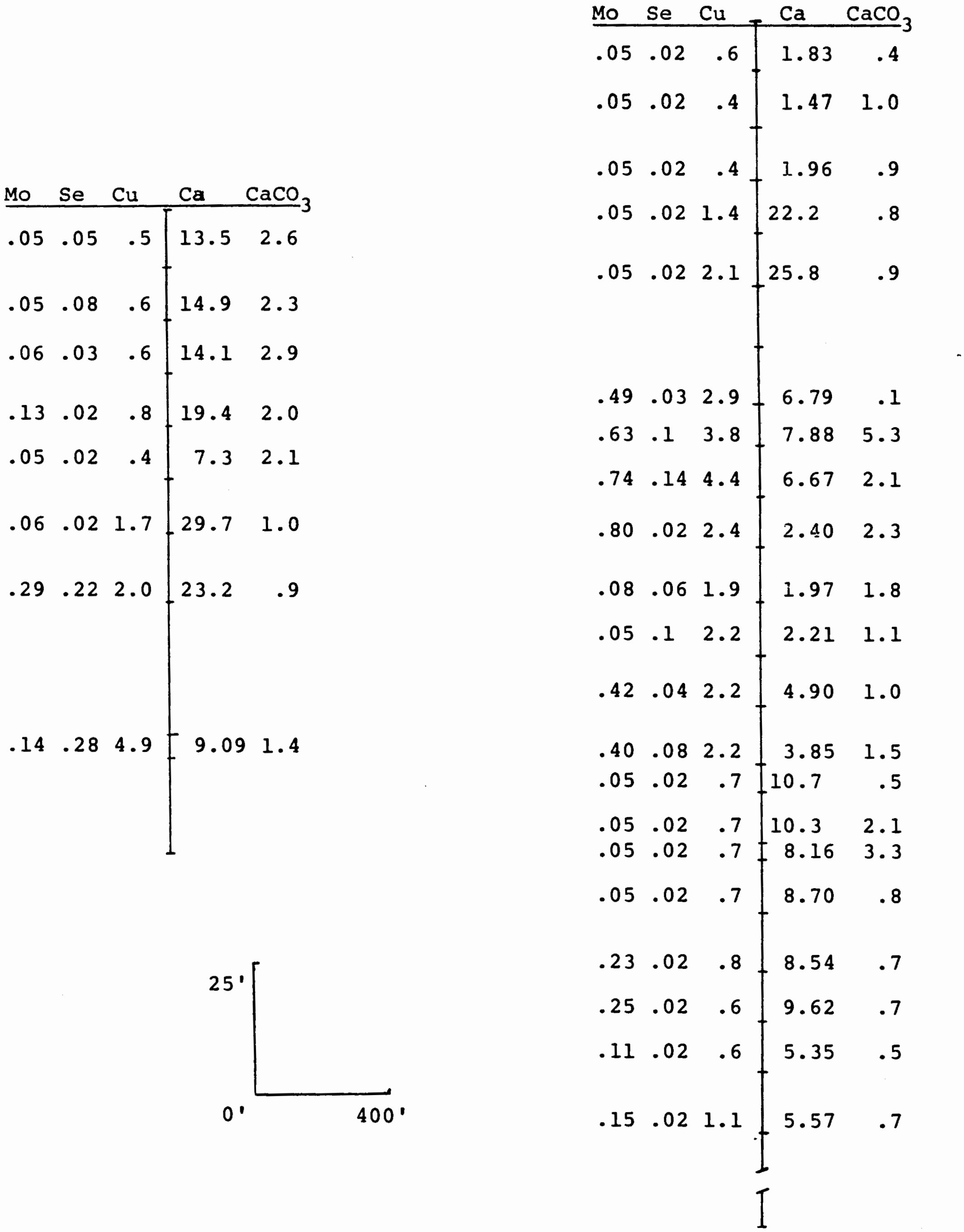
CHAPTER 4

ION DISTRIBUTION

Chemical analyses of the overburden cores provides some data on metal ion distribution in the Dave Johnston Coal Field. These analyses were studied to determine if the distributions were related in any manner to the altered-unaltered areas. The analyses provided values for Cu, Se, Mo, Ca and calcite, and these values were plotted on cross sections (see Figures 16 and 17 and Plate III).

The data available for the sandstone in the Dave Johnston Coal Field do not show any strong correlations between ion distribution and proximity to the areas of yellow-to-gray interface. There is an increase in the metal ion concentration in the siltstones and claystones of the overburden, which is most likely due to an increase in the clay size particles which in turn provide more sites for ion substitution.

The selenium values do not show any trend between the altered and unaltered sandstones, and copper, molybdenum and calcium also fail to show definite correlations. However, between drill holes 80001-OB and 81002-OB some changes in ion concentration are seen. Drill hole 80001-OB is located westward and updip from 81002-OB. The



Mo	Se	Cu	Ca	$CaCO_3$
.05	.05	.5	13.5	2.6
.05	.08	.6	14.9	2.3
.06	.03	.6	14.1	2.9
.13	.02	.8	19.4	2.0
.05	.02	.4	7.3	2.1
.06	.02	1.7	29.7	1.0
.29	.22	2.0	23.2	.9
.14	.28	4.9	9.09	1.4

Mo	Se	Cu	Ca	$CaCO_3$
.05	.02	.6	1.83	.4
.05	.02	.4	1.47	1.0
.05	.02	.4	1.96	.9
.05	.02	1.4	22.2	.8
.05	.02	2.1	25.8	.9
.49	.03	2.9	6.79	.1
.63	.1	3.8	7.88	5.3
.74	.14	4.4	6.67	2.1
.80	.02	2.4	2.40	2.3
.08	.06	1.9	1.97	1.8
.05	.1	2.2	2.21	1.1
.42	.04	2.2	4.90	1.0
.40	.08	2.2	3.85	1.5
.05	.02	.7	10.7	.5
.05	.02	.7	10.3	2.1
.05	.02	.7	8.16	3.3
.05	.02	.7	8.70	.8
.23	.02	.8	8.54	.7
.25	.02	.6	9.62	.7
.11	.02	.6	5.35	.5
.15	.02	1.1	5.57	.7

Figure 16. Ion distribution for drill holes 80001 and 81002. Refer to Figure 3 for lithologies and Appendix 3 for chemical data.

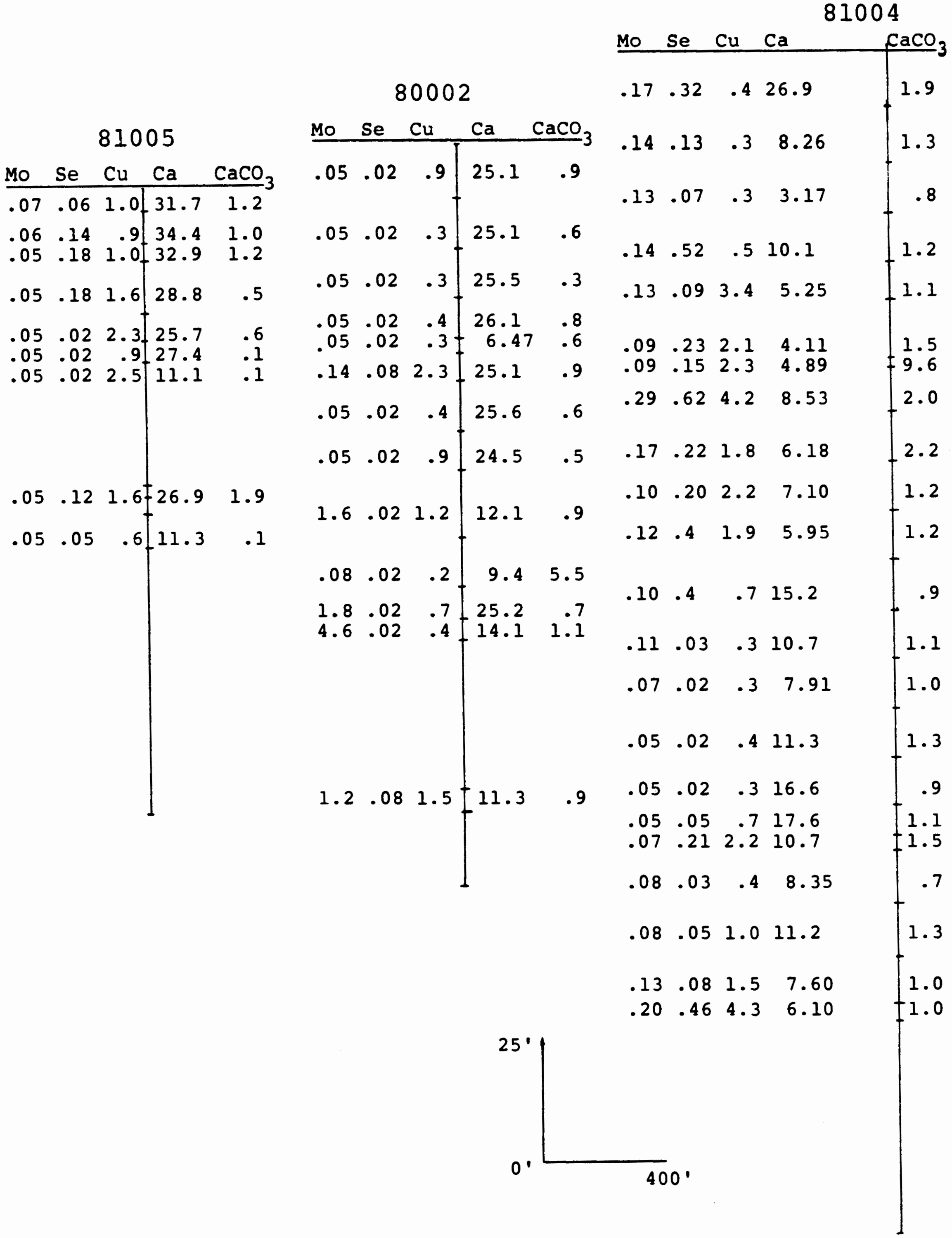


Figure 17. Ion distribution for drill holes 81005, 80002 and 81004. Refer to Figure 4 for lithologies and Appendix 3 for chemical data.

overburden sandstones in 80001-OB are tan to yellow and are iron stained, while the stratigraphically corresponding sandstones in 81002-OB are gray in color (see Figure 3). The concentration of copper is lower in the updip samples by a few parts per million. There is also a slight increase in the copper concentration between 80002-OB and 81004-OB, where 81004-OB is in the downdip, gray sandstone.

The one substance which shows a definite trend between the yellow and gray sandstones is calcite. The altered sandstones having less $CaCO_3$ (measured on saturated extract) than the unaltered gray sandstones. Those sandstones which are yellow and orange have the lowest values, with the yellowish gray sandstones intermediate between the gray and yellow.

Thus the limonite-stained and enriched sandstones also lack some of the cementing materials of the gray sandstones. The excessive core loss problems at Dave Johnston are in the areas of calcite depletion, the altered, yellow sandstone units.

CHAPTER 5

SCANNING ELECTRON MICROSCOPY

Samples were selected for scanning electron microscopy after x-ray analysis showed differences in the clays in the yellow and gray sandstones. The samples were examined with the ISI, model SS 40 microscope in the Physics Department at Portland State University.

Determination of particular clays in the disaggregated samples was not successful. The clays were quite small and difficult to identify and photograph. Several samples could be identified as smectites, and an example is shown in the photo of 80002-OB 10 in Figure 18. Photos of 80002-OB 10 show the crinkly, puckering coating of smectite clays on feldspar and quartz grains.

Feldspar grains are subject to leaching and dissolution in acidic environments and may show etching along cleavage traces as a result of low pH environments (Birkland, 1974; Dahl and Hagmaier, 1976). SEM photos of feldspars in the reduced and oxidized zones illustrate the differences in environment between the yellow and gray sandstones. Sample 81004-OB 19 shows a feldspar grain with clean, sharp cleavage traces (see Figure 19). Sample 80001-OB 5, shown in Figure 20, shows a clay coated, etched

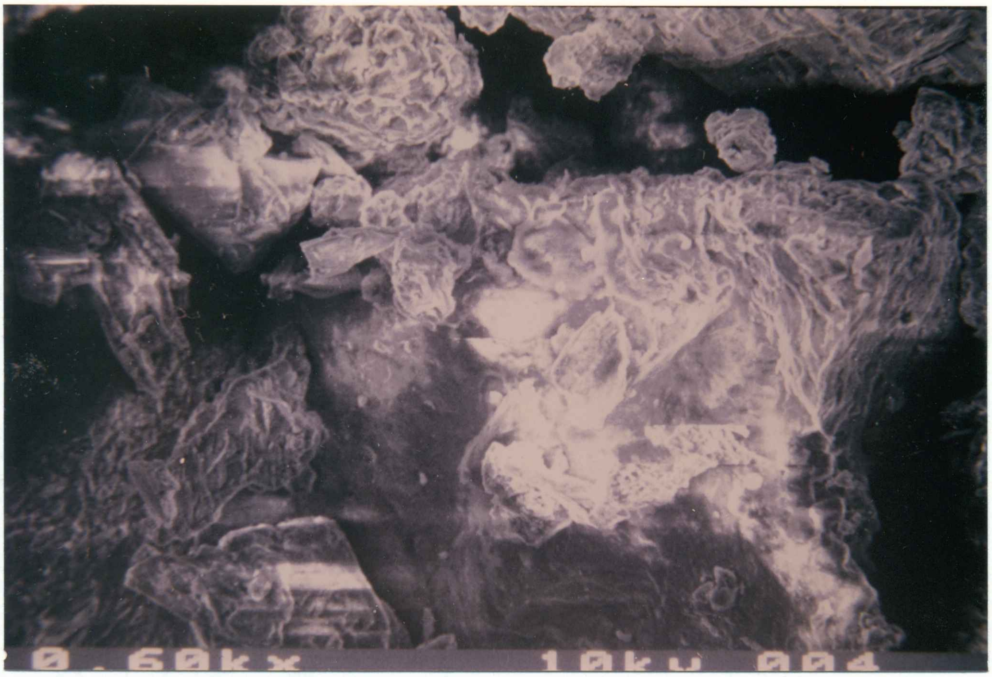


Figure 18. Photomicrograph of smectite clay in sample 80002-OB 10.

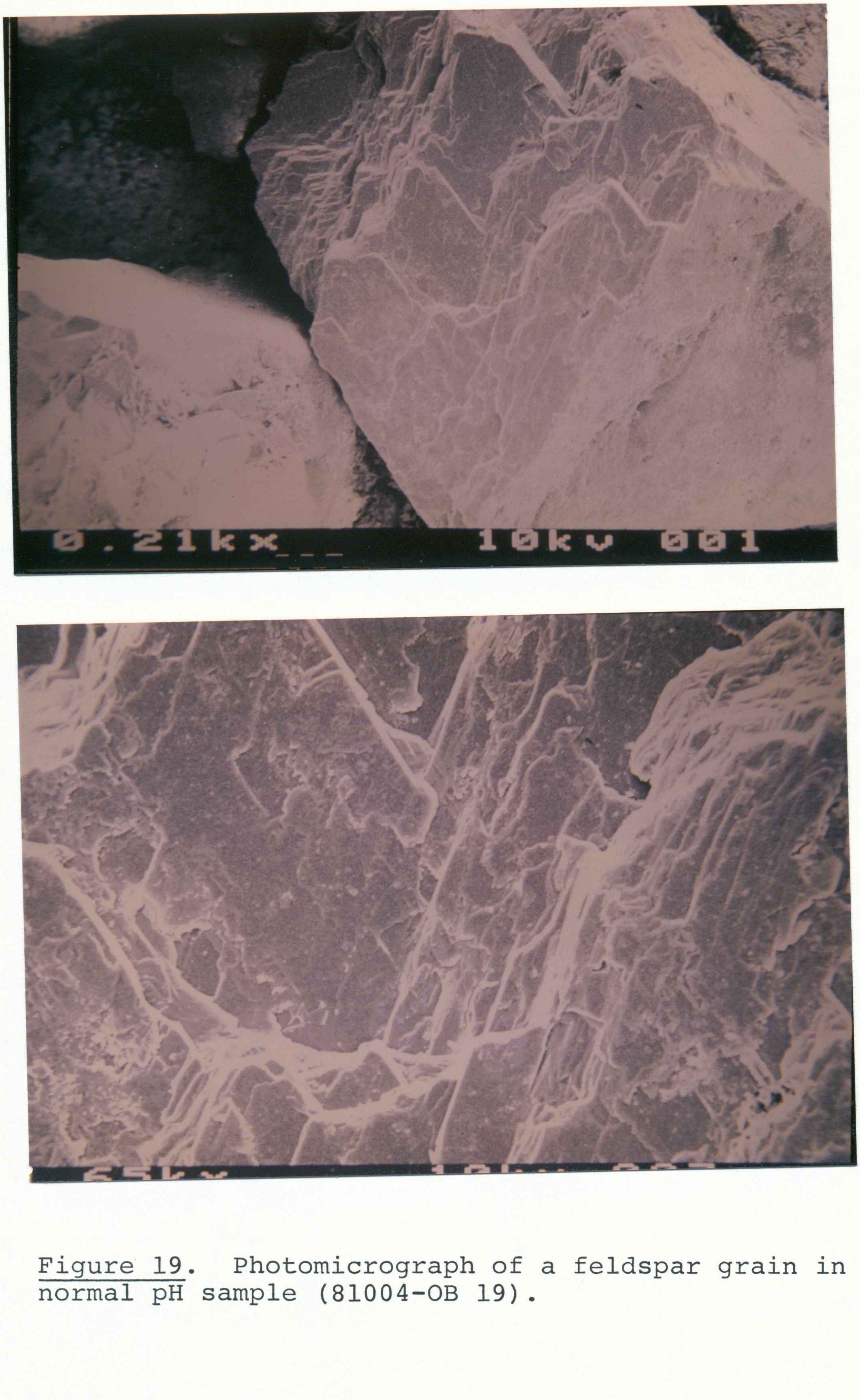


Figure 19. Photomicrograph of a feldspar grain in a normal pH sample (81004-OB 19).

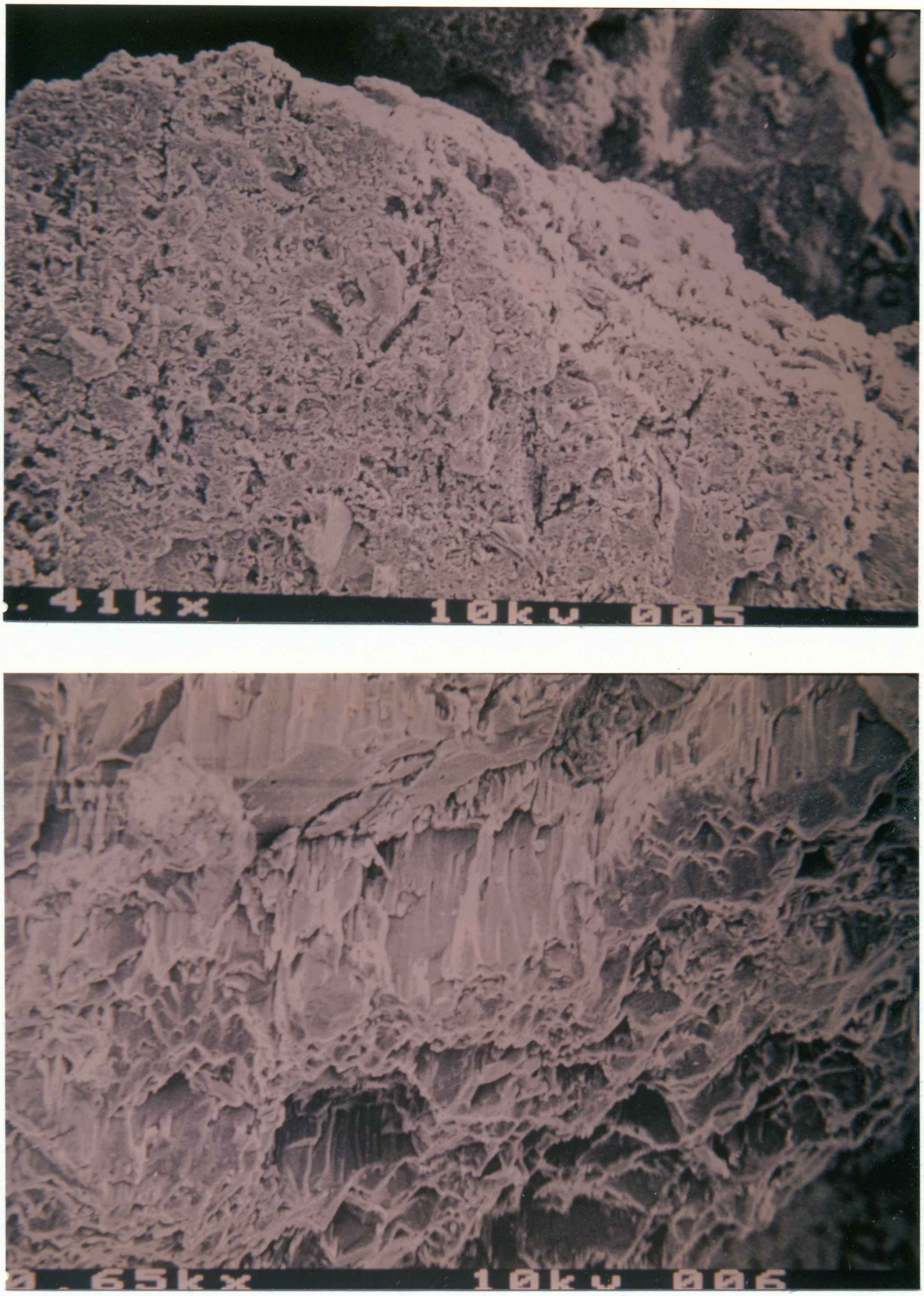


Figure 20. Photomicrograph of an etched feldspar grain in a low pH sample (80001-OB 5).

feldspar with indistinct cleavage traces, showing signs of dissolution along the cleavage traces. Sample 81004-OB 19 is from a gray sandstone, while 80001-OB 5 is from a yellow, oxidized zone.

CHAPTER 6

DISCUSSION AND CONCLUSION

Uranium Roll Front Deposits

Uranium roll front deposits were initially defined by Adler (1964) as having C or E shaped cross sections and forming sinuous lines in map view. Early workers (Adler, 1964; Shawe and Granger, 1965) thought the configuration was the result of precipitation of uranium ore at an interface between solutions of differing compositions and densities. The development of roll front deposits was linked to groundwater movement which caused changes in the Eh and pH of the host sandstones by several workers (Adler, 1964 and 1972; Shawe and Granger, 1965; Butler, 1969; Tilsley, 1980). Uranium minerals precipitated as a result of oxidation-reduction reactions occurring within the sandstone as the groundwater or mineralizing solution moved through permeable beds (Harshman, 1972).

In the Powder River Basin of Wyoming, uranium roll front deposits have been characterized as a type of supergene enriched (sulfide) deposits by Granger and Warren (1978). The roll fronts of the Powder River Basin typically occur in porous, permeable, gently dipping fluvial or marginal-marine sandstones. They are often closely spaced and form multiple, finger-like roll fronts (Davis, 1969). Alteration associated with uranium roll fronts in the basins of Wyoming display distinct boundaries between the altered and unaltered sandstones, with altered sandstone on the concave side of the roll and unaltered host rock on the convex side of the roll front (see Figure 21) (Davis, 1969; Harshman, 1972). The altered sandstone is greenish yellow to orangish red, while the unaltered host sandstone is light to medium gray in color. Davis (1969) and Adler (1972) also identify occasional areas of almost white bleached sandstones occurring adjacent to zones of mineralization. The change in coloration is due to the presence of iron oxides produced by the oxidation of pyrite in the gray sandstones as the mineralizing solutions moved downdip (Adler, 1964 and 1974; Shawe and Granger, 1965; Davis, 1969; Harshman, 1972; Dahl and Hagmaier, 1976).

Several elements besides uranium and iron are affected by the mineralizing solutions. Selenium, molybdenum, copper and calcite are all precipitated or lost at different areas within the roll front and zone of mineralization (see Figure 21) (Davis, 1969; Adler, 1972; Harshman, 1972; Dahl and Hagmaier, 1976; Granger and Warrent, 1978). According to Davis (1969) a correlation also exists between the position of the roll front and $CO_3^=$ and $SO_4^=$ concentrations. The reactions involved are well explained in Moran and others, 1978, and in Granger and Warren, 1978. The

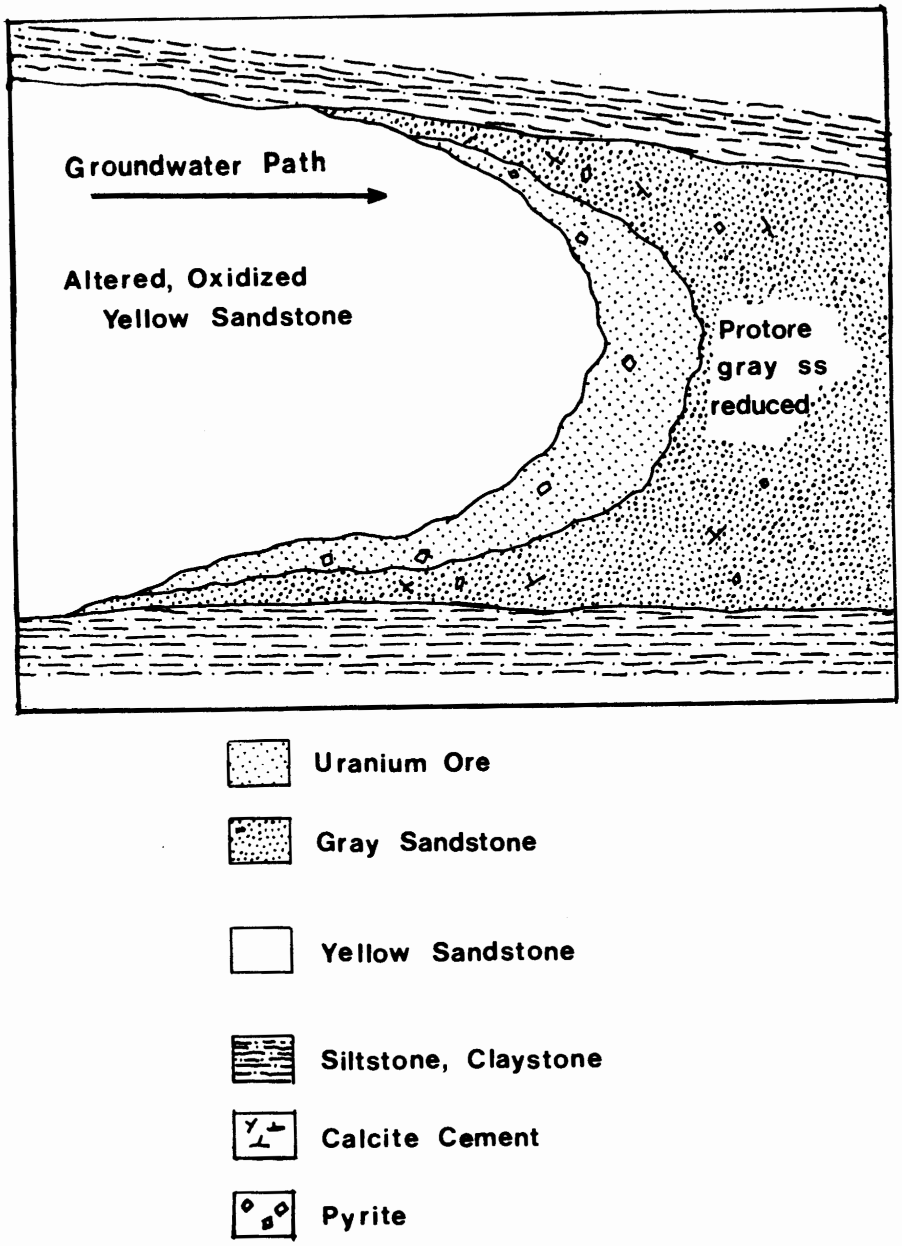


Figure 21. Idealized cross section of roll-type ore body (uranium roll front), no scale (adapted from Dahl and Hagmaier 1976).

interaction of the carbonate ion, the sulfate ion and even selenium are important as the major constituents in the process of alteration (Hostetter and Garrels, 1962; Harshman, 1972). Along the leading edge of the oxidation tongue, the Eh of the host rock changes abruptly, resulting in the accumulation of various metallic and nonmetallic elements in the mineralizing zone. Uranium, which is soluble to some degree in oxidizing environments (dependent on the interaction of Eh and pH), precipitates in contact with the reducing environment of the gray, unaltered sandstone (Harshman, 1972). The other elements also precipitate at various areas within the zone (see Figure 22). Most of these precipitates are readily leached in oxidizing environments, and would thus be dissolved again as the mineralizing solution moved further downdip and they were again in an oxidized environment.

Pyrite has been identified as a part of the unaltered sandstone by Shawe and Granger (1965), Davis (1969), Harshman (1972), and Dahl and Hagmaier (1976), and is considered to be epigenetic, but predates ore formation. The pyrite was formed in the reduced environment produced by saturation of the sediments by groundwaters during burial and early diagenesis (Birkland, 1974; Ethridge and others, 1981). Pyrite has also been found immediately adjacent to the roll front (Davis, 1969), in the ore zone. The presence of pyrite at the zone of deposition indicates strongly reducing

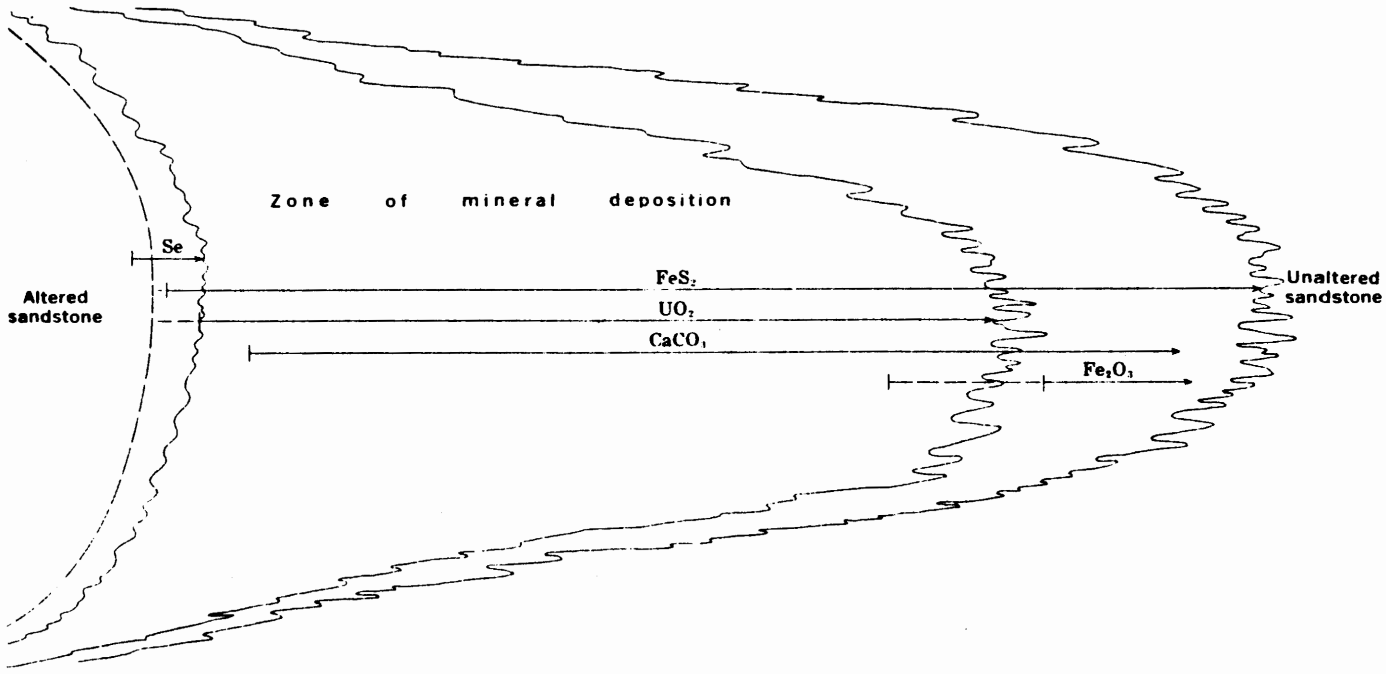


Figure 22. Summary of mineral deposition in the Shirley Basin (Harshman 1972). Arrow lengths show relative positions and widths of zones in which various minerals were deposited; dashed lines are possible deviations from normal conditions. No scale (from Harshman 1972).

conditions in the altered rock of the ore zone (Davis, 1969). According to Davis (1969) and Harshman (1972) these conditions prevail in a zone only a few feet wide, and the occurrence of pyrite in the altered rock is limited to that zone. Behind the ore zone, in the altered sandstone, pyrite is absent or present only in very small scattered amounts. Where pyrite has been found in the altered sandstones, the grain aggregates are corroded and irregular in outline (Harshman, 1972).

The oxidation of the pyrite updip from the roll front produces the characteristic coloring of the altered sandstones (Shawe and Granger, 1965; Davis, 1969; Adler, 1972; Harshman, 1972). Limonite, including hematite and goethite, are produced and give the yellow to red coloration associated with oxidized and mineralized sandstones (Davis, 1969; Adler, 1972). The oxidation of the pyrite also produces an acidic environment updip from the roll front which is acidic enough to cause the dissolution of magnitite (Adler, 1972).

Limonite is the inclusive term given to the iron oxides of the altered zone, though hematite and goethite are also associated with altered zones. Limonite is used as a field term for iron staining throughout this paper and follows the definition found in Deer and others (1966). Roll front type deposits formed below the surface of the water table (Granger and Warren, 1978) and are not well preserved in surface exposures.

CONCLUSION

Uranium roll front deposits are thus characterized by changes in the host sandstone of color, mineralogy, cement, pH, Eh and ion distribution. The deposits are the result of downdip movement of an oxidizing, slightly alkaline solution which has the capacity to oxidize pyrite and change the Eh of the strata along the leading edge of the solution. Physical and chemical changes in the sedimentary environment result in the precipitation of various metal ions, among them uranium. Oxidation of pyrite in the host sandstone further changes the chemical environment behind the solution front, reducing the pH enough to degrade feldspar grains and dissolve calcite cement.

Several features found at the Dave Johnston Coal Field fit the parameters suggested by the mineralizing solutions responsible for the formation of uranium roll front deposits. The changes in color of sandstone units, the problems with core loss, and the acidic overburden values could be explained by changes in environment resulting from roll front mineralization.

Stratigraphic relationships between the Badger and School coal seams, along with petrologic evidence, establishes the continuity of the overburden sandstone units.

Changes in color and cementation occur within the same unit, and are particularly noticeable in downdip sections.

The oxidation of the pyrite in the gray sandstone produced the limonite found in the yellow sandstone at Dave Johnston. Pyrite is noted in core samples from reduced units, but is not reported in core samples of oxidized sediments. An environment that is oxidizing with respect to pyrite is also oxidizing with respect to chlorite. The absence of chlorite in the yellow sandstone is a result of the destruction of chlorite clays by an oxidizing solution moving through the sandstone.

As a consequence of the oxidation of the pyrite, the pH of the area behind the advancing front was lowered to a slightly acidic condition. The area behind the roll front (or updip) is then more likely to lose calcite through dissolution in the acidic environment. Excessive core loss in overburden cores at Dave Johnston are correlative with areas of oxidized sandstone: the calcite cement has been lost because of the acidic environment produced behind the roll front by the oxidation of pyrite. The destruction of chlorite is also further advanced by the changes in the pH of the zone behind the roll front since chlorite is vulnerable in acidic environments. Feldspar grains in the altered sandstones also show the affect of the acidic environment by the etching and dissolution of the grains along cleavage boundaries.

The x-ray analyses of the overburden drill cores at Dave Johnston corroborates this interpretation. Chlorite is restricted to the reduced environment of the gray sandstone and is absent from those sandstones which show the characteristics of an oxidized zone. The sandstones in the oxidized zones lack clays which are associated with alkaline environments, and reflect a change in ion substitution in the interlayer sites in the montmorillonite clays. Dissolution of the calcite freed calcium ions for substitution, replacing the sodium already present in those sites.

Changes in calcite concentration are also reflected in the chemical analyses of the overburden, which show less calcite in the altered sandstones. Copper also shows a slight decrease in the altered sandstone, though none of the values show the degree of change in concentration that Harshman reports in the uranium deposits of the Petrotomics Company Section 9 pit. Harshman's study was located in the Shirley Basin of Wyoming (see Figure 1), where he found as much as 20 ppm copper in the unaltered sandstones compared to 2-4 ppm in the altered sandstone (Harshman, 1972).

Alternative explanations for the changes in the chemical and physical characteristics of the overburden sandstone include facies changes and cut and fill through the sandstone unit. Stratigraphic and petrologic constraints preclude the acceptance of either of these hypotheses. The gray sandstone is stratigraphically equivalent to the yellow sandstone, and is found in this position both downdip to the east and to the north. An erosional channel would continue northward, following the drainage patterns of the Eocene Wasatch, or would turn eastward toward the synclinal axis. Drill hole data does not show a continuation of the yellow sandstone eastward, or to the north. Rather, the yellow sandstone ends abruptly in both directions. A facies change does not offer a reasonable solution for the changes observed in the clay mineralogy while the sand size minerals remain essentially the same in both the gray and yellow units. A facies change should also produce greater changes in the particle size than is reflected in the two sandstone units, and should not appear as a continuous unit throughout the mine area.

Uranium roll front models require a solution with the same characteristics as the one proposed for the overburden sandstone at the Dave Johnston Coal Field. A roll front solution fits the parameters indicated by this study and probably is responsible for the alteration at the Dave Johnston Coal Field.

The physical and chemical changes in portions of the overburden sandstones at the Dave Johnston Coal Field appear to be the direct result of a solution moving in a downdip direction. The parameters established by the results of this study require that the solution be oxidizing with respect to pyrite and have an Eh potential capable of leaching copper. The oxidation of pyrite would, in turn, produce an environment acidic enough to dissolve calcite, destroy chlorite and etch feldspar grains, as well as giving an iron oxide stain to the altered sandstone.

The failure of this study to find any close correlation between metal ion distribution and the altered and unaltered zones may be attributable to the scale on which the analysis was done. The studies which have shown the correlations have been conducted in uranium pits, across the roll fronts themselves, with samples taken at one or five foot intervals. The drill cores used in this study are all several hundred feet apart and do not offer an opportunity to study ion distribution across a localized area of mineralization.

In a study of the Highland uranium deposits, Dahl and Hagmaier (1976) were unable to find any particular relationship between the uranium mineralization and metal concentrations. This study is of particular interest since the Highland deposits are in sandstone which underlie a large portion of the Powder River Basin and are approximately 600 feet below the Badger coal seam. Specifically, the information used by Dahl and Hagmaier came from drill holes and mines 1 to 18 miles east of the Dave Johnston Coal Field. Again their data was primarily from drill cores spaced several hundred feet apart.

If a detailed, closely spaced program were initiated within the Dave Johnston mine, in a downdip direction, it might be possible to demonstrate some of the correlations between roll front mineralization that others have found.

CHAPTER 7

POTENTIAL PROBLEMS FOR RECLAMATION

The acidic values measured for portions of the overburden at the Dave Johnston mine pose several questions regarding the removal and eventual reclamation of the mine area. The potential negative effect on re-establishing ground cover due to acidic soils and the possibility of groundwater contamination by acidic waters and ion movement in groundwater are major ecological concerns.

The ability of metal ions and the sulfate ion to migrate in the water in spoils could have an impact on groundwater systems adjacent to mined areas. The water moving into and through a mined area, both vertically and horizontally, could become enriched in undesirable cations such as Ca^{++} and Na^{+}, and $SO_4^{=}$ and HCO_3^{-} anions.

The potential effects on the groundwater and on reclamation depend in large part on the hydrology of the mined area and its surroundings. Before effective reclamation can be done, it is necessary to know the groundwater-surface water interactions of the area, the recharge-discharge relations, and the water table configuration and potentiometric head (see Groenewold and others, 1981). The rate of groundwater movement can greatly affect the salinity and sodium ion concentration in sediments. Repeated leaching and flushing can keep these levels low. Lateral movement of water into a mined area, or upward from below the spoils, can bring dissolved constituents into the mined area. If this water evaporates, those constituents are precipitated and can result in the accumulation of Na^+ and the build up of salinity. Low precipitation, or non-movement of groundwater causes the weathering of spoils in place, with the products remaining in situ (Moran, Groenewold and Cherry, 1978).

The availability of ions depends upon the mineralogy and oxidation state of the spoils material. Mineralogy of the sediments in the Powder River Basin is tied to provenance and the original depositional environment of the lithologies (Sandoval, 1973; Groenewold and others, 1981). In particular, the mineralogy at the Dave Johnston Coal Field has been affected by post-depositional mineralizing solutions. Studies by the North Dakota Geological Survey have shown pyrite, gypsum, calcite, dolomite and clay minerals to be the most important minerals affecting groundwater chemistry, especially in the unsaturated zone between the surface and the water table (Groenewold and others, 1981).

Oxidation of pyrite and the decay of organic matter, which produces CO_2, are two reactions that produce an acidic environment unless they are buffered by the dissolution of carbonate minerals. These reactions will take place in the near surface zones of the strata, where oxygen is available from the atmosphere and rainwater. Salt accumulation also occurs in this zone because of the alternating wet and dry conditions (see Groenewold and others, 1981). These reactions are part of the natural cycle and are a given in the Powder River Basin. If there is a concentration of detrimental ions near the surface, these reactions could result in toxic or hazardous build ups of Na^+, $SO_4^=$, Ca^{++}, and/or HCO_3^-, particularly if oxygen has been incorporated into the strata during excavation and reclamation. Oxygen in the trapped air in the spoils would be consumed in the oxidation of pyrite if pyrite was present in the spoils (Groenewold and others, 1981), thus contributing to potential build ups of $SO_4^=$ and Na^+.

If the spoils in a near surface position are lacking in, or are low in pyrite, other minerals need to be evaluated in terms of detrimental weathering products. Oxidized units may lack pyrite, but they may have secondary accumulations of gypsum or sulfate from the previous oxidation of pyrite. The presence of sulfate would then depend upon whether or not the salts have been flushed out of the strata (Moran and others, 1978).

At Dave Johnston reclamation of spoils could pose problems, both in terms of the oxidized and the reduced sandstones. Research by the North Dakota Survey has shown that detrimental chemical reactions can be minimized by selective handling and placement of overburden materials, as well as control of the degradation of the groundwater. Specifically, unweathered pyritic sediments should be restricted from the chemically active near-surface zone (Moran and others, 1978; Groenewold and others, 1981). The problems of accumulations of sulfate and sodium ions can be addressed by selective placement of the oxidized and reduced units at Dave Johnston.

The yellow oxidized sandstones could be utilized as outlined by Moran and others (1978) whereby the production of sulfate from pyrite oxidation is greatly reduced by the placement of permeable sand beneath the soil veneer, particularly if most, or all, of the pyrite has been previously oxidized. A permeable sand in the subsoil zone would quicken infiltration and help prevent the formation and accumulation of detrimental minerals.

By restricting the unweathered pyritic sandstones to lower positions in the spoils, and placing the oxidized poorly indurated yellow sandstones directly beneath the reclaimed soil, the resultant porewater should be lower in dissolved solids. In other words, the reduced gray sandstones quite possibly hold a greater potential for groundwater contamination and salt build up than do the oxidized yellow sandstones. There is a greater amount of pyrite and calcite in the gray sandstones, two of the key factors in the chemical reactions leading to groundwater contamination. The oxidized sandstones have far fewer soluble ions available for leaching by groundwater.

The sodium content of the montmorillonite clays and the entire overburden must be examined to judge the potential amount of Na^+ available in the spoils. The dissolution of calcite frees Ca^{++} for exchange with the Na^+ in the montmorillonite, causing an increase in the amount of free Na^+. The x-ray analysis shows an increase in Ca^{++} substitution in the oxidized sandstones. The sodium rich montmorillonites of the gray sandstones become calcium rich as a result of the dissolution of calcite, freeing sodium ions for possible salt formation. The pertinent question is how much sodium is left in the oxidized sandstone? If the oxidized sandstone is placed in a near surface environment, the Na^+ may be mobilized in the groundwater if they are still present in the oxidized sandstone.

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APPENDIX 1

METHODS OF SAMPLE TREATMENT

3. Overburden Sampling*

a. Sample holes should be located so as to adequately represent the quality of the overburden and interburden. The following sampling procedures are recommended.

(1) Sampling intensity should be at a minimum of one sample hole per 160 acres (four per section). Holes should be relatively evenly spaced and at least two holes per section should be cored. This spacing may need to be adjusted due to the nature of the geology of the area. Sample holes should extend to below the mineral to be mined, with samples taken so as to represent all strata.

(2) If the proposed pit size is to be less than 160 acres, then at least two holes should be taken. At least one of these holes should be cored.

(3) For areas with dipping mineral seams, the holes should generally be located on the low side of the dip to insure that all overburden is sampled. Holes should be parallel to the strike at a 1000 foot spacing.

(4) Detailed geologist logs should be provided for each sample hole.

b. All lithotypes and unconsolidated units of the overburden and interburden should be sampled and evaluated by laboratory analyses. Recommended procedures for sampling are:

(1) drilling methods which will prevent contamination of samples should be used (Power and Sandoval, 1976);

(2) samples should be taken such that total thickness of the sampled strata is not greater than ten feet. Those strata that may have adverse characteristics (i.e., pyrites) should be specifically sampled;

(3) where lithotypes have a thickness greater than ten feet, samples should be taken at ten foot intervals and composited for analysis. In no instance should a composited sample represent more than a thirty foot thickness;

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*Taken from the Wyoming D.E.Q. Guideline No. 1.

(4) each stratum sampled should be designated by thickness, depth, and hole number;

(5) coal that is to be spoiled (rider seams, thin stringers, etc.) should be sampled as overburden;

(6) polyethylene plastic bags should be used for sample collection and shipping. Moist or wet samples should be immediately frozen or spread to dry on a waterproof material, and stored in closed water resistant containers until analyzed (Sandoval and Power, 1978). Chemically unstable constitutents, i.e., nitrate-nitrogen, will require special precautions to obtain accurate analysis. All samples should be ground to pass through a 2 mm (10 mesh) sieve.

4. Laboratory Analysis

a. Table I-1 (Appendix I) lists the parameters of greatest concern for establishing overburden and interburden quality and the recommended methods of analysis. Other methods may be used if they provide comparable results. Any change in the recommended procedures should be cleared with the Land Quality Division.

b. Analysis of parameters in addition to those listed in Table I-1 may be required based upon the geologic nature of a mining area. It is recommended that Land Quality personnel be consulted prior to doing any analytical work.

Appendix I

Parameters, Analytical Procedures and Suitability Criteria for Topsoil and Overburden Analyses and Evaluation.

Table I-1: Recommended procedures for analyzing soils and overburden/interburden quality for coal and uranium mines.

Parameter			
Topsoil	Overburden/ Interburden	Reported As	Recommended Procedure
1. pH	pH	Hydrogen ion activity at saturation (paste)	USDA Handbook 60, method (21a), pg. 102
2. Conductivity	Conductivity	mmhos/cm @ 25°C	USDA Handbook 60, method (3a), pg. 84 and method (4b), pg. 89-90, or ASA Mono. No. 9, Pt. 2, pg. 937-940 1/
3. Saturation	Saturation	Percent	USDA Handbook 60, method (27a & b) pg. 107
4. Particle-size Analysis		% clay, silt, sand, and very fine sand (vfs=0.05 - 0.1 mm)	ASA Mono. No. 9, Pt. I, method 43-5, pgs. 562-566. Sieve Analysis for vfs (140-270 mesh)
5.	Particle size Analysis	% clay, silt, and sand	ASA Mono. No. 9, Pt. I, method 43-5, pg. 562-566
6. Texture	Texture	USDA textural class	USDA Handbook 18, pgs. 205-223
7. Soluble Ca, Mg, and Na	Soluble Ca, Mg, and Na	meq/l	Extraction of Ca, Mg, & Na by USDA Handbook 60, method (3a), pg. 84. Analysis by atomic absorption spectrophotometry
8. Sodium-adsorption ratio	Sodium-adsorption ratio	SAR calculated from soluble Ca, Mg, & Na concentrations	USDA Handbook 60, pg. 26

9. Carbonates 2/		Percent	USDA Handbook 60, method (23b), pg. 105
10. Selenium 3/	Selenium	ppm to a lower detection limit of 0.02	Extraction by ASA Mono. No. 9, pt. 2, method 80-3, pg. 1122; Analysis by the DAN-Flourometric method (Levesque & Vendett, 1971) or the Gaseous Hydride Method (US EPA 1979) & atomic absorption spectrophotometry
11. Boron 4/	Boron	ppm	Extraction by ASA Mono No. 9, Pt. 2, method 75-4, pg. 1062. Analysis by the curcumin method (Standard Methods, 1976)
12.	Nitrate-Nitrogen	ppm	Extraction by ASA Mono No. 9, Pt. 2, method 84-5. 3.3, pg. 1216
13. Organic Matter		Percent	ASA Mono. No. 9 Pt. 2, method 90-3, pg. 1372-1376
14.	Molybdenum	ppm to a lower detection limit of 0.1	$(NH_4)_2CO_3$ extractable (Vlek, 1975). Acceptable procedure available from LQD
15.	Copper	ppm	DTPA Extraction (Follett & Lindsay, 1971). Analysis by atomic absorption spectrophotometry
16.	Acid-base potential 5/	Acid potential in meq H^+/100 gr., neutralization potential in tons $CaCO_3$ equiv. 1000 tons acid-base potential ± tons $CaCO_3$ equiv. 1000 tons	Smith R.M. et al. (1974) pg. 48-51
17.	Lead 6/	ppm	DTPA Extraction (Follett & Lindsay, 1971). Analysis by atomic absorption spectrophotometry

18.	Arsenic 7/	ppm	pH<6.5 Mixed acid extractable As (0.04N HCl & 0.025N H_2SO_4), (Nelson et al. 1953). pH>6.5 Bicarbonate-Extractable As (0.4N $NaHCO_3$) (Olsen et al. 1954)
19.	Coarse Fragment	Percent	USDA Handbook 436, App. I, pg. 472; Soil Survey Laboratory Methods & Procedures for Collecting Soil Samples, pgs. 9 and 12-13

1/ Conductivity should be determined immediately after the extract is obtained.

2/ Analysis recommended where calcic horizon is suspected.

3/ Analysis for selenium recommended on soils where primary selenium indicator plants are present (Rosenfeld and Beath, 1964).

4/ Analysis recommended for mining operations in Sweetwater County, Wyoming.

5/ Referred to as acid-neutralization account by Smith et al. (1974).

6/ Analysis recommended for coal mine operations in Sheridan and Campbell counties, Wyoming.

7/ Analysis recommended for uranium operations.

APPENDIX 2

X-RAY DATA

Laboratory work completed by author using standard methods

		Mont-morillonite		Illite		Kao-linite		Illite		Illite &/or Mont.		Quartz		Feldspar (Plag.)		Kao-linite		Quartz		Feldspar		Feldspar (Plag.)	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
80001-OB 3	ph 6.8	14.71		9.92	9.92	7.13		4.97	5.00			4.24	4.26			3.55		3.33	3.34	3.24	3.24	3.18	3.19
80001-OB 4	pH 4.5	14.71		9.92	9.70	7.13		4.97	4.97		4.43	4.24	4.24		3.70	3.57		3.33	3.33	3.24	3.24		
80001-OB 5	pH 4.2	15.49		10.39	9.92	7.30		5.60	4.95	4.45	4.45	4.28	4.24			3.60		3.36	3.33	3.27	3.24	3.21	3.19
80001-OB 6	pH 6.0	14.94		10.04	9.92	7.18		5.00	4.97	4.45	4.43	4.26	4.24	3.70	3.70	3.58		3.36	3.34	3.25	3.24	3.19	
80001-OB 7	pH 7.2	15.22	13.79	9.92	10.04	7.13		4.97	5.00		4.48	4.24	4.26			3.57		3.33	3.36	3.24	3.24	3.15	
80002-OB 4	pH 4.8	14.96		10.04	9.98	7.18		5.00	5.00	4.45	4.43	4.26	4.24		3.70	3.57		3.34	3.34	3.25	3.25	3.19	3.19
80002-OB 5	pH 5.2	14.96		9.92	9.92	7.13		4.97	4.97	4.43	4.39	4.24	4.24		3.65	3.55		3.33	3.33	3.24	3.24	3.18	3.19
80002-OB 6	pH 6.9	14.71	14.24	10.15	9.92	7.24		5.03	4.97			4.28	4.24			3.58		3.36	3.33	3.27	3.24	3.25	3.19
80002-OB 8	pH 4.4	14.96		10.04	9.92	7.18		4.95	5.00	4.45	4.45	4.26	4.24	3.68	3.67	3.57		3.34	3.33	3.25	3.24	3.19	3.19
80002-OB 9	pH 5.2	15.22		9.92	10.09	7.18		4.96	5.00		4.45	4.24	4.28	3.72		3.57		3.34	3.36	3.24	3.24		
80002-OB 10	pH 6.5	15.49		10.04	10.04	7.18		5.00	5.00	4.45	4.45	4.24	4.28			3.57		3.33	3.36	3.25	3.26	3.19	3.20
80002-OB 11	pH 5.9	14.71	14.01	9.92	9.92	7.07		4.95	5.00	4.43	4.43	4.24	4.26			3.55		3.31	3.34	3.24	3.25	3.17	3.19
80002-UB 1	pH 6.9	14.47	14.01	9.92	10.04	7.07		4.95	5.00			4.24	4.28		3.72	3.55		3.33	3.36	3.22	3.24		
80004-OB 4	pH 6.5	14.96	13.58	9.92	9.92	7.13		4.97	4.95			4.24	4.24			3.55		3.33	3.31	3.24	3.24	3.19	3.18
80004-OB 8	pH 4.4	14.24		9.92	10.04	7.13		4.97	5.00	4.45	4.45	4.24	4.24	3.75		3.57		3.36	3.34	3.24	3.24	3.18	3.19
80004-OB 9	pH 6.8	14.24		9.92	9.92	7.07		4.95	4.97	4.41		4.24	4.24	3.68		3.55		3.33	3.33	3.24	3.24		
80004-OB 10	pH 7.0	14.24	14.01	9.92	10.15	7.13		4.97	5.00			4.24	4.27	3.68	3.74	3.57		3.33	3.36	3.24	3.24		
80006-OB 6	pH 6.4	14.71	14.01	9.81	10.04	7.07		4.97	5.00	4.43	4.43	4.20	4.24			3.54		3.31	3.33	3.21	3.24	3.17	3.19
80006-OB 10	pH 7.1	13.58	14.01	9.92	10.04	7.13		4.97	5.00		4.45	4.26	4.26	3.70	3.72	3.55		3.34	3.36	3.24			
81001-OB 7	pH 3.6	14.71		9.92	9.98	7.13		4.97		4.43	4.48	4.24	4.26	3.72	3.67	3.57		3.33	3.34	3.24	3.25	3.18	3.19
81001-OB 8	pH 3.5	14.47		9.92	9.92	7.07		4.95	4.97	4.43	4.45	4.24	4.26			3.55		3.33	3.34	3.24	3.25	3.18	3.19
81001-OB 9	pH 3.7	14.71		10.04	9.97	7.13		4.95	5.00		4.45	4.24	4.26			3.55		3.33	3.36	3.24	3.26	3.18	3.21
81001-OB 10	pH 6.3	14.47	13.18	10.04	9.92	7.13		4.97	5.00	4.45	4.45	4.24	4.24	3.68	3.69	3.57		3.34	3.37				
81001-OB 11	pH 7.3	14.71	14.03	9.92	10.04	7.13		4.97	5.00	4.45	4.48	4.24	4.26			3.57		3.32	3.34	3.24	3.26	3.18	3.20

A= air dried
B= baked

81002-OB 5	pH 3.8	14.96	14.01	9.92	9.92	7.07	4.97	5.00		4.48	4.24	4.26		3.72	3.57	3.33	3.34	3.24	3.25	3.19	
81002-OB 6	pH 7.1	14.96	14.04	9.92	9.92	7.18	5.00	4.97			4.24	4.24	3.68	3.68	3.55	3.33	3.34		3.24		3.19
81002-OB 7	pH 7.2	14.59	14.24	9.92	10.15	7.13	5.00	4.97		4.45	4.24	4.24	3.70	3.68	3.57	3.34	3.33		3.24		
81002-OB10a	pH 7.1	14.96		9.92	9.92	7.13	4.97	4.95			4.24	4.24	3.70	3.68	3.57	3.33	3.33	3.24	3.22		
81002-OB10b	pH 7.1	14.97	13.79	10.04	9.92	7.18	4.97	4.97			4.26	4.24	3.70	3.68	3.57	3.24	3.24	3.24			
81002-OB 12	pH 7.4	14.96	13.79	9.98	10.04	7.10	4.95	4.84			4.24	4.26			3.55	3.33	3.36	3.24	3.24		
81003-OB 3	pH 3.8	14.47		9.92	9.98	7.13	5.00	5.00		4.45	4.24	4.27	3.65	3.67	3.55	3.34	3.34	3.24	3.25	3.19	3.19
81003-OB 4	pH 5.4	15.22	13.79	10.04	9.92	7.13					4.24	4.28		3.72	3.55	3.33	3.36	3.24	3.25	3.18	3.19
81003-OB 5	pH 5.7	14.47	13.79	9.92	9.92	7.13	4.97		4.45	4.46	4.24	4.27		3.57	3.57	3.33	3.35	3.24	3.25	3.19	3.19
81003-OB 6	pH 3.9	14.47	13.90	9.98	10.04	7.13	4.99	5.86		4.45	4.24	4.28		3.69	3.57	3.32	3.34	3.24	3.24	3.19	3.18
81003-OB 10	pH 4.1	14.24		10.04	10.04	7.18	4.97	5.00			4.24	4.24			3.57	3.34	3.34	3.25	3.25	3.20	3.19
81003-OB 11	pH 7.1	14.01	14.01	9.80	10.15	7.07	4.95	5.00			4.22	4.28	3.68	3.72	3.55	3.32	3.36	3.22	3.24		
81003-OB 12	pH 7.4	14.71	13.79	9.92	9.92	7.07	4.95	4.97			4.22	4.24		3.68	3.54	3.33	3.34	3.22	3.24		
81004-OB 9	pH 7.3	15.22	14.01	10.04	9.92	7.18	5.00	4.95			4.26	4.24			3.57	3.34	3.33		3.22		
81004-OB 12	pH 7.3	14.24	14.01	9.92	9.92	7.07	4.97	4.97	4.45	4.45	4.24	4.24		3.68	3.55	3.33	3.33	3.24	3.24	3.18	3.16
81004-OB 15	pH 7.2	14.96	14.21	9.92	10.15	7.07	4.95	5.00	4.43	4.48	4.22	4.24	3.65	3.68	3.55	3.32	3.36	3.22	3.25	3.18	3.20
81004-OB 17	pH 6.7	15.49	14.01		9.92	7.18	5.00	4.95	4.48	4.41	4.28	4.24	3.67	3.68	3.58	3.36	3.33	3.24	3.24	3.20	3.18
81004-OB 19	pH 7.3	15.22	14.24	10.04	10.04	7.13	5.00		4.45	4.48	4.24	4.26	3.76	3.67	3.57	3.33	3.36	3.24	3.26	3.19	3.19
81005-OB 4	pH 3.9	14.71		9.98	9.98	7.07	4.95	5.00	4.45	4.45	4.24	4.26	3.70	3.72	3.55	3.33	3.34	3.25	3.26	3.20	
81005-OB 5	pH 3.3	14.71		9.92	10.15	7.13	4.97		4.43	4.41	4.24	4.26	3.70	3.70	3.57	3.38	3.36	3.28	3.24		
81005-OB 6	pH 3.5	14.24		9.98	9.98	7.18	5.00	5.00		4.48	4.24	4.26	3.83		3.57	3.33	3.36	3.24	3.25		
81005-OB 7	pH 6.0	14.24		9.92	10.15	7.18	4.99	5.03	4.45	4.45	4.24	4.24	3.68	3.70	3.55	3.33	3.36	3.24	3.25		
81006-OB 4	pH 5.9	tr		9.92	9.92	7.13	4.97	4.95	4.43		4.26	4.24		3.89	3.55	3.31	3.34				
81006-OB 5	pH 7.8	14.71	tr	9.92	9.92	7.13	4.95	5.06			4.24	4.32		3.72	3.55	3.33	3.38	3.24	3.24		
81006-OB 6	pH 7.1	14.24	14.01	9.92	10.04	7.07	4.95	4.97			4.24	4.24		3.68	3.55	3.33	3.33	3.24	3.24		
81006-OB 8	pH 6.4	14.47	tr	9.92	10.04	7.13	4.97	4.97	4.45	4.45	4.24	4.24			3.57	3.34	3.34	3.24	3.24	3.18	3.18
81006-OB 9	pH 6.6	14.71		9.92	9.92	7.13	4.95	5.03	4.48	4.48	4.26	4.24		3.70	3.57	3.37	3.34	3.25	3.25	3.20	3.19
81006-OB 10	pH 7.2	14.24	14.47	9.92	10.15	7.13	5.00	5.06		4.45	4.26	4.28	3.72	3.79	3.57	3.34	3.36	3.24	3.26	3.19	3.21
81006-OB 11	pH 6.2	14.71	14.01	10.04	10.04	7.18	4.95	5.00	4.41	4.45	4.24	4.26	3.64	3.65	3.55	3.33	3.34	3.24	3.25	3.18	3.19
81006-OB 12	pH 5.6	14.24		9.92	10.15	7.13	4.97	5.03	4.45	4.45	4.24	4.26	3.68	3.72	3.57	3.34	3.36	3.24	3.25	3.19	3.19
81006-OB 13	pH 6.6	14.47	14.01	9.92	10.04	7.07	4.95	5.03	4.45		4.24	4.24	3.68	3.70	3.55	3.33	3.34		3.24		
81006-OB 14	pH 7.3	14.71	14.24	9.92	9.92	7.18	4.97	5.00			4.24	4.24	3.68	3.70	3.55	3.33	3.33	3.24	3.24		

Sample	Mont-morillonite	Chlorite		Illite		Kao-linite
	A	A	B	A	B	A
81001-OB 7 pH 3.6	18.59			10.04	9.81	7.13
81002-OB 5 pH 3.8	18.01			9.92	9.98	7.13
81003-OB 6 pH 3.9	18.39			9.92	9.92	7.07
81005-OB 4 pH 3.9	18.79			10.04	9.92	7.18
81005-OB 5 pH 3.3	18.78			9.92	9.81	7.13
81005-OB 6 pH 3.5	18.39			9.92	9.92	7.13
81005-OB 7 pH 6.0	19.19			10.04	9.92	7.18
80002-OB 6 pH 6.9	18.78		13.58	9.60	9.98	7.13
81002-OB 7 pH 7.2	18.78		14.24	9.92	10.09	7.13
81002-OB 12 pH 7.4	19.40		13.58	9.87	9.92	7.18
81003-OB 4 pH 5.4	20.00		14.01	10.27	9.92	7.30
81003-OB 5 pH 5.7	18.39		13.68	9.92	9.92	7.07
81006-OB 4 pH 5.9	19.61	14.24	13.79	10.04	10.04	7.18
81006-OB 5 pH 7.8	19.61	14.24	13.79	9.92	9.92	7.13
81006-OB 6 pH 7.1	19.61	14.47	13.68	9.92	9.92	7.07
81006-OB 11 pH 6.2	18.37	14.01	13.79	9.92	9.81	7.07
81006-OB 12 pH 5.6	18.78		13.58	9.92	9.92	7.13
81006-OB 13 pH 6.6	18.78		14.01	9.81	10.04	7.07
81006-OB 14 pH 7.3	18.78		13.79	9.92	9.92	7.07

APPENDIX 3

CHEMICAL ANALYSES

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.
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LABORATORY REPORT

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WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ 80001										
SAMPLE NO.	1		2	3	4	5	6		7	
HOLE NO.	OB-1	OB-2	OB-3	OB-4	OB-5	OB-6	OB-7		UB-1	
DEPTH, FT.	0-10	10-20	20-30	30-40	40-50	50-60	60-72.6		96.9-102.0	
$pH^{(1)}$	7.3	NO SAMPLE SUBMITTED - CORE LOSS 10-20 ft.	7.4	6.8	7.4	6.0	7.2		7.0	
COND., mmhos$^{(2)}$	2.59		4.06	3.34	3.35	3.77	3.28		1.48	
SATURATION, %$^{(1)}$	25.1		20.2	18.0	17.4	27.0	44.2		50.4	
PARTICLE SIZE								NO SAMPLE SUBMITTED		
% SAND	71		79	87	85	65	29		19	
% SILT	19		17	13	15	27	46		39	
% CLAY	10		4	<2	<2	8	25		42	
TEXTURE*	SL		LS	S	LS	SL	L		C	
CALCIUM., meq/1$^{(3)}$	13.5		30.2	28.5	28.3	29.7	23.2		9.09	
MAGNESIUM, meq/1$^{(3)}$	10.2		11.5	11.5	11.2	20.4	17.2		4.87	
SODIUM, meq/1$^{(3)}$	5.39		9.38	4.71	4.91	2.71	1.77		1.07	
SAR$^{(4)}$	1.60		2.05	1.05	1.11	0.54	0.39		0.41	
ESP	1.26		1.97	1.38	1.53	0.66	0.34		0.24	
LIME$^{(5)}$	2.6		1.7	22.0	12.1	1.0	0.9		1.4	
COPPER, ppm	0.5		0.4	0.3	0.4	1.7	2.0		4.9	
SELENIUM, ppm (6)	0.04		0.10	<0.02	<0.02	<0.02	0.22		0.28	
BORON, ppm (6)	0.2		0.3	0.4	0.4	0.4	0.3		0.7	
NITRATE-N, ppm	1.8		31	2.6	2.9	1.5	1.0		<1.0	
MOLYDENUM, ppm (7)	<0.05		<0.05	0.13	0.05	0.06	0.29		0.14	
POT. ACIDITY (8)	<1		<1	<1	<1	<1	3.06		<1	
NEUT. POT. (9)	26		17	22	121	10	9		14	
ACID BASE POT. (10)	+26		+17	+22	+121	+10	+7.5		+14	

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY @ 25°C, MEASURED ON SATURATED EXTRACT. (3) MEASURED ON SATURATED EXTRACT. (4) SODIUM ABSORPTION RATIO. (5) QUALITATIVE BY EFFERVESCENCE. SL = SLIGHTLY CALCAREOUS, MOD = MODERATELY CALCAREOUS, HI = HIGHLY CALCAREOUS. (6) WATER SOLUBLE. (7) MEASURED AFTER $(NH_4)_2CO_3$ EXTRACTION. (8) MEQ. H^+ PER 100 g. (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL. *USDA TEXTURAL CLASS KEY: S = SAND(Y); Si = SILT(Y); L = LOAM(Y); C = CLAY.

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MINE LAB NO. 80-3338

Redrill #1 J 80001										
SAMPLE NO.	124	125	126	127						
HOLE NO.	OB-2	OB-3	OB-4	OB-5						
DEPTH, FT.	10-20	20-30	30-40	40-50						
pH(1)	6.8	6.8	4.5	4.24						
COND., mmhos(2)	2.69	2.50	2.99	1.60						
SATURATION, %(1)	25.3	27.0	30.9	30.2						
PARTICLE SIZE										
% SAND	71	73	75	81						
% SILT	15	13	15	13						
% CLAY	14	14	10	6						
TEXTURE*	SL	SL	SL	LS						
CALCIUM, meq/1(3)	14.9	14.1	19.4	7.03						
MAGNESIUM, meq/1(3)	6.11	5.48	7.32	3.85						
SODIUM, meq/1(3)	5.25	6.15	6.35	3.40						
SAR(4)	1.62	1.97	1.74	1.46						
ESP	1.62	1.92	1.17	1.03						
LIME(5)	2.3	2.9	2.0	2.1						
COPPER, ppm	0.6	0.6	0.8	0.4						
SELENIUM, ppm(6)	0.08	0.03	<0.02	<0.02						
BORON, ppm(6)	0.3	0.2	0.2	0.1						
NITRATE-N, ppm(7)	23	20	5.5	<1.0						
MOLYBDENUM, ppm(8)	<0.05	0.06	0.05	<0.05						
T. ACIDITY (8)	<1	<1	<1	<1						
EUT. POT. (9)	23	29	20	21						
ACID BASE POT. (10)	+23	+29	+20	+21						

SAMPLE NO.										
HOLE NO.										
DEPTH, FT.										
pH(1)										
COND., mmhos(2)										
SATURATION, %(1)										
PARTICLE SIZE										
% SAND										
% SILT										
% CLAY										
CALCIUM, meq/1(3)										
MAGNESIUM, meq/1(3)										
SODIUM, meq/1(3)										
SAR(4)										
LIME(5)										
SELENIUM, ppm(6)										
ON, ppm (6)										
NITRATE-N, ppm(7)										
MOLYBDENUM, ppm(8)										

(See Notes page 1)

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MINE ______ LAB NO. 80-3338

DJ 80002										
SAMPLE NO.	8	9	10	11	12	13	14	15	16	17
HOLE NO.	OB-1	OB-2	OB-3	OB-4	OB-5	OB-6	OB-7	OB-8	OB-9	OB-1
DEPTH, FT.	0-10	10-20	20-30	30-38	38-41.6	41.6-47.7	47.7-57.0	57.0-65.5	65.5-79.8	79.8 89.
pH (1)	6.8	5.1	4.9	[illegible]	5.2	6.9	[illegible]	4.4	5.2	6.5
COND., mmhos (2)	3.73	3.38	3.46	3.57	1.30	3.53	4.09	4.55	2.09	1.3
SATURATION, % (1)	27.3	20.0	17.3	19.6	18.4	48.0	22.4	22.5	36.4	24.5
PARTICLE SIZE										
% SAND	73	91	88	87	89	33	87	83	63	87
% SILT	19	9	12	13	11	43	13	17	33	13
% CLAY	8	<2	<2	<2	<2	24	<2	<2	4	<2
TEXTURE*	SL	S	S	S	S	L	S	LS	SL	S
CALCIUM, meq/1 (3)	25.1	25.1	25.5	26.2	6.47	25.1	25.6	24.5	12.1	9.43
MAGNESIUM, meq/1 (3)	16.4	13.4	13.3	14.6	4.27	17.8	23.5	29.3	11.2	4.16
SODIUM, meq/1 (3)	8.21	3.65	3.59	3.44	1.86	2.03	4.31	3.59	1.47	1.26
SAR (4)	1.80	0.83	0.82	0.76	0.80	0.44	0.87	0.69	0.43	0.48
ESP	1.65	1.21	1.21	0.86	1.40	0.41	0.63	0.19	0.38	0.37
LIME (5)	0.9	0.6	0.3	0.8	0.6	0.9	0.6	0.5	0.9	5.5
COPPER, ppm	0.9	0.3	0.3	0.4	0.3	2.3	0.4	0.9	1.2	0.2
SELENIUM, ppm (6)	<0.02	<0.02	<0.02	<0.02	<0.02	0.08	<0.02	<0.02	<0.02	<0.02
BORON, ppm (6)	0.3	0.3	0.4	0.3	0.2	0.1	0.3	0.3	0.4	0.3
NITRATE-N, ppm (7)	1.2	<1.0	<1.0	<1.0	<1.0	1.9	<1.0	<1.0	<1.0	<1.0
MOLYBDENUM, ppm (8)	<0.05	<0.05	<0.05	<0.05	<0.05	0.14	<0.05	<0.05	0.16	0.08
POT. ACIDITY (8)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
NEUT. POT. (9)	9	6	3	8	6	9	6	5	9	55
ACID BASE POT. (10)	+9	+6	+3	+8	+6	+9	+6	+5	+9	+55

DJ 80002				
SAMPLE NO.	18	19	NO SAMPLE SUBMITTED	20
HOLE NO.	OB-11	OB-12		UB-1
DEPTH, FT.	89.8-96.1	96.1-100.6		131.7-136.7
pH (1)	5.9	5.9		6.9
COND., mmhos (2)	3.12	1.96		1.69
SATURATION, % (1)	27.7	28.3		31.4
PARTICLE SIZE				
% SAND	80	80		72
% SILT	18	16		20
% CLAY	2	4		8
TEXTURE*	LS	LS		SL
CALCIUM, meq/1 (3)	25.2	14.1		11.3
MAGNESIUM, meq/1 (3)	14.3	9.07		5.52
SODIUM, meq/1 (3)	1.31	0.99		1.07
SAR (4)	0.29	0.29		0.58
ESP	0.22	0.24		0.33
LIME (5)	0.7	1.1		0.9
COPPER, ppm	0.7	0.4		1.5
SELENIUM, ppm (6)	<0.02	<0.02		0.08
BORON, ppm (6)	0.3	0.4		0.3
NITRATE-N, ppm (7)	<1.0	<1.0		<1.0
MOLYBDENUM, ppm (8)	1.8	4.6		1.2
POT. ACIDITY (8)	<1	1.02		<1
NEUT. POT. (9)	7	11		9
ACID BASE POT. (10)	+7	+10.5		+9

(See Notes page 1)

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MINE LAB NO. 80-3338

. 80004										
SAMPLE NO.	27	28	29	30	31	32	33	34	35	36
HOLE NO.	OB-1	OB-2	OB-3	OB-4	OB-5	OB-6	OB-7	OB-8	OB-9	OB-10
DEPTH, FT.	0-10	10-23.5	23.5-28	28-38	38-48	48-60	60-70	70-83	83-93	93-103.
pH(1)	7.1	7.1	7.0	6.5	4.9	4.5	4.5	4.4	6.8	7.0
COND., mmhos(2)	1.14	4.74	3.92	2.87	3.63	3.96	3.57	3.82	1.98	1.87
SATURATION, %(1)	21.8	37.8	38.8	20.2	18.9	19.5	39.0	25.4	48.8	43.9
PARTICLE SIZE										
% SAND	82	50	41	90	89	86	84	86	38	46
% SILT	16	24	32	10	11	14	16	14	39	31
% CLAY	2	26	27	<2	<2	<2	<2	<2	23	23
TEXTURE*	LS	SCL	CL	S	S	S	LS	S	L	L
CALCIUM, meq/1(3)	5.69	38.2	28.7	17.2	26.9	27.2	26.6	17.8	14.9	12.9
MAGNESIUM, meq/1(3)	3.29	15.4	13.7	10.2	13.2	12.1	10.0	6.92	7.27	5.81
SODIUM, meq/1(3)	2.57	6.94	5.07	4.38	3.54	4.50	3.60	3.18	0.95	0.94
SAR(4)	1.21	1.34	1.10	1.18	0.79	1.02	0.84	0.90	0.29	0.31
ESP	1.35	0.79	1.18	0.88	0.90	0.73	0.39	0.40	0.24	0.31
LIME(5)	1.1	1.9	1.3	0.7	0.7	0.4	0.5	0.7	1.3	1.8
COPPER, ppm	0.3	0.7	0.8	0.4	0.3	0.6	0.3	0.6	2.2	2.7
SELENIUM, ppm(6)	<0.02	0.08	0.21	0.05	<0.02	<0.02	<0.02	<0.02	0.13	0.19
BORON, ppm(6)	0.1	0.6	0.5	0.3	0.2	0.4	0.4	0.3	0.5	0.6
NITRATE-N, ppm(7)	<1.0	31	56	19	7.8	3.0	2.2	<1.0	1.2	1.0
MOLYBDENUM, ppm(8)	<0.05	0.10	0.07	0.06	<0.05	0.07	<0.05	0.09	0.10	0.12
T. ACIDITY (8)	<1	<1	<1	<1	<1	<1	<1	<1	<1	10.2
NEUT. POT. (9)	11	19	13	7	7	4	5	7	13	18
ACID BASE POT. (10)	+11	+19	+13	+7	+7	+4	+5	+7	+13	+13

DJ 80004										
SAMPLE NO.	37									
HOLE NO.	UB-1									
DEPTH, FT.	135-140									
pH(1)	7.2									
COND., mmhos(2)	1.79									
SATURATION, %(1)	39.4									
PARTICLE SIZE										
% SAND	42									
% SILT	33									
% CLAY	25									
TEXTURE*	L									
CALCIUM, meq/1(3)	12.5									
MAGNESIUM, meq/1(3)	5.69									
SODIUM, meq/1(3)	1.07									
SAR(4)	0.35									
ESP	0.24									
LIME(5)	1.0									
COPPER, ppm	3.1									
ENIUM, ppm(6)	0.12									
ION, ppm(6)	0.6									
NITRATE-N, ppm(7)	<1.0									
MOLYBDENUM, ppm(8)	0.16									
POT. ACIDITY (8)	31.6									
NEUT. POT. (9)	10									
ACID BASE POT. (10)	-5.8									

(See Notes page 1)

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.

P.O. BOX 893 • 1107 SOUTH BROADWAY • BILLINGS, MT 59103 • PHONE (406) 252-6325

EERC ENERGY AND ENVIRONMENTAL RESOURCE CONSULTANTS, INC

LABORATORY REPORT

Lab. No. 81-2330

To NERCO, INC.
Date 7-2-81 jgs

Address 111 S.W. Columbia Suite 800 Portland, Oregon 97201

WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE Dave Johnston

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ 81001-OB										
SAMPLE NO.	1	2	3	4	5	6	7	8	9	10
HOLE NO.	OB1	OB2	OB3	OB4	OB5	OB6	OB7	OB8	OB9	OB10
DEPTH, FT.	0.0-10.0	10.0-19.6	19.6-28.0	28.0-37.9	37.9-47.8	47.8-57.8	57.8-66.6	66.6-76.5	76.5-81.0	81.0-86.3
pH (1)	5.3	3.7	3.8	7.0	4.2	3.9	3.6	3.5	3.7	6.3
mmhos (2)	6.30	3.58	1.01	1.83	3.48	3.60	3.98	3.68	1.51	1.59
RATION, %	58.2	27.1	26.7	67.6	25.3	28.3	29.4	34.0	28.4	57.3
PARTICLE SIZE										
% SAND	29	77	83	15	81	73	79	80	75	25
% SILT	39	17	14	36	14	20	16	17	22	48
% CLAY	32	6	3	49	5	7	5	3	3	27
TEXTURE (3)	CL	LS	LS	C	LS	SL	LS	LS	LS	CL
CALCIUM., meq/l (4)	25.1	26.0	5.53	10.3	26.1	25.8	25.3	26.2	7.52	8.11
MAGNESIUM, meq/l (4)	71.0	16.8	2.62	7.15	18.7	23.1	28.5	23.9	5.40	5.61
SODIUM, meq/l (4)	16.1	4.17	1.89	1.47	2.26	2.40	2.72	2.26	2.11	1.69
SAR (5)	2.32	0.90	0.94	0.50	0.48	0.49	0.52	0.45	0.83	0.65
ESP (6)	1.67	1.91	1.57	0.53	1.21	0.96	1.07	0.97	1.09	0.69
LIME (7)	<0.1	<0.1	0.2	1.4	0.4	<0.1	<0.1	0.4	0.5	1.4
COPPER, ppm	2.9	1.1	0.8	2.7	0.9	0.8	1.5	1.4	0.6	2.2
SELENIUM, ppm	0.14	<0.02	0.02	0.03	0.03	<0.02	<0.02	0.02	<0.02	<0.02
BORON, ppm	0.5	0.2	0.3	0.5	0.3	0.2	0.2	0.2	0.2	0.3
NITRATE-N, ppm	<1.0	1.2	<1.0	1.1	<1.0	<1.0	1.0	<1.0	1.4	1.1
MOLYDENUM, ppm	<0.05	<0.05	<0.05	0.24	0.60	<0.05	<0.05	<0.05	<0.05	0.32
POT. ACIDITY (8)	<1.0	<1.0	<1.0	1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
NEUT. POT. (9)	<1.0	<1.0	2.1	14.1	4.2	<1.0	<1.0	3.9	5.2	14.1
ACID BASE POT. (10)	<1.0	<1.0	+2.1	+13.3	+4.2	<1.0	<1.0	+3.9	+5.2	+14.1

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY, mmhos/cm @ 25°C, MEASURED ON SATURATED EXTRACT. (3) USDA TEXTURAL CLASS. KEY: S=SAND(Y); Si=SILT(Y); L=LOAM(Y); C=CLAY. (4) MEASURED ON SATURATED EXTRACT. (5) SODIUM ABSORPTION RATIO. (6) EXCHANGEABLE SODIUM PERCENTAGE. (7) % AS $CaCO_3$ (8) MEQ. H^+ PER 100 g. (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL — + = LIME EXCESS: — = LIME DEFICIENCY.

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MINE LAB NO.

Redrill #1 DJ 80004										
SAMPLE NO.	113				114		115			
HOLE NO.	OB-2		OB-4		OB-6		OB-7			
DEPTH, FT.	10-18		28-33.5		48-60		60.3-64.8			
pH(1)	7.0				4.5		4.0			
COND., mmhos(2)	4.71				1.95		1.88			
SATURATION, %(1)	32.3				23.0		27.9			
PARTICLE SIZE										
% SAND	59				79		77			
% SILT	21				15		15			
% CLAY	20	NO SAMPLE SUBMITTED	NO SAMPLE SUBMITTED	NO SAMPLE SUBMITTED	6	NO SAMPLE SUBMITTED	8			
TEXTURE*	SCL				LS		SL			
CALCIUM, meq/1(3)	29.7				12.1		11.6			
MAGNESIUM, meq/1(3)	18.9				4.21		4.43			
SODIUM, meq/1(3)	8.20				4.20		3.80			
SAR(4)	1.66				1.47		1.34			
ESP	1.02				1.00		0.80			
LIME(5)	2.6				1.7		1.6			
COPPER, ppm	0.8				0.3		1.5			
SELENIUM, ppm(6)	0.13				<0.02		<0.02			
BORON, ppm(6)	0.3				0.2		0.3			
NITRATE-N, ppm(7)	47				7.6		4.1			
MOLYBDENUM, ppm(8)	0.05				0.05		0.75			
POT. ACIDITY (8)	<1				<1		<1			
NEUT. POT. (9)	26				17		16			
ACID BASE POT. (10)	+26				+17		+16			

SAMPLE NO.										
HOLE NO.										
DEPTH, FT.										
pH(1)										
COND., mmhos(2)										
SATURATION, %(1)										
PARTICLE SIZE										
% SAND										
% SILT										
% CLAY										
CALCIUM, meq/1(3)										
MAGNESIUM, meq/1(3)										
SODIUM, meq/1(3)										
SAR(4)										
LIME(5)										
SELENIUM, ppm(6)										
BORON, ppm(6)										
NITRATE-N, ppm(7)										
MOLYBDENUM, ppm(8)										

(See Notes page 1)

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MINE LAB NO. 80-3338

80006										
SAMPLE NO.	50	51	52	53	54					
HOLE NO.	OB-1	OB-2	OB-3	OB-4	OB-5					
DEPTH, FT.	0-10	10-20	20-30.2	30.2-40	40-51.5					
pH(1)	7.2	7.2	7.1	7.3	7.1					
COND., mmhos(2)	2.38	2.19	1.68	1.39	1.31					
SATURATION, %(1)	24.2	24.2	22.2	22.7	23.4					
PARTICLE SIZE										
% SAND	81	91	90	85	87					
% SILT	13	9	10	15	13					
% CLAY	6	<2	<2	<2	<2					
TEXTURE*	LS	S	S	LS	S					
CALCIUM, meq/1(3)	14.1	15.1	10.6	8.87	8.59					
MAGNESIUM, meq/1(3)	7.78	5.65	3.87	3.01	2.81					
SODIUM, meq/1(3)	5.08	4.04	2.38	2.11	1.79					
SAR(4)	1.54	1.25	0.88	0.87	0.75					
ESP	1.50	1.36	0.64	0.77	0.90					
LIME(5)	1.4	0.9	0.9	8.8	1.0					
COPPER, ppm	0.4	0.2	0.2	0.3	0.3					
SELENIUM, ppm(6)	0.03	<0.02	<0.02	<0.02	<0.02					
BORON, ppm(6)	0.5	0.4	0.3	0.2	0.2					
NITRATE-N, ppm(7)	1.3	1.5	1.5	1.4	1.9					
MOLYBDENUM, ppm(8)	<0.05	<0.05	<0.05	0.06	<0.05					
. ACIDITY (8)	<1	<1	<1	<1	<1					
NEUT. POT. (9)	14	9	9	88	10					
ACID BASE POT. (10)	+14	+9	+9	+88	+10					

SAMPLE NO.										
HOLE NO.										
DEPTH, FT.										
pH(1)										
COND., mmhos(2)										
SATURATION, %(1)										
PARTICLE SIZE										
% SAND										
% SILT										
% CLAY										
CALCIUM, meq/1(3)										
MAGNESIUM, meq/1(3)										
SODIUM, meq/1(3)										
SAR(4)										
LIME(5)										
ENIUM, ppm(6)										
.ON, ppm (6)										
NITRATE-N, ppm(7)										
MOLYBDENUM, ppm(8)										

(See Notes page 1)

COMPANY Nerco, Inc. DATE 12-19-80 jgs PAGE NO. 13

MINE LAB NO. 80-3338

Redrill #1

J 80006 OB

SAMPLE NO.	116	117	118	119	120	121	122	NO SAMPLE SUBMITTED	123	
HOLE NO.	OB-5	OB-6	OB-7	OB-8	OB-9	OB-10	OB-11		UB-1	
DEPTH, FT.	40-50	50.0- 60.9	60.9- 69	69-72	72-80	80-90	90-96.1		130-135	
pH$^{(1)}$	6.6	6.4	6.7	6.2	7.0	7.1	6.4		6.0	
COND., mmhos$^{(2)}$	0.81	0.84	1.26	2.19	1.28	1.58	2.12		1.62	
SATURATION, %$^{(1)}$	25.9	27.0	53.8	60.7	56.9	50.7	56.6		62.1	
PARTICLE SIZE										
% SAND	83	85	25	47	52	29	25		19	
% SILT	13	11	41	27	18	39	37		33	
% CLAY	4	4	34	26	30	32	38		48	
TEXTURE*	LS	LS	CL	SCL	SCL	CL	CL		C	
CALCIUM, meq/1$^{(3)}$	4.93	5.40	8.10	17.1	7.42	8.13	14.0		8.35	
MAGNESIUM, meq/1$^{(3)}$	1.75	2.01	4.84	8.75	4.10	4.23	6.93		4.45	
SODIUM, meq/1$^{(3)}$	1.22	1.60	0.92	1.10	0.93	0.90	1.47		1.92	
SAR$^{(4)}$	0.67	0.83	0.36	0.31	0.39	0.36	0.45		0.76	
ESP	1.06	1.08	0.42	0.32	0.38	0.37	0.20		0.17	
LIME$^{(5)}$	4.4	1.9	2.6	3.8	2.5	2.5	2.6		3.2	
COPPER, ppm	0.4	0.3	4.3	3.2	3.3	3.7	3.8		9.0	
SELENIUM, ppm$^{(6)}$	<0.02	<0.02	0.09	0.09	0.13	0.15	0.20		0.44	
BORON, ppm$^{(6)}$	0.3	0.3	0.3	1.7	0.3	0.2	0.4		0.4	
NITRATE-N, ppm$^{(7)}$	1.5	1.3	1.2	<1.0	<1.0	<1.0	<1.0		1.0	
MOLYBDENUM, ppm$^{(8)}$	0.06	0.05	0.06	0.09	0.14	0.21	0.65		0.85	
T. ACIDITY (8)	<1	<1	1.02	29.5	2.0	<1	2.0		19.3	
EUT. POT. (9)	44	19	26	38	25	25	26		32	
ACID BASE POT. (10)	+44	+19	+25.5	+23	+24	+25	+25		+22.5	

SAMPLE NO.										
HOLE NO.										
DEPTH, FT.										
pH$^{(1)}$										
COND., mmhos$^{(2)}$										
SATURATION, %$^{(1)}$										
PARTICLE SIZE										
% SAND										
% SILT										
% CLAY										
CALCIUM, meq/1$^{(3)}$										
MAGNESIUM, meq/1$^{(3)}$										
SODIUM, meq/1$^{(3)}$										
SAR$^{(4)}$										
LIME$^{(5)}$										
SELENIUM, ppm$^{(6)}$										
ON, ppm$^{(6)}$										
NITRATE-N, ppm$^{(7)}$										
MOLYBDENUM, ppm$^{(8)}$										

(See Notes page 1)

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EERC FORMERLY ENERGY AND ENVIRONMENTAL RESOURCE CONSULTANTS, INC

LABORATORY REPORT

Lab. No. 81-2330

To NERCO, INC.

Date 7-2-81 jgs

Address 111 S.W. Columbia Suite 800 Portland, Oregon 97201

WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE Dave Johnston

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ 81002-OB										
SAMPLE NO.	14	15	16	17	18	NO SAMPLE SUBMITTED	19	20	21	22
HOLE NO.	OB1	OB2	OB3	OB4	OB5		OB6	OB7	OB8	OB9
DEPTH, FT.	0.0-10.0	10.0-20.0	20.0-30.0	30.0-40.0	40.0-50.0		65.5-72.5	72.5-79.1	79.1-89.1	89.1-99.1
pH (1)	6.2	6.0	6.2	6.3	[illegible]		7.1	7.2	7.1	7.5
COND., mmhos (2)	0.41	0.31	0.45	0.50	2.91		1.00	1.10	1.04	0.60
URATION, %	25.8	29.5	27.0	29.2	44.7		50.7	44.6	55.7	47.1
PARTICLE SIZE										
% SAND	86	84	84	70	52		2	31	29	35
% SILT	11	13	13	21	31		67	38	32	34
% CLAY	3	3	3	9	17		31	31	39	31
TEXTURE (3)	LS	LS	LS	SL	L		SiCL	CL	CL	CL
CALCIUM., meq/1 (4)	1.83	1.47	1.96	2.22	25.8		6.79	7.88	6.67	2.40
MAGNESIUM, meq/1(4)	0.42	0.49	1.03	1.01	10.2		2.91	2.33	1.08	0.99
SODIUM, meq/1 (4)	0.69	0.73	0.68	0.75	1.01		0.90	1.08	1.67	1.22
SAR (5)	0.65	0.74	0.56	0.59	0.24		0.41	0.48	0.85	0.94
ESP (6)	0.67	0.62	0.67	0.54	0.29		0.49	0.47	0.43	0.62
LIME (7)	0.4	1.0	0.9	0.8	0.9		<0.1	5.3	2.1	2.3
COPPER, ppm	0.6	0.4	0.4	1.4	2.1		2.9	3.8	4.4	2.4
SELENIUM, ppm	<0.02	<0.02	<0.02	<0.02	<0.02		0.03	0.10	0.14	0.02
BORON, ppm	0.2	0.2	0.2	0.2	0.3		0.4	0.2	0.6	<0.1
NITRATE-N, ppm	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0	<1.0	<1.0	<1.0
MOLYDENUM, ppm	<0.05	<0.05	<0.05	<0.05	<0.05		0.49	0.63	0.74	0.80
POT. ACIDITY (8)	<1.0	<1.0	<1.0	<1.0	8.0		3.5	<1.0	1.0	<1.0
NEUT. POT. (9)	3.9	10.1	8.9	8.0	8.7		<1.0	52.6	21.2	22.6
ACID BASE POT. (10)	+3.9	+10.1	+8.9	+8.0	+4.7		-1.8	+52.6	+20.7	+22.6

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY, mmhos/cm @ 25°C, MEASURED ON SATURATED EXTRACT. (3) USDA TEXTURAL CLASS. KEY: S=SAND(Y); Si=SILT(Y); L=LOAM(Y); C=CLAY. (4) MEASURED ON SATURATED EXTRACT. (5) SODIUM ABSORPTION RATIO. (6) EXCHANGEABLE SODIUM PERCENTAGE. (7) % AS $CaCO_3$ (8) MEQ. H^+ PER 100 g. (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL - + = LIME EXCESS: - = LIME DEFICIENCY.

COMPANY NERCO, INC. DATE 7-2-81 lrs PAGE NO

MINE Dave Johnston LAB NO. 81-2330

DJ 81001-OB

SAMPLE NO.	11	12	NO SAMPLE SUBMITTED	13						
HOLE NO.	OB11	OB12		OB13						
DEPTH, FT.	86.3- 94.0	94.0- 99.4		124.5- 127.4						
pH (1)	6.2	5.9		6.7						
COND., mmhos (2)	1.71	2.10		0.63						
SATURATION, %	29.0	31.2		54.2						
PARTICLE SIZE										
% SAND	79	78		18						
% SILT	18	15		41						
% CLAY	3	7		41						
TEXTURE (3)	LS	LS		SiC						
CALCIUM, meq/1 (4)	10.6	15.6		3.59						
MAGNESIUM, meq/1 (4)	6.65	9.07		1.71						
SODIUM, meq/1 (4)	1.56	1.63		0.98						
SAR (5)	0.53	0.46		0.60						
ESP (6)	0.95	0.75		0.45						
LIME (7)	0.8	0.9		<0.1						
COPPER, ppm	0.9	1.6		2.4						
SELENIUM, ppm	<0.02	<0.02		0.07						
BORON, ppm	0.4	0.4		0.6						
NITRATE-N, ppm	<1.0	<1.0		<1.0						
MOLYBDENUM, ppm	<0.05	0.48		0.40						
POT. ACIDITY (8)	1.0	2.0		1.5						
NEUT. POT. (9)	8.2	8.9		<1.0						
ACID BASE POT. (10)	+7.7	+7.9		-0.8						

SAMPLE NO.										
HOLE NO.										
DEPTH, FT.										
pH (1)										
COND., mmhos (2)										
SATURATION, %										
PARTICLE SIZE										
% SAND										
% SILT										
% CLAY										
TEXTURE (3)										
CALCIUM, meq/1 (4)										
MAGNESIUM, meq/1 (4)										
SODIUM, meq/1 (4)										
SAR (5)										
ESP (6)										
LIME (7)										
COPPER, ppm										
SELENIUM, ppm										
BORON, ppm										
NITRATE-N, ppm										
MOLYBDENUM, ppm										
POT. ACIDITY (8)										
NEUT. POT. (9)										
ACID BASE POT. (10)										

(See Notes page 1)

COMPANY NERCO, INC. DATE 7-2-81 jcs PAGE NO

MINE Dave Johnston LAB NO. 81-2330

81002-OB										
SAMPLE NO.	23	24	25	26	27	28	29	30	31	32
HOLE NO.	OB10	OB11	OB12	OB13	OB14	OB15	OB16	OB17	OB18	OB19
DEPTH, FT.	99.1-109.1	109.1-119.1	119.1-129.1	129.1-140.0	140.0-144.0	144.0-154.0	154.0-159.0	159.0-168.4	168.4-178.4	178.4-188.4
pH (1)	7.2	7.7	7.4	7.7	7.2	7.2	7.3	7.2	7.0	7.0
COND., mmhos (2)	0.57	0.62	0.70	0.59	1.63	1.58	1.15	1.22	1.18	1.34
SATURATION, %	52.2	53.6	41.4	45.1	26.4	25.4	25.7	28.5	29.9	29.4
PARTICLE SIZE										
% SAND	29	19	53	53	85	80	81	79	77	85
% SILT	30	36	26	30	12	17	15	15	19	11
% CLAY	41	45	21	17	3	3	4	6	4	4
TEXTURE (3)	C	C	SCL	SL	LS	LS	LS	LS	LS	LS
CALCIUM, meq/1 (4)	1.97	2.21	4.90	3.85	10.7	10.3	8.16	8.70	8.54	9.62
MAGNESIUM, meq/1 (4)	0.86	0.93	1.51	1.38	4.29	4.40	3.47	3.75	3.52	4.09
SODIUM, meq/1 (4)	1.12	1.11	1.07	0.92	1.81	1.43	1.09	1.21	1.11	1.42
SAR (5)	0.94	0.89	0.60	0.57	0.66	0.53	0.45	0.48	0.45	0.54
ESP (6)	0.64	0.56	0.65	0.66	0.87	0.93	0.64	0.54	0.56	0.77
LIME (7)	1.8	1.1	1.0	1.5	0.5	2.1	3.3	0.8	0.7	0.7
COPPER, ppm	1.9	2.2	2.2	2.3	0.7	0.7	0.7	0.7	0.8	0.6
SELENIUM, ppm	0.06	0.10	0.04	0.08	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BORON, ppm	0.2	0.3	<0.1	<0.1	0.2	<0.1	<0.1	0.2	0.3	0.4
NITRATE-N, ppm	1.0	1.2	1.1	1.0	1.0	1.0	<1.0	<1.0	1.1	1.0
MOLYBDENUM, ppm	0.08	<0.05	0.42	0.40	<0.05	<0.05	<0.05	<0.05	0.23	0.25
(I. ACIDITY (8)	<1.0	<1.0	11.5	1.5	3.5	7.5	<1.0	2.5	2.0	<1.0
NEUT. POT. (9)	18.3	11.0	9.6	15.0	4.7	21.2	33.3	7.5	6.8	6.6
ACID BASE POT. (10)	+18.3	+11.0	+3.8	+14.2	+2.9	+17.4	+33.3	+6.2	+5.8	+6.6

DJ 81002-OB										
SAMPLE NO.	33	34								
HOLE NO.	OB20	OB21								
DEPTH, FT.	188.4-198.4	198.4-208.0								
pH (1)	7.6	7.5								
COND., mmhos (2)	0.78	0.91								
SATURATION, %	27.0	35.2								
PARTICLE SIZE										
% SAND	83	83								
% SILT	13	3								
% CLAY	4	14								
TEXTURE (3)	LS	SL								
CALCIUM, meq/1 (4)	5.35	5.57								
MAGNESIUM, meq/1 (4)	2.11	1.82								
SODIUM, meq/1 (4)	1.05	1.21								
SAR (5)	0.54	0.63								
ESP (6)	0.77	0.75								
LIME (7)	0.5	0.7								
COPPER, ppm	0.6	1.1								
(NIUM, ppm	<0.02	<0.02								
BORON, ppm	0.2	0.3								
NITRATE-N, ppm	<1.0	<1.0								
MOLYBDENUM, ppm	0.11	0.15								
POT. ACIDITY (8)	<1.0	1.0								
NEUT. POT. (9)	4.5	6.6								
ACID BASE POT. (10)	+4.5	+6.1								

(See Notes page 1)

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EERC FORMERLY ENERGY AND ENVIRONMENTAL RESOURCE CONSULTANTS INC

LABORATORY REPORT

Lab. No. 81-2330

To NERCO, INC. Date 7-2-81 jgs

Address 111 S.W. Columbia Suite 800 · Portland, Oregon 97201

WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE Dave Johnston

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ 81003-OB										
SAMPLE NO.	35	36	37	38	39	40	41	42	43	44
HOLE NO.	OB1	OB2	OB3	OB4	OB5	OB6	OB7	OB8	OB9	OB10
DEPTH, FT.	0.0- 12.0	12.0- 22.0	22.0- 32.0	32.0- 42.0	42.0- 52.0	52.0- 62.0	62.0- 67.0	67.0- 75.0	75.0- 84.6	84.6- 94.4
pH (1)	6.0	4.6	3.8	5.4	5.7	3.9	[illegible]	4.9	3.7	4.1
ND., mmhos (2)	3.69	3.45	3.51	3.29	2.90	3.45	3.42	3.51	3.30	2.70
ATURATION, %	49.9	44.0	25.0	26.6	26.2	32.5	34.0	37.6	26.5	24.1
PARTICLE SIZE										
% SAND	29	35	83	81	85	76	73	69	95	89
% SILT	39	35	13	15	11	20	21	21	1	7
% CLAY	32	30	4	4	4	4	6	10	4	4
TEXTURE (3)	CL	CL	LS	LS	LS	LS	SL	SL	S	S
CALCIUM., meq/1 (4)	23.4	25.3	25.1	26.1	26.9	22.7	25.2	25.4	24.2	20.8
MAGNESIUM, meq/1(4)	24.6	21.2	19.4	17.7	14.5	23.7	20.9	24.0	21.1	12.4
SODIUM, meq/1 (4)	4.36	2.76	2.65	2.68	2.18	2.34	2.15	2.41	2.26	2.34
SAR (5)	0.89	0.57	0.56	0.57	0.48	0.49	0.45	0.48	0.47	0.57
ESP (6)	0.75	0.73	1.35	1.28	1.38	0.87	1.14	0.82	1.46	0.97
LIME (7)	0.5	<0.1	0.3	0.8	1.7	0.4	0.5	0.5	0.4	<0.1
COPPER, ppm	2.3	2.8	0.9	0.8	0.7	1.3	1.2	1.4	1.1	0.8
SELENIUM, ppm	0.15	0.04	<0.02	0.03	<0.02	0.06	0.02	0.02	<0.02	<0.02
BORON, ppm	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NITRATE-N, ppm	1.2	5.1	2.4	1.1	1.2	<1.0	<1.0	<1.0	<1.0	<1.0
MOLYDENUM, ppm	0.08	0.06	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05
POT. ACIDITY (8)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
NEUT. POT. (9)	4.7	<1.0	3.1	7.5	17.2	3.8	5.2	5.4	3.8	<1.0
ACID BASE POT. (10)	+4.7	<1	+3.1	+7.5	+17.2	+3.8	+5.2	+5.4	+3.8	<1.0

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY, mmhos/cm @ 25°C, MEASURED O SATURATED EXTRACT. (3) USDA TEXTURAL CLASS. KEY: S=SAND(Y); Si=SILT(Y); L=LOAM(Y); C=CLAY. (4) MEASURED ON SATURATED EXTRACT. (5) SODIUM ABSORPTION RATIO. (6) EXCHANGEABLE SODIUM PERCENTAGE. (7) % AS $CaCO_3$ (8) MEQ. H^+ PER 100 (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL + = LIME EXCESS: - = LIME DEFICIENCY.

COMPANY NERCO, INC. DATE 7-2-81 jcs PAGE NO.

NE Dave Johnston LAB NO. 81-2330

DJ 81003 OB

SAMPLE NO.	45	46	47	48
HOLE NO.	OB11	OB12	OB13	OB14
DEPTH, FT.	94.4- 103.25	103.25- 109.65	109.65- 119.8	119.8- 123.8
pH (1)	7.1	7.4	7.5	7.5
COND., mmhos (2)	1.61	0.98	0.74	0.73
SATURATION, %	51.9	46.3	51.9	58.7
PARTICLE SIZE				
% SAND	29	41	21	23
% SILT	41	39	47	41
% CLAY	30	20	32	36
TEXTURE (3)	CL	L	CL	CL
CALCIUM, meq/1 (4)	11.5	6.67	5.16	5.58
MAGNESIUM, meq/1 (4)	5.57	2.56	1.68	1.60
SODIUM, meq/1 (4)	1.22	0.71	0.79	0.72
SAR (5)	0.42	0.33	0.43	0.38
ESP (6)	0.49	0.85	0.47	0.56
LIME (7)	1.4	1.1	1.2	1.2
COPPER, ppm	2.6	1.4	1.9	2.0
SELENIUM, ppm	0.13	0.08	0.21	0.26
BORON, ppm	0.2	0.2	0.3	0.4
NITRATE-N, ppm	1.0	<1.0	1.0	1.2
LYBDENUM, ppm	0.06	0.32	0.10	0.33
OT. ACIDITY (8)	<1.0	<1.0	8.0	7.5
NEUT. POT. (9)	13.9	11.3	12.0	11.7
ACID BASE POT. (10)	+13.9	+11.3	+8.0	+7.9

SAMPLE NO.				
HOLE NO.				
DEPTH, FT.				
pH (1)				
COND., mmhos (2)				
SATURATION, %				
PARTICLE SIZE				
% SAND				
% SILT				
% CLAY				
TEXTURE (3)				
CALCIUM, meq/1 (4)				
MAGNESIUM, meq/1 (4)				
SODIUM, meq/1 (4)				
SAR (5)				
ESP (6)				
LIME (7)				
PPER, ppm				
ENIUM, ppm				
BORON, ppm				
NITRATE-N, ppm				
MOLYBDENUM, ppm				
POT. ACIDITY (8)				
NEUT. POT. (9)				
ACID BASE POT.				

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WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE Dave Johnston

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ 81004 OB SAMPLE NO.	49	50	51	52	53	54	55	56	57	58
HOLE NO.	OB1	OB2	OB3	OB4	OB5	OB6	OB7	OB8	OB9	OB10
DEPTH, FT.	0.0-12.0	12.0-22.6	22.6-32.9	32.9-42.9	42.9-51.0	51.0-61.7	61.7-65.3	65.3-74.0	74.0-84.4	84.4-94.3
pH (1)	7.1	7.0	6.6	4.3	6.1	7.4	7.4	7.3	7.3	7.6
ND., mmhos (2)	4.29	1.72	0.67	1.60	0.76	0.58	0.69	1.06	0.81	0.90
SATURATION, %	24.1	33.4	27.5	43.3	53.9	51.0	32.9	57.8	54.6	52.4
PARTICLE SIZE										
% SAND	73	86	81	74	36	30	49	21	27	25
% SILT	17	10	15	22	22	38	33	41	35	41
% CLAY	10	4	4	4	42	32	18	38	38	34
TEXTURE (3)	SL	LS	LS	SL	C	CL	L	CL	CL	CL
CALCIUM., meq/1 (4)	26.9	8.26	3.17	10.1	5.25	4.11	4.89	8.52	6.18	7.10
MAGNESIUM, meq/1 (4)	26.5	4.48	1.55	5.40	1.61	1.03	1.17	2.37	1.52	1.99
SODIUM, meq/1 (4)	11.1	4.81	1.87	1.47	0.83	0.63	0.80	0.92	0.87	1.08
SAR (5)	2.15	1.91	1.22	0.58	0.45	0.39	0.46	0.39	0.44	0.51
ESP (6)	2.50	1.79	1.74	0.47	0.63	0.63	0.68	0.63	0.55	0.56
LIME (7)	1.9	1.3	0.8	1.2	1.1	1.5	9.6	2.0	2.2	1.2
COPPER, ppm	0.4	0.3	0.3	0.5	3.4	2.1	2.3	4.2	1.8	2.2
SELENIUM, ppm	0.32	0.13	0.07	0.52	0.09	0.23	0.15	0.62	0.22	0.20
BORON, ppm	0.3	<0.1	0.2	2.3	0.9	0.2	0.1	0.5	0.6	<0.1
NITRATE-N, ppm	1.1	1.2	1.2	<1.0	<1.0	1.0	1.1	1.1	1.1	1.1
MOLYDENUM, ppm	0.17	0.14	0.13	0.14	0.13	0.09	0.09	0.29	0.17	0.10
POT. ACIDITY (8)	<1.0	<1.0	<1.0	409	33.1	10.5	1.0	1.0	7.0	<1.0
NEUT. POT. (9)	18.6	13.2	8.0	11.8	11.3	14.6	95.9	20.0	21.5	12.0
ACID BASE POT. (10)	+18.6	+13.2	+8.0	-193	-5.3	+9.3	+95.4	+19.5	+18.0	+12.0

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY, mmhos/cm @ 25°C, MEASURED ON SATURATED EXTRACT. (3) USDA TEXTURAL CLASS. KEY: S=SAND(Y); Si=SILT(Y); L=LOAM(Y); C=CLAY. (4) MEASURED ON SATURATED EXTRACT. (5) SODIUM ABSORPTION RATIO. (6) EXCHANGEABLE SODIUM PERCENTAGE. (7) % AS $CaCO_3$ (8) MEQ. H^+ PER 100 g (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL + = LIME EXCESS: - = LIME DEFICIENCY.

COMPANY NERCO, INC. DATE 7-2-81 jgs PAGE NO

NE Dave Johnston LAB NO. 81-2330

DJ 81004 OB										
SAMPLE NO.	59	60	61	62	63	64	65	66	67	68
HOLE NO.	OB11	OB12	OB13	OB14	OB15	OB16	OB17	OB18	OB19	OB20
DEPTH, FT.	94.3- 105.0	105.0- 115.0	115.0- 125.0	125.0- 135.0	135.0- 145.0	145.0- 155.0	155.0- 161.0	161.0- 164.7	164.7- 175.0	175.0- 185.0
pH (1)	7.7	7.3	7.2	7.4	7.2	6.8	6.7	7.1	7.3	7.2
COND., mmhos (2)	0.76	1.94	1.40	1.09	1.42	2.10	2.29	1.49	1.21	1.71
SATURATION, %	46.2	33.6	28.9	30.2	26.9	28.4	32.3	50.7	27.9	34.1
PARTICLE SIZE										
% SAND	47	78	84	82	79	78	77	38	79	65
% SILT	31	16	12	14	13	16	19	48	13	25
% CLAY	22	6	4	4	8	6	4	14	8	10
TEXTURE (3)	L	LS	LS	LS	LS	LS	LS	L	LS	SL
CALCIUM, meq/1 (4)	5.95	15.2	10.7	7.91	11.3	16.6	17.6	10.7	8.35	11.2
MAGNESIUM, meq/1 (4)	1.33	4.81	3.09	1.90	3.08	5.75	6.72	4.40	4.66	5.85
SODIUM, meq/1 (4)	0.82	1.82	1.74	1.62	1.68	1.64	1.84	0.76	1.02	1.69
SAR (5)	0.43	0.58	0.66	0.73	0.63	0.49	0.53	0.28	0.40	0.58
ESP (6)	0.70	0.91	0.83	0.90	0.84	0.52	0.60	0.52	0.65	0.46
LIME (7)	1.2	0.9	1.1	1.0	1.3	0.9	1.1	1.5	0.7	1.3
COPPER, ppm	1.9	0.7	0.3	0.3	0.4	0.3	0.7	2.2	0.4	1.0
SELENIUM, ppm	0.40	0.40	0.03	<0.02	<0.02	0.02	0.05	0.21	0.03	0.05
BORON, ppm	<0.1	0.2	0.1	<0.1	0.1	0.2	0.5	0.2	0.2	0.2
NITRATE-N, ppm	1.0	1.1	1.0	<1.0	1.0	<1.0	1.1	1.0	1.2	1.1
YBDENUM, ppm	0.14	0.10	0.11	0.07	0.05	0.05	0.05	0.07	0.08	0.08
OT. ACIDITY (8)	<1.0	9.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.0	1.0	<1.0
NEUT. POT. (9)	11.8	8.5	10.8	10.3	12.5	8.5	10.7	14.6	6.5	12.7
ACID BASE POT. (10)	+11.8	+4.0	+10.8	+10.3	+12.5	+8.5	+10.7	+13.6	+6.0	+12.7

DJ 81004-OB										
SAMPLE NO.	69	70								
HOLE NO.	OB21	OB22								
DEPTH, FT.	185.0- 195.0	195.0- 197.7								
pH (1)	7.8	7.5								
COND., mmhos (2)	1.13	0.98								
SATURATION, %	43.7	49.6								
PARTICLE SIZE										
% SAND	47	31								
% SILT	33	29								
% CLAY	20	40								
TEXTURE (3)	L	C								
CALCIUM, meq/1 (4)	7.60	6.10								
MAGNESIUM, meq/1 (4)	3.53	2.42								
SODIUM, meq/1 (4)	0.81	0.99								
SAR (5)	0.34	0.48								
ESP (6)	0.69	0.60								
LIME (7)	1.0	1.0								
PER, ppm	1.5	4.3								
ENIUM, ppm	0.08	0.46								
BORON, ppm	0.3	0.3								
NITRATE-N, ppm	<1.0	<1.0								
MOLYBDENUM, ppm	0.13	0.20								
POT. ACIDITY (8)	<1.0	1.5								
NEUT. POT. (9)	10.0	10.3								
ACID BASE POT.	+10.0	+9.5								

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EERC FORMERLY ENERGY AND ENVIRONMENTAL RESOURCE CONSULTANTS, INC.

LABORATORY REPORT

Lab. No. 81-2330

To NERCO, INC. Date 7-2-81 jgs

Address 111 S.W. Columbia Suite 800 Portland, Oregon 97201

WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE Dave Johnston

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ 81005-OBC										
SAMPLE NO.	88	89	90	91	92	93	94	NO SAMPLES SUBMITTED	95	NO SAMPLES SUBMITTED
HOLE NO.	OB1	OB2	OB3	OB4	OB5	OB6	OB7		OB8	
DEPTH, FT.	0.0- 6.0	6.0- 12.0	12.0- 16.0	16.0- 26.0	26.0- 31.7	31.7- 33.6	33.6- 36.5		60.2- 62.6	
pH (1)	6.8	6.1	6.6	3.9	3.3	3.5	6.0		3.3	
COND., mmhos (2)	3.30	3.60	3.83	4.52	4.50	4.00	1.51		4.80	
SATURATION, %	35.1	34.6	37.8	38.7	39.9	31.1	58.7		43.7	
PARTICLE SIZE										
% SAND	51	50	44	48	42	74	42		44	
% SILT	27	26	30	32	36	18	30		26	
% CLAY	22	24	26	20	22	8	28		30	
TEXTURE (3)	SCL	SCL	L	L	L	SL	CL		CL	
CALCIUM., meq/1 (4)	31.7	34.4	32.9	28.8	25.7	27.4	11.1		26.9	
MAGNESIUM, meq/1 (4)	16.6	13.8	21.4	41.9	34.1	24.2	4.19		36.7	
SODIUM, meq/1 (4)	5.48	7.35	7.71	5.23	2.55	2.76	1.67		2.28	
SAR (5)	1.12	1.50	1.48	0.88	0.47	0.54	0.60		0.41	
ESP (6)	1.03	1.52	1.03	0.94	0.85	1.14	0.54		0.39	
LIME (7)	1.2	1.0	1.2	0.5	0.6	<0.1	<0.1		1.9	
COPPER, ppm	1.0	0.9	1.0	1.6	2.3	0.9	2.5		1.6	
SELENIUM, ppm	0.06	0.14	0.18	0.08	<0.02	<0.02	<0.02		0.12	
BORON, ppm	0.8	0.8	0.6	0.2	<0.1	0.4	1.2		0.1	
NITRATE-N, ppm	1.3	1.2	1.2	6.4	6.3	4.4	2.8		1.4	
MOLYDENUM, ppm	0.07	0.06	0.05	<0.05	<0.05	<0.05	<0.05		<0.05	
POT. ACIDITY (8)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		19.1	
NEUT. POT. (9)	12.2	10.3	11.8	4.7	5.5	<1.0	<1.0		18.8	
ACID BASE POT. (10)	+12.2	+10.3	+11.8	+4.7	+5.5	<1.0	<1.0		±9.2	

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY, mmhos/cm @ 25°C, MEASURED ON SATURATED EXTRACT. (3) USDA TEXTURAL CLASS. KEY: S=SAND(Y); Si=SILT(Y); L=LOAM(Y); C=CLAY. (4) MEASURED ON SATURATED EXTRACT. (5) SODIUM ABSORPTION RATIO. (6) EXCHANGEABLE SODIUM PERCENTAGE. (7) % AS $CaCO_3$ (8) MEQ. H^+ PER 100 g. (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL - + = LIME EXCESS: - = LIME DEFICIENCY.

COMPANY NERCO, INC. DATE 7-2-81 jcs PAGE NO

MINE Dave Johnston LAB NO 81-2330

DJ 81005-OBC									
SAMPLE NO.	96								
HOLE NO.	UB1								
DEPTH, FT.	64.5– 75.0								
pH (1)	6.0								
COND., mmhos (2)	1.59								
SATURATION, %	26.9								
PARTICLE SIZE									
% SAND	80								
% SILT	12								
% CLAY	8								
TEXTURE (3)	LS								
CALCIUM, meq/1 (4)	11.3								
MAGNESIUM, meq/1 (4)	4.64								
SODIUM, meq/1 (4)	1.41								
SAR (5)	0.50								
ESP (6)	0.73								
LIME (7)	0.1								
COPPER, ppm	0.6								
SELENIUM, ppm	0.05								
BORON, ppm	<0.1								
NITRATE-N, ppm	1.0								
MOLYBDENUM, ppm	<0.05								
)T. ACIDITY (8)	<1.0								
NEUT. POT. (9)	1.4								
ACID BASE POT. (10)	+1.4								

SAMPLE NO.									
HOLE NO.									
DEPTH, FT.									
pH (1)									
COND., mmhos (2)									
SATURATION, %									
PARTICLE SIZE									
% SAND									
% SILT									
% CLAY									
TEXTURE (3)									
CALCIUM, meq/1 (4)									
MAGNESIUM, meq/1 (4)									
SODIUM, meq/1 (4)									
SAR (5)									
ESP (6)									
LIME (7)									
COPPER, ppm									
(NIUM, ppm									
BORON, ppm									
NITRATE-N, ppm									
MOLYBDENUM, ppm									
POT. ACIDITY (8)									
NEUT. POT. (9)									
ACID BASE POT. (10)									

(See Notes page 1)

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P.O. BOX 593 • 1107 SOUTH BROADWAY • BILLINGS, MT 59103 • PHONE (406) 252-6325

LABORATORY REPORT

Lab. No. 81-2330

To - NERCO, Inc.

Date 7-13-81 jgs

Address 111 S.W. Columbia Suite 800 Portland, Oregon 97201

WYOMING SOIL OVERBURDEN / INTERBURDEN ANALYSIS

MINE

(Analysis by procedures recommended by Land Quality Division Guidelines, Wyoming Department of Environmental Quality.)

DJ-81006-OB										
SAMPLE NO.	97	98	99	100	NO SAMPLE SUBMITTED	101	102	NO SAMPLE SUBMITTED	103	104
HOLE NO.	OB1	OB2	OB3	OB4		OB5	OB6		OB7	OB8
DEPTH, FT.	0.0-8.0	8.0-18.0	18.0-25.5	25.5-28.0		29.0-36.5	36.5-47.0		52.4 58.9	58.9-68.6
pH (1)	6.0	[illegible]	6.2	5.9		7.8	7.1		6.1	6.4
C[illegible] mmhos (2)	3.91	3.90	2.36	2.52		1.29	2.41		3.21	2.99
SATURATION, %	51.2	42.4	57.0	72.0		61.3	51.6		55.5	29.4
PARTICLE SIZE										
% SAND	43	47	31	67		31	39		64	78
% SILT	27	29	33	17		29	35		22	14
% CLAY	30	24	36	16		40	26		14	8
TEXTURE (3)	CL	L	CL	SL		C	L		SL	SL
CALCIUM, meq/1 (4)	31.6	29.1	15.1	23.6		9.38	17.3		29.6	30.3
MAGNESIUM, meq/1 (4)	30.6	33.5	16.6	11.7		3.31	9.73		20.3	13.6
SODIUM, meq/1 (4)	3.70	2.47	1.69	1.55		1.11	1.84		1.52	1.87
SAR (5)	0.66	0.44	0.42	0.37		0.44	0.50		0.30	0.40
ESP (6)	1.06	1.40	0.63	0.32		0.53	0.55		0.45	1.33
LIME (7)	1.7	1.3	1.7	3.8		1.2	1.4		9.0	2.8
COPPER, ppm	2.6	2.0	6.1	3.4		4.5	2.9		1.7	0.6
SELENIUM, ppm	0.06	0.04	0.07	0.06		0.03	0.06		0.03	<0.02
BORON, ppm	0.7	0.7	0.5	3.4		0.2	0.3		0.3	0.2
NITRATE-N, ppm	<1.0	<1.0	<1.0	<1.0		<1.0	<1.0		<1.0	<1.0
MOLYDENUM, ppm	0.13	0.09	0.12	0.09		0.12	0.82		0.68	0.22
POT. ACIDITY (8)	<1.0	<1.0	<1.0	42.2		<1.0	3.5		5.0	<1.0
NEUT. POT. (9)	17.2	13.6	17.2	38.2		12.0	13.9		90.1	27.7
ACID BASE POT. (10)	+17.2	+13.6	+17.2	+17.1		+12.0	+12.1		+87.6	+27.7

NOTES: (1) MEASURED ON SATURATED PASTE. (2) CONDUCTIVITY, mmhos/cm @ 25°C, MEASURED ON SATURATED EXTRACT. (3) USDA TEXTURAL CLASS. KEY: S=SAND(Y); Si=SILT(Y); L=LOAM(Y); C=CLAY. (4) MEASURED ON SATURATED EXTRACT. (5) SODIUM ABSORPTION RATIO. (6) EXCHANGEABLE SODIUM PERCENTAGE. (7) % AS $CaCO_3$ (8) MEQ. H^+ PER 100 g. (9) TONS $CaCO_3$/1000 TONS DRY MATERIAL. (10) TONS $CaCO_3$/1000 TONS DRY MATERIAL - + = LIME EXCESS: - = LIME DEFICIENCY.

COMPANY NERCO, Inc. DATE 7-14-81 ics PAGE NO 2

MINE LAB NO. 81-2330

31006-OB										
SAMPLE NO.	NO SAMPLE SUBMITTED	105	NO SAMPLE SUBMITTED	106	107	108	109	110		
HOLE NO.		OB9		OB10	OB11	OB12	OB13	OB14		
DEPTH, FT.		68.8- 79.0		79.7- 86.7	86.7- 94.9	94.9- 102.0	102.0- 109.0	109.0- 123.3		
pH (1)		6.6		7.2	6.2	5.6	6.6	7.3		
COND., mmhos (2)		2.92		2.69	3.10	3.00	2.05	1.39		
SATURATION, %		28.5		26.4	22.3	26.8	53.8	55.2		
PARTICLE SIZE										
% SAND		78		80	78	72	26	22		
% SILT		16		14	12	18	44	44		
% CLAY		6		6	10	10	30	34		
TEXTURE (3)		LS		LS	SL	SL	CL	CL		
CALCIUM, meq/1 (4)		30.9		27.9	28.5	28.0	14.4	8.92		
MAGNESIUM, meq/1 (4)		19.4		15.9	11.4	10.6	7.45	4.08		
SODIUM, meq/1 (4)		1.68		1.56	2.27	1.79	1.66	1.65		
SAR (5)		0.33		0.33	0.51	0.41	0.50	0.65		
ESP (6)		1.10		1.47	1.76	1.11	0.49	0.36		
LIME (7)		2.9		14.2	1.0	0.8	0.9	1.9		
COPPER, ppm		0.4		0.3	0.4	0.9	3.2	2.5		
SELENIUM, ppm		<0.02		<0.02	<0.02	<0.02	0.04	0.08		
BORON, ppm		<0.1		<0.1	<0.1	0.1	0.2	0.2		
NITRATE-N, ppm		1.9		1.3	<1.0	<1.0	<1.0	<1.0		
MOLYBDENUM, ppm		0.05		0.09	0.10	0.12	0.21	0.19		
T. ACIDITY (8)		<1.0		<1.0	1.0	<1.0	<1.0	2.0		
NEUT. POT. (9)		29.4		142	10.3	7.8	8.7	18.9		
ACID BASE POT. (10)		+29.4		+142	+9.8	+7.8	+8.7	+17.9		

SAMPLE NO.										
HOLE NO.										
DEPTH, FT.										
pH (1)										
COND., mmhos (2)										
SATURATION, %										
PARTICLE SIZE										
% SAND										
% SILT										
% CLAY										
TEXTURE (3)										
CALCIUM, meq/1 (4)										
MAGNESIUM, meq/1 (4)										
SODIUM, meq/1 (4)										
SAR (5)										
ESP (6)										
LIME (7)										
COPPER, ppm										
.ENIUM, ppm										
BORON, ppm										
NITRATE-N, ppm										
MOLYBDENUM, ppm										
POT. ACIDITY (8)										
NEUT. POT. (9)										
ACID BASE POT. (10)										

(See Notes page 1)