3.5 Gasification Ash and Slag Characterization

GASIFICATION ASH AND SLAG CHARACTERIZATION

Semiannual Technical Progress Report
for the Period January 1, 1992, through June 30, 1992

by

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for

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GASIFICATION ASH AND SLAG CHARACTERIZATION

1.0 TASK I: THERMAL CONDUCTIVITY OF COAL ASHES

1.1 Introduction

In combustion and gasification systems, a buildup of deposits on heat-transfer surfaces in the convective pass reduces the heat transfer. Therefore, it is important to know the thermal conductivity of the deposited coal ashes to predict the energy loss on the boiler tube heat-transfer surfaces. In this project the Energy and Environmental Research Center (EERC) has developed an apparatus to measure the thermoconductivity of coal ashes.

The thermal conductivity is defined as the proportionality coefficient between the heat flux passing through a material and the temperature gradient resulting from the causative heat flux. This arises from the lattice thermal conduction, k_l; the electronic thermal conduction, k_e; and ionic thermal conduction, k_i (1). The latter factor usually occurs at high temperatures and is a result of the transport of mobile alkali metal ions.

$$k = k_l + k_e + k_i \qquad \text{[Eq. 1]}$$

The primary concern when trying to measure thermoconductivity is to obtain a controlled heat flow in a prescribed direction such that the actual boundary conditions in the experiment agree with those assumed in the theory. The appropriate method is determined by the physical nature of the material, the geometry of the samples available, the required accuracy of results, the speed of operation, and the time and funds available. The various methods for the measurement of thermal conductivity fall into two categories: the steady-state and the nonsteady-state methods. The steady-state method is appropriate for materials of low thermal conductivity such as coal ashes. The measurements of thermal conductivity under steady-state conditions require guard heaters (combined with thermal insulation in most cases). The supplied heat must flow through the defined area of the sample without gain or loss. To achieve such precise conductivity in practice is simply impossible. However, from the practical point of view, it is important to carry out experiments under the same conditions to allow reliable comparison of obtained results. The nonsteady-state method is applied to measure thermal diffusivity (2,3).

The heat flux, defined as Q/t, can result from radiative heat. This effect is mostly observed in large sample sizes (4). Also, one measurement on a large sample takes a long time. Based on the literature, generally a small length-to-width ratio for samples which are poor conductors is recommended to measure thermal conductivity at high temperatures (2,3). To minimize errors in temperature gradient measurements and save time, the thin-plate method was selected for thermal conductivity measurements. The applied method is based on the assumption that there is the same heat flow, Q, through both a sample of unknown conductivity and a standard of known conductivity (5).

Very little data on thermal conductivity of coal ashes exist in the open literature. The problems with obtaining good data on ashes are related to the extremely inhomogeneous chemical and mineralogical compositions present in coal ashes. The purpose of this work is twofold: 1) to gain an understanding of the effects of inhomogeneity, crystallinity, and porosity of coal ash deposits on heat-transfer phenomena; and 2) to determine the relationship between thermal and electrical conductivities in sintered coal ashes in the temperature range of 25°-500°C. To accomplish these objectives, special care was taken with sample preparation.

1.2 Experimental Apparatus

Thermal conductivity measurement was based on the axial one-dimensional heat flow method (6,7). The apparatus used for the thermal and electrical conductivity measurements is shown in Figure 1. A cylindrical pellet with unknown thermal conductivity was placed between a heater at one end and a reference material, Pyrex 7740, with known thermal conductivity (8), at the other end. The hot source was made with a Pt disc and was warmed by a heating element in a stainless steel block with a peripherical guard shield to assure uniform heat flow. The metal block was kept at a constant temperature by controlling a direct current supplied to the main heater using the thermocouple and a temperature controller "EOMEGA." The platinum disc and the metal block were called the "heat" sink. A second platinum disc on top of the sample was called the "cold" sink. A small force was applied to the top of the column to simultaneously improve the connectivity between the pellets and to reduce the radiation processes.

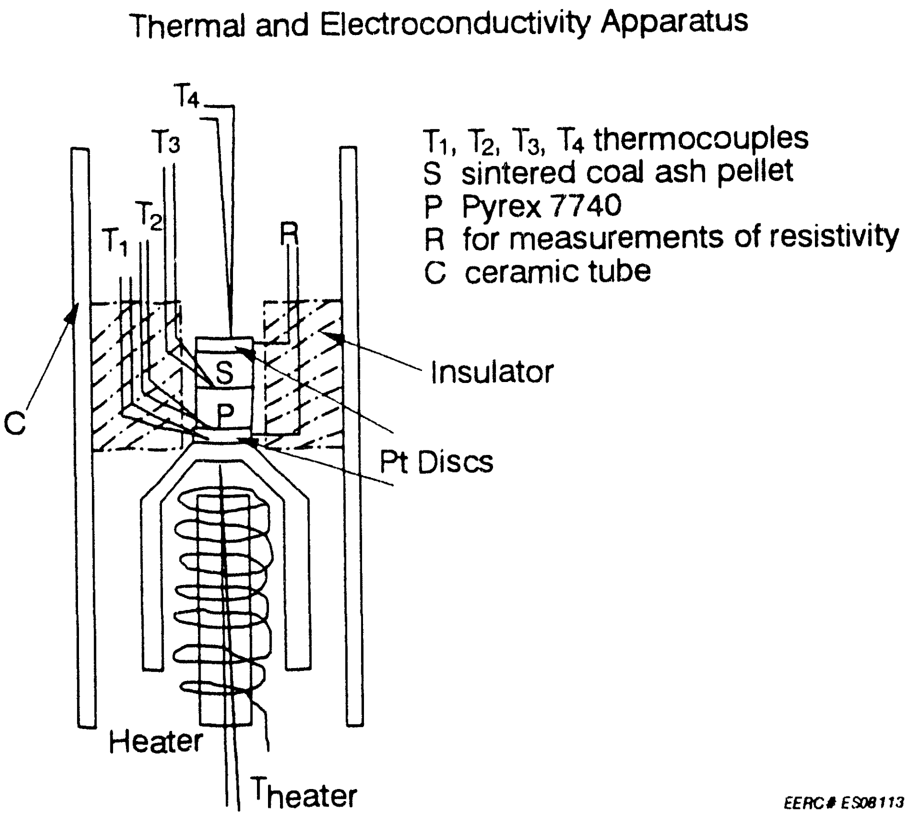

Figure 1. Scheme of thermal and electrical conductivity apparatus.

The thickness and the area of the coal ash specimens were 0.4-0.5 cm and 1.8-1.9 cm^2, respectively. The platinum discs and Pyrex 7740 had the same area, and thicknesses were 0.254 and 0.325 cm, respectively.

In order to get correct temperature measurements and to minimize the error, the Pt-PtRh thermocouples were made with fine wires (fabrication diameters of 0.1 mm). The temperatures were recorded from the central zones.

To prevent radial heat losses, two guard cylinders were used. An inside cylinder surrounding the specimen was made with Zircar® commercials available ceramic material and located around the heater and samples. The outside cylinder was a mullite tube. The ratio of the inside guard cylinder to the specimen radius was 2.0. Additionally, the space between the inside guard shield and the specimen was filled by bubbled alumina which had a low thermal conductivity coefficient (5). This reduced heat losses resulting from the convection process.

1.3 Experimental Procedure

1.3.1 Measurements of Thermal Conductivity

Five Pt-PtRh thermocouples were arranged to measure and to regulate the temperatures: T_1 recorded the temperature of the heater (first platinum disc) at the bottom of a sample; T_2 recorded the temperature between the reference sample and the Pt disc, T_3 recorded the temperature between the reference sample and the coal ash sample, and T_4 recorded the temperature of the cold sink.

To evaluate the accuracy of the recorded temperature, the temperature on Pt/Pyrex/Pt sandwich specimens was measured using two fine-wire thermocouples at each interface. The precision of the measured temperature was ±0.05°C.

For temperature measurements, a Fluke Hydra 2620A data acquisition unit was used. The direct current in the heating element, the switching mechanism for reading temperatures, and the "beaded" thermocouples have shown that the reproducibility of measuring temperatures on Pt discs is superior, with absolute error ±0.6°C in the temperature range of 100°-500°C.

Tests on all specimens were run for a fixed time (usually 5 min), and the outputs at that time were recorded until equilibrium was achieved. Figure 2 shows the variation of thermal conductivity with time, recorded at the heater temperatures of 125°, 415°, and 480°C for Beulah coal ash sintered at 1100°C for 3 h in air. We have developed a computer program which allows us to control and record all of the results, saving them to disc.

All test were run on well-polished pellets, previously sintered in an air atmosphere at appropriate temperatures and times, to assure good surface contact. Pellets with any flaws were rejected from further tests.

As mentioned above, Pyrex 7740 was selected as a reference material since its conduction area matched those in coal ash deposits well. Pyrex conductivity was, in turn, controlled using a specimen of fused silica. The accuracy of the thermal conductivity of Pyrex 7740 was compared with that cited in literature and was about 5%. Figure 3 shows the variation of thermal

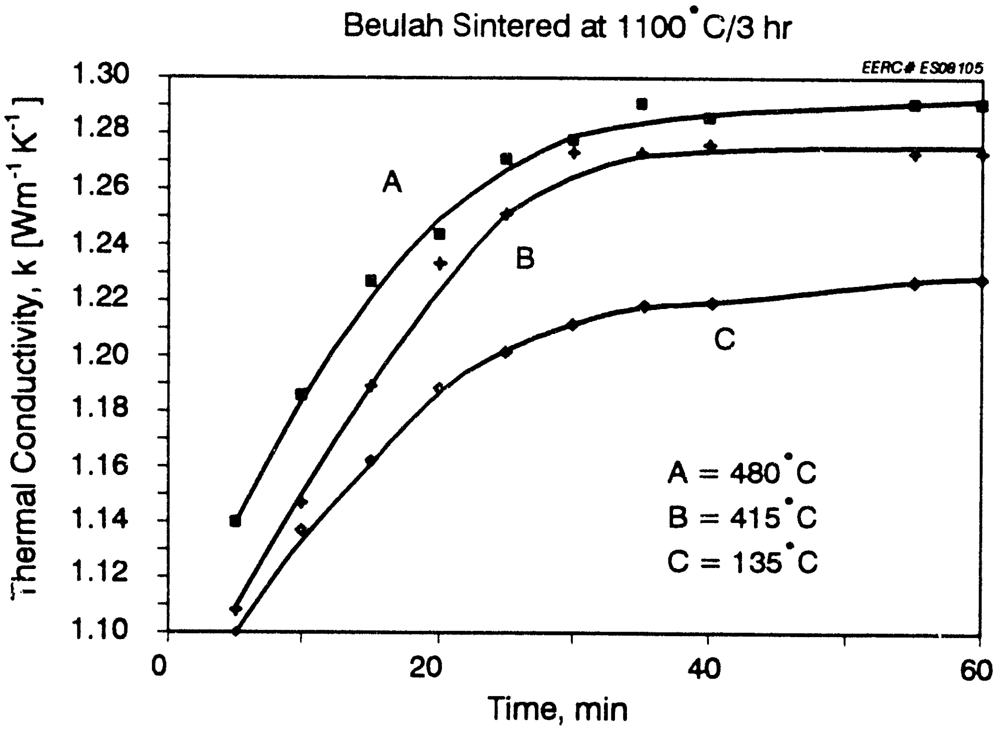

Figure 2. Variation of thermal conductivity with time in Beulah coal ash sintered at 1100°C for 3 h. Measurements were taken at heater temperatures of 135°, 415°, and 480°C.

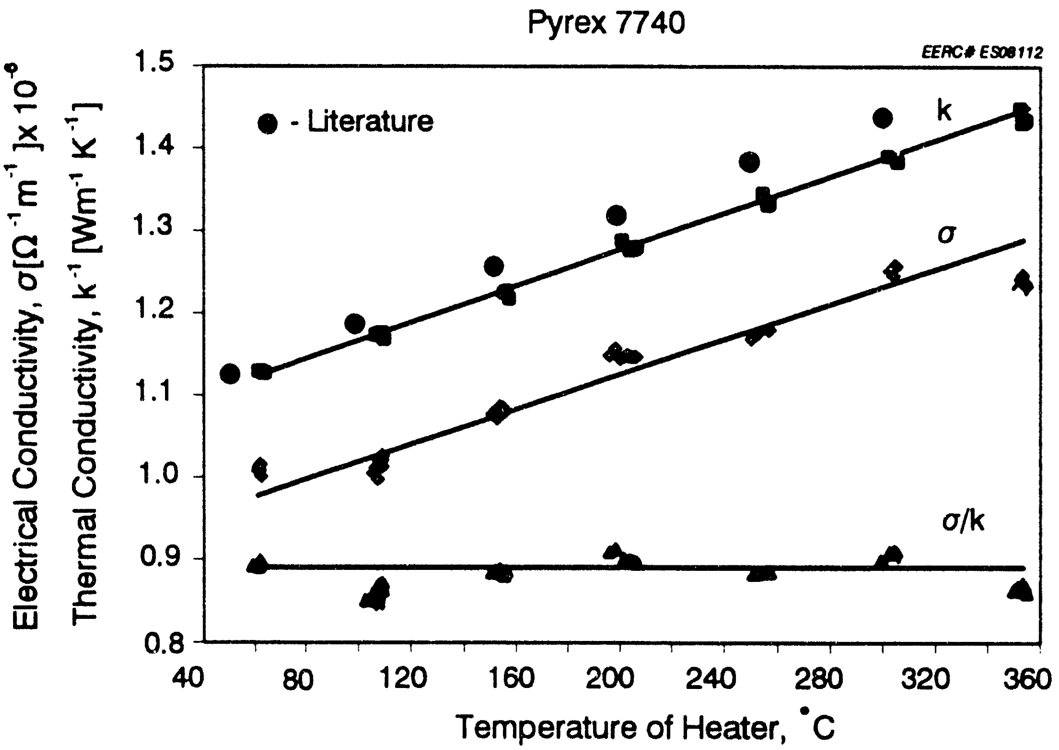

Figure 3. Calibration curve of Pyrex 7740.

conductivity with temperature for several runs in the temperature range of 50°-400°C, determined in our experiment and compared with those in literature (4).

1.3.2 Measurements of Electrical Conductivity

Electrical resistivity was determined separately, in the same apparatus, on the same coal ash samples, without a reference sample, and as a function of temperature using a Hewlet Packard model 3478A multimeter. This allowed us to calculate the electrical conductivity to compare that with the thermal conductivity of the coal ashes. The results of electrical conductivity variation with temperature for Pyrex 7740 are shown in Figure 3. Also, the ratio of electrical and thermal conductivities is shown in Figure 3.

1.3.3 Determination of Chemical and Mineralogical Compositions

The chemical and mineralogical compositions of the tested coal ashes were determined by x-ray fluorescence and x-ray diffraction techniques, respectively.

1.3.4 Measurements of Porosity

The porosity of sintered samples was estimated after measuring thermal and electrical conductivities using the automated image analysis of backscattered electron images. Also, closed porosity was evaluated for selected coal ashes from the weight gain of the samples after they were kept in anhydrous methanol for 24 hours.

1.3.5 Density Measurements

Densities were determined from the displacement of anhydrous methanol at room temperature using a pycnometric method with an accuracy of ±0.02 g/cm^3. Duplicate samples were used in the experiments, and average values are presented.

1.4 Materials

Since thermal conductivity is very sensitive to the inhomogeneity of chemical and mineralogical compositions, a special processing technique was developed. Homogeneous amorphous coal ashes were prepared by melting at 1500°C, homogenatizing at that temperature for 3 h, and quenching at room temperature (Table 1). The glass was ground to -30 mesh and sintered at the appropriate temperature for the design time. Before sintering, all samples were in amorphous form; however, after sintering, some crystallized phases were detected. The mineralogical composition of the tested samples is listed in Table 2. Unfortunately, we were unable to determine the quantity of amorphous phase left in the samples after sintering, particularly in the grain boundaries.

Also, model sodium silicate glass and gehlenite, with the chemical compositions listed in Table 1, were used. They were prepared from oxides/ carbonates by melting at 1500°C, homogenizing at that temperature, and quenching at room temperature. Before sintering, the glass was ground to -38 mesh.

TABLE 1

Composition of Beulah Coal Ash and Model Glass

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	P_2O_5
Beulah	30.1	16.2	12.3	1.7	23.8	7.2	7.4	0.1	1.2
Gascoyne	35.2	11.5	8.8	1.5	27.6	7.5	6.7	0.1	1.0
Illinois #6	50.7	18.7	21.3	0.7	5.3	0.8	0.6	1.8	0.1
Glass	61.7	14.9	--	--	11.9	1.9	9.5	--	--
Gehlenite	19.9	10.7	5.9	--	57.8	3.8	0.5	--	--

TABLE 2

Mineralogical Composition of Sintered Coal Ashes

Coal Ash	Treatment	Major Phases
Beulah	900°C/3 h	Nepheline ($NaAlSiO_4$) Gehlenite ($Ca_2Al_2SiO_7$)
	1000°C/3 h	Gehlenite
	1100°C/3 h	Gehlenite
	1100°C/20 h	Gehlenite Haüyne ($[Na,Ca]_8[Al_2Si_2O_{24}][SO_4]_2$)
Gascoyne	1100°C/15 h	Gehlenite Merwinite ($Ca_3Mg[SiO_4]_2$) Ferrite Spinel ($Mg[Al,Fe]_2O_4$)
Illinois #6	1100°C/15 h	Anorthite ($CaAl_2Si_2O_8$) Hematite (Fe_2O_3)
Gehlenite	1300°C/3 and 5 h	Gehlenite

1.5 Method of Calculation

The heat flow between two isothermal surfaces and heat losses due to radiation were assumed to be the same in all experiments. This assumption allowed the determination of the thermal conductivity coefficients for unknown materials, with the same range of error.

Under such ideal conditions, the thermal conductivity coefficient of the sample was calculated from the following equation:

$$k_s = k_{ref}\, S_{ref}\, (\Delta T/x)_{ref}/S_s\, (\Delta T/x)_s \quad [Wm^{-1}\, K^{-1}] \qquad \text{[Eq. 2]}$$

where k_s and k_{ref} are the thermal conductivities of the specimen and reference material, respectively; S_s and S_{ref} are surfaces of the specimen and reference material, respectively; and x_s and x_{ref} are appropriate lengths.

Electrical conductivity, Ω^{-1}m, was calculated separately from resistivity results.

1.6 Results and Discussion

1.6.1 Thermal and Electrical Conductivities of Selected Coal Ashes and Model Silicates

Generally, the thermal and electrical conductivities increase with temperature and are dependent both on the chemical and mineralogical compositions (Figures 4-8). Thermal and electrical conductivities results presented on all figures correspond to those measured at equilibrium. Also, calculations of thermal conductivities of amorphous forms of coal ashes are included in the figures. Usually they are lower than those measured on crystalline forms. Calculations were performed by steady-state methods using factors provided by the literature (8,9) representing the contribution of individual oxides (on a weight-percent basis) at 30°C. The microporosity, as determined by automated image analysis of backscattered electron images, was lower than 4%. However, the microporosity of gehlenite sintered at 1300°C for 3 h was higher than 10%, and this corresponds with sample density of 3.039 g/cm^3. Figure 9 shows the microstructure of gehlenite sintered at that temperature.

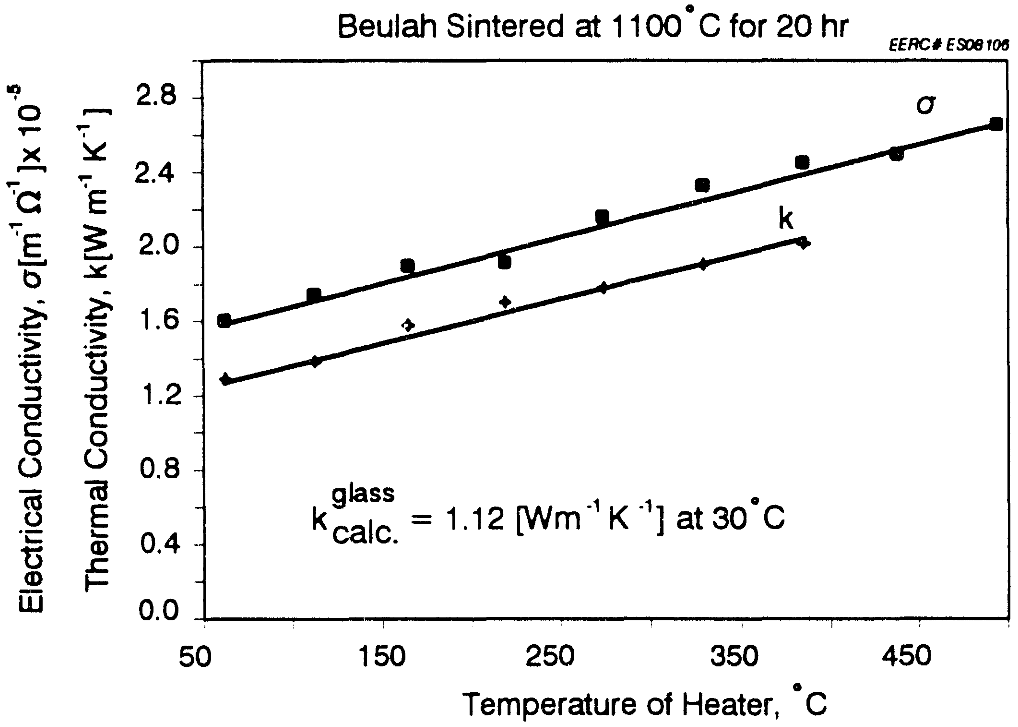

Figure 4. Thermal and electrical conductivities of Beulah coal ash sintered at 1100°C for 20 h in air.

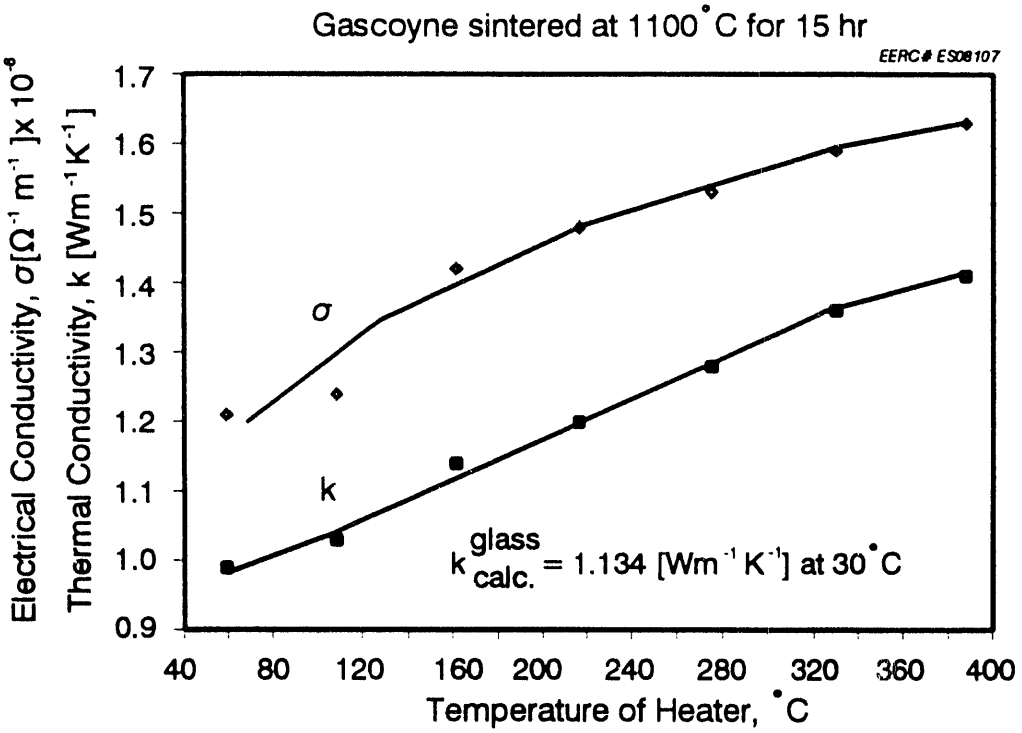

Figure 5. Thermal and electrical conductivities of Gascoyne coal ash sintered at 1100°C for 15 h in air.

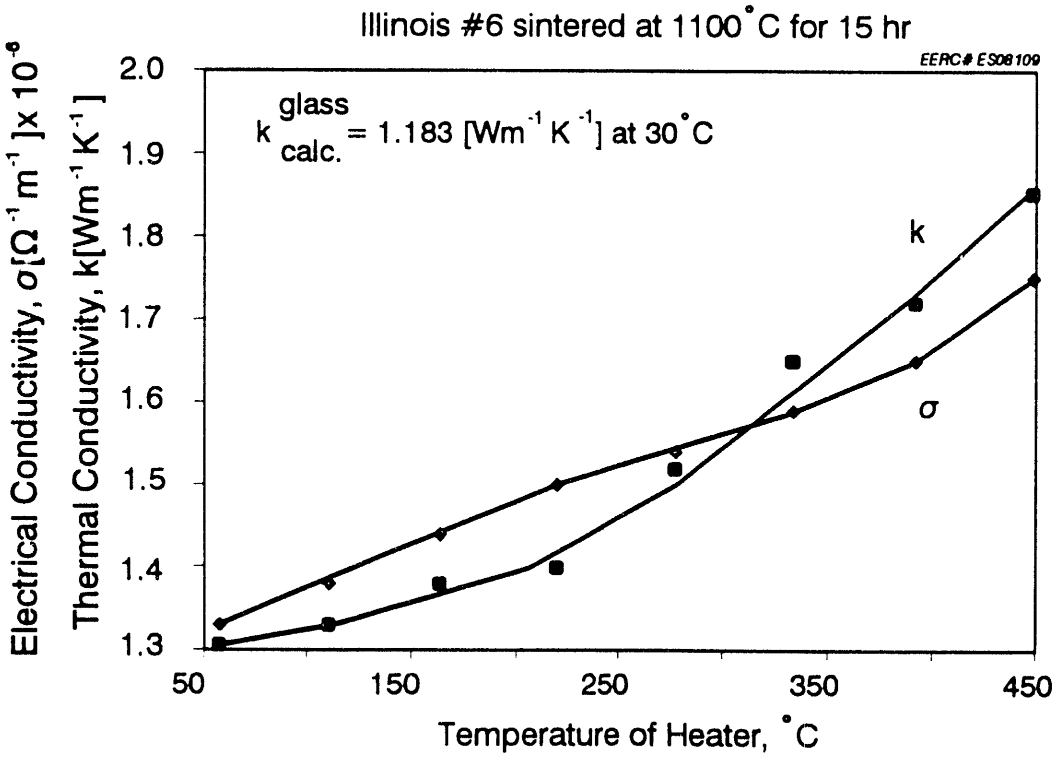

Figure 6. Thermal and electrical conductivities of Illinois #6 coal ash sintered at 1100°C for 15 h in air.

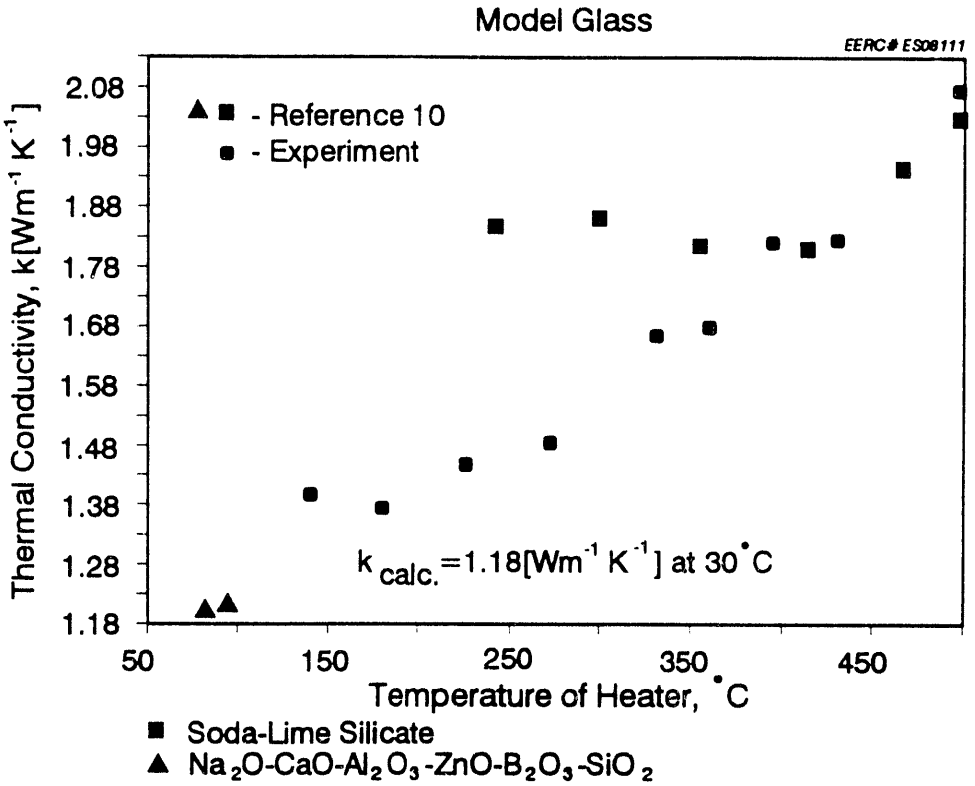

Figure 7. Thermal conductivity of model silicate glass.

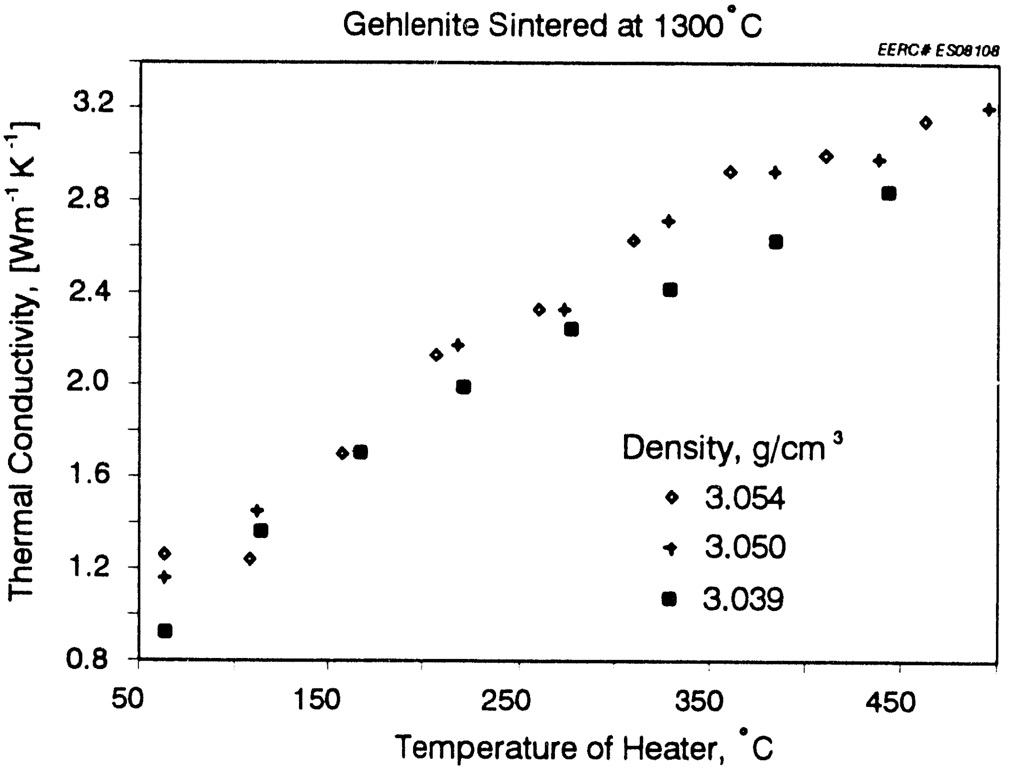

Figure 8. Thermal conductivity of gehlenite sintered at 1300°C for 3 h (density 3.039 g/cm^3) and 5 h (density 3.050 g/cm^3) in air.

Figure 9. Microstructure of gehlenite sintered at 1300°C for 3 h.

The results of thermal conductivity of model silicate glass shown in (Figure 7) were compared with two selected from the literature with compositions that match as closely as possible to our specimen (10). Some discrepancy exists, however, between our results and those from the literature. Also, a discrepancy exists between the literature values of thermal conductivities, if measured as a function of temperature, on the order of 10% or higher.

Generally, heat in solids is conducted by: 1) free electrons that occur in metals and alloys at low temperatures, 2) by thermal vibrations of atoms that are observed in the stoichiometric dielectrics, 3) by free electrons and holes as well as the lattice vibration at the sufficiently high temperatures that are recorded in semiconductors, and also 4) ions in amorphous materials at high temperatures. In our case, the linear variations of both thermal and electrical conductivities suggest also that ionization of point defects related to nonstoichiometry, impurities, and dopants play some role in the thermal conductivity at intermediate and high temperatures. They create free carriers, such as electrons and holes, and the concentration increases with temperature. The electron/hole conductivity is reflected by the Arrhenius relationship: $\sigma = \sigma_o \exp(-E/kT)$ where E is an energy of activation, and k is the Boltzmann constant. The magnitude of this electronic component of thermal conductivity is very low, since σ/k is about 10^{-5}. The ionic component in heat transfer, related to the diffusion of alkali ions, does not play any major role in this range of temperature and can be neglected. This component may occur above some critical temperature, across the surface, or through the volume of the material and is strongly dependent on the glass structure.

1.6.2 Effect of Porosity on Thermal Conductivity

Figure 10 shows the effect of porosity on the thermal conductivity of Beulah coal ash. Thermal conductivity decreases with the increase of porosity. Two kinds of pores are distinguished: large pores, and fine pores inside the large ones. The latter are likely formed from necks. Figure 11 shows the microstructure of Beulah coal ash sintered at 1100°C for 3 h. Porosity numbers in percent are listed in Table 3 that were estimated after measuring thermal conductivity.

TABLE 3

Porosity of Sintered Beulah Coal Ash

Experimental Conditions	Porosity, in %		
	Large Pores	Fine Pores	Density g/cm^3
1000°C/3 h	~15	16-17	2.57
1100°C/3 h	~15	17-20	2.54

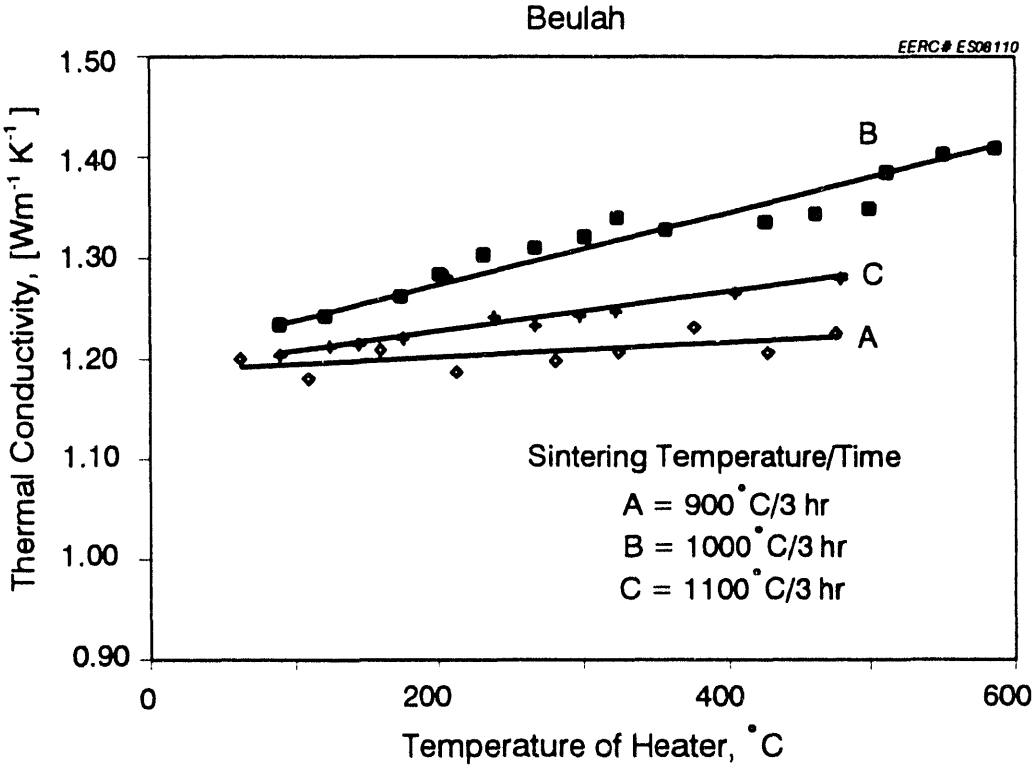

Figure 10. Thermal conductivity of Beulah coal ash with varied porosity.

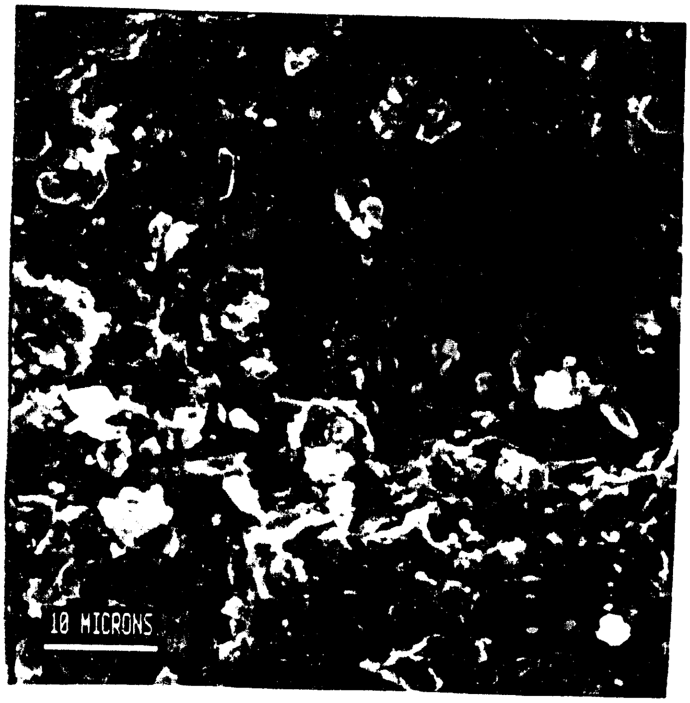

Figure 11. Microstructure of Beulah coal ash sintered at 1100°C for 3 h.

1.7 Conclusions

Thermal conductivity of coal ashes with low porosity (below 4%) depends upon the chemical and mineralogical compositions of the ash. Results of electrical conductivities imply that the electronic component cannot be neglected in consideration of the transport mechanism of heat. Thermal conductivity is significantly affected by porosity: it decreases with the increase of porosity.

2.0 FUTURE WORK

We intend to extend the temperature range up to 1000°C to measure the thermal conductivity of coal ashes with well-defined crystalline structures. The high temperature limit will depend on the stability of the reference material applied in measuring thermal conductivity. Also, we intend to employ model silicate systems derived from the mineralogical composition of coal ashes and amorphous phases to distinguish the variation of thermal conductivity with solid phases.

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APPENDIX A

CALCULATION PROCEDURE OF THERMAL CONDUCTIVITY OF AMORPHOUS SILICATES

CALCULATION PROCEDURE OF THERMAL CONDUCTIVITY OF AMORPHOUS SILICATES

Calculations are based on the following equation (8,9):

$$10^3\, k_{calc}\, (Wm^{-1}\, K^{-1}) = \sum f_i x_i$$

where f_i is the thermal conductivity factor for the component oxide and x_i is the weight percent of the component oxide. Table A-1 lists "f" factors for selected oxides derived from coal ash.

TABLE A-1

Factors for Calculating Thermal Conductivity at 30°C From Amounts of Constituent Oxides in Glass

Oxide	Factor f ($Wm^{-1}K^{-1} \times 10^3$)
SiO_2	13.33
Na_2O	-4.76
K_2O	2.17
MgO	21.73
CaO	13.06
Al_2O_3	13.61
Fe_2O_3	7.24
TiO_2	-31.38

FORM EIA 459E
(10/80)

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

FORM APPROVED
OMB NO. 1900 0127
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1. Program/Project Identification No. DE-FC21-86MC10637	2. Program/Project Title Physical and Chemical Properties of Ashes and Slags (3.5)	3. Reporting Period 4-1-92 through 6-30-92
4. Name and Address	Energy and Environmental Research Center University of North Dakota Box 8213, University Station, Grand Forks, ND 58202 (701) 777-5000	5. Program/Project Start Date 4-1-86 6. Completion Date 9-30-92

7. FY 91/92

8. Months or Quarters: Quarters

9. Cost Status — a. Dollars Expressed In Thousands — b. Dollar Scale

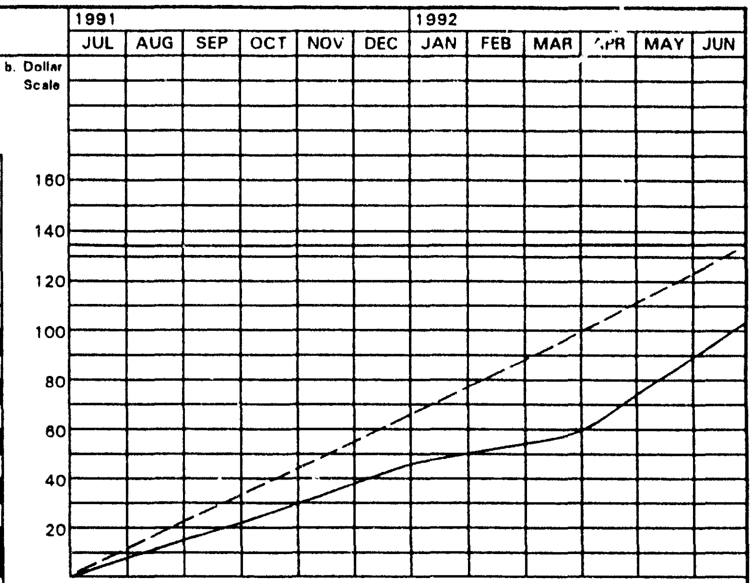
10. Cost Chart

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
DOE	P	33	34	33	34	134	134
	A	21	26	12	44	103	
	P						
	A						
	P						
	A						
	P						
	A						
Total P		33	34	33	34	134	134
Total A		21	26	12	44	103	
Variance		12	8	21	(10)	31	

P = Planned A = Actual

Total Planned Costs for Program/Project

$134



c. Cumulative Accrued Costs

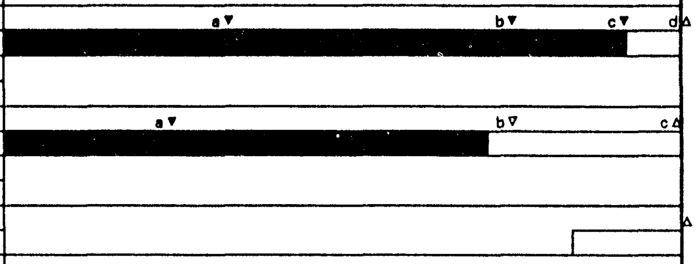
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Planned			33			67			100			134
Actual			21			47			59			103
Variance			12			20			41			31

11. Major Milestone Status — Units Planned / Units Complete

1. Thermal Conductivity — P / C

2. Strength Measurement — P / C

3. Final Project Report — P / C



12. Remarks

Due to the EERC fiscal year end, the June books do not close until July 25, 1992. Costs posted through July 8 have been included.

13. Signature of Recipient and Date

7/[illegible]/92

14. Signature of DOE Reviewing Representative and Date

FORM E1A-459E
(10/80)

U.S. DEPARTMENT OF ENERGY
FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

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1. Program/Project Identification No. DE-FC21-86MC10637	2. Program/Project Title Physical and Chemical Properties of Ashes and Slags (3.5)	3. Reporting Period 4-1-92 through 6-30-92
4. Name and Address	Energy and Environmental Research Center University of North Dakota Box 8213, University Station Grand Forks, ND 58202 (701) 777-5000	5. Program/Project Start Date 4-1-86 6. Completion Date 9-30-92

Milestone ID. No.	Description	Planned Completion Date	Actual Completion Date	Comments
Task 1	Thermal Conductivity:			
1.a	Thermal conductivity measurement device design study	10-31-91	10-31-91	
1.b	Completion of thermal conductivity device	3-31-92	3-31-92	
1.c	Completion of shakedown test matrix	5-31-92	6-15-92	
1.d	Completion of analysis of three selected coal ash slags	7-31-92		
Task 2	Strength Measurement:			
2.a	Purchase of strength measurement device	9-15-91	4-6-92	
2.b	Strength testing of two selected coal ash slags under various gasification atmospheres	3-31-92		
2.c	Completion of analysis and interpretation of strength data	6-30-92		
Task 3	Final Project Report	8-31-92		

3.6 Coal Science

COAL SCIENCE
EARTH RESOURCE EVALUATION AND MANAGEMENT

Semiannual Technical Progress Report
for the Period January 1, 1992 - June 30, 1992

by

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July 1992

Work Performed Under Cooperative Agreement No. DE-FC21-86MC10637

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COAL SCIENCE
EARTH RESOURCE EVALUATION AND MANAGEMENT

1.0 GOALS AND OBJECTIVES

The general "Coal Science" objective of the Energy and Environmental Research Center (EERC) Mining and Mineral Resources Research Institute (MMRRI) is directed towards a fuller utilization of energy and associated energy-related data, currently available as published and unpublished documents, to better evaluate resource potential through a thorough knowledge and understanding of the geologic context of the resource. This objective is to be implemented through computer-based data management systems involving specific field examples. The focus of Year Three of the project is to further develop a computerized basis for evaluating North Dakota's lignite resource in a stratigraphic and paleontologic context. Specific goals include the construction of enhanced, but flexible, relatable database designs in stratigraphy, paleontology, and geochemistry and the testing of these designs through practical examples.

2.0 ACCOMPLISHMENTS

This semiannual reporting period is presented as a summary of the last year's effort in coal science earth resource evaluation and management. Thus this report represents a revised and more encompassing version of the January semiannual to be comprehensive. Research was undertaken during the last year that dealt with each of the milestone tasks. These tasks included A) reevaluation of the main and supplementary database designs, stratigraphic (e.g., *MNOS, *UNIT) and paleontologic (*LOC); B) database augmentation for counties in far western North Dakota and adjacent areas in easternmost Montana; C) assessment of geochemical database design and data gathering; and D) modification and expanded utilization of previously employed techniques and consideration of new techniques for displaying database information.

Substantial consideration was given to the effective use of existing databases. Revisions undertaken resulted from the desire to simplify the design of the database, as well as providing more easily interpreted output (primarily in the form of designs). Desired design changes were made possible, in part, because of new features available in Release 4 of Q&A® (by Symantec), the main database program utilized for database management at MMRRI. Additional changes result from greater output programming flexibility with the new Hewlett Packard Laser Jet III. Although some changes may appear to be somewhat cosmetic in nature, greater font control with the Laser Jet III provides the opportunity to alter the database design in the Q&A® Write module to produce easier-to-read and more self-explanatory field label descriptions.

Task B specifically included the augmentation of coal-related databases for Bowman and Slope Counties (B.1), Billings and Golden Valley Counties (B.2), McKenzie and Williams (B.3), and relevant adjacent areas in eastern Montana (B.4), including Roosevelt, Richland, Dawson, Wibaux, and Fallon Counties. As earlier database construction was based primarily on project-specific areas, current database augmentation has focused on providing general coverage, supplementing and upgrading areas with earlier database designs. Although this activity and approach is of some scale and detail in nature, under such conditions the databases can be far more rigorously tested for practical use.

Database designs and data inputting were preliminarily completed for a variety of geochemical data types (Task C). Five databases were constructed to deal with descriptive and numerical information about rock geochemistry, rock mineralogy, groundwater geochemistry, coal geochemistry data, and rock lithologies. This aspect of the project was undertaken with the desire to integrate geochemically oriented data with stratigraphic and paleontologic databases to better facilitate the reconstruction of paleoenvironments and more definitive coal-related stratigraphic correlations. Unfortunately, few previous researchers have understood the value of having stratigraphically controlled samples, and thus much good geochemical data is of immediately limited value, beyond its original intent.

Task D encompassed consideration for improved data presentation of stratigraphic correlation data (D.1) and map presentation of stratigraphic data (D.2). Approaches taken include automated stratigraphic column construction with existing public domain programming substantially revised by this project. This method provides tremendous flexibility in facilitating the organization of stratigraphic data. Several hundreds of stratigraphic columns have been produced at a variety of scales for numerous purposes. Many of these columns have been correlated in various parts of the general project area, including Slope, Golden Valley, Billings, and Williams Counties, North Dakota, and Roosevelt County, Montana. Essentially all of the site-specific geological and paleontological observations have been plotted on both the large- and small-scale U.S. Geological Survey maps. Detailed plotting has been completed on 7.5-minute, 1:24,000-scale topographic quadrangles. Many coal-related observations were originally collected without regard to elevation. Plotting on large-scale topographic maps provides the opportunity, given the nature of the observations, to closely approximate the elevation of a particular observation. Such controlled information is of considerable importance in attempting to correlate and contour a variety of geological data types. In addition, most localities have also been plotted on linen-backed mosaics of 0.5° x 1°, 1:100,000 topographic quadrangles. These mosaics were constructed to best reflect the likely distribution of data for certain study areas, including 1) the Fort Union corridor of Williams and McKenzie Counties, North Dakota, and Roosevelt and Richland Counties, Montana; 2) the northern portion of the Little Missouri River, McKenzie County, Montana; 3) the main north-south drainage system of the Little Missouri River in Billings and Golden Valley Counties, North Dakota; and 4) additional natural outcrop and subsurface study areas in Slope and Bowman Counties, North Dakota.

Utilizing geological and paleontological database information in selected study areas tests the appropriateness of the database design for a number of specific applications, including organization and illustration of data for research and general publications, presentations, and for the construction of summary diagrams, tables, and slides. Ongoing analysis of database applications, through the integration of a variety of software, permits flexible but powerful access to a variety of information types for coal-bed stratigraphy, coal correlation and documentation, and coal characterization and assessment. These efforts have led to the development of a wide range of database applications within the MMRRI. Of significance, in the development of these applications, is the recognition that databases can be designed for immediate (and possibly short-term) use to relate to larger existing databases. The ability to design and redesign databases for whatever purpose is particularly important in our current environment where the needs and technical resources change dramatically over short periods of time. Computing systems that do not permit the flexibility to change with changing needs will ultimately require the researcher to attempt to circumvent the best-laid plans based on current dogma.

2.1 Database Management (Task A)

Overview of Database Design. Several purposes are served by effective database management. The foremost is the utilization of data in an effective manner. "Effective," however, is relative depending on goals and means of analysis available at a person's disposal. An understanding of coal resources and their litho- and chronostratigraphic context were "effectively" met 70 years ago under the goals of the time. Today's goals are different only in that we require (or want) greater precision in our assessments of resource characterization and context, which necessitates more data more rigorously controlled to serve specific purposes. Resource management is in a state of flux, in part, because the techniques of database management are undergoing a revolution for the individual user due to advances in computer technology and software development. Computer-based data management applications require flexibility (and transportability) while we take advantage of developments in off-the-shelf data acquisition, management, and display programming.

Q&A® Files. The data management program Q&A®, by Symantec, is particularly well-suited to the nature of geologic data, where 1) a wide range of information types are employed to manage closely related and disparate data types; 2) applications vary, and form and report modifications are made frequently; and 3) extended documentation is necessary to track on inputed numeric and descriptive data. The primary Q&A® "form" design is more appropriate than a "table" design employed by most other data managers. Q&A®'s ease of use in rigorously controlled applications presently outweighs its limitations in relational database management. These limitations were substantially overcome, however, by increased relational power in Version 4.0 of the program available for use during this reporting period.

Four main Q&A® databases control MMRRI data types: 1) geologic section or observation location information (*MNOS), 2) geologic section unit descriptions (*UNIT), 3) paleontologic specimen location and stratigraphic information (*LOC), and 4) taxon identification information (*SPP). The prefix "*" denotes a specific file name, such as "WB" for Williston Basin. A number of other databases are employed to "feed" basic information to these primary databases. These secondary databases serve several useful functions in promoting control over frequently general (descriptive) information. Examples of secondary databases include EPCODES (chronostratigraphic terminology), FMCODES (lithostratigraphic terminology), COLOR (color coding, as per the Geological Society of America's Rock Color Chart (with Munsell color standards), and MAPS (U.S. Geological Survey 7.5-minute, 1:24,000-scale topographic quadrangles).

The *MNOS files contain information on the location of geologic observations, such as surface and subsurface measured sections (Appendix I). The *MNOS form contains 141 fields, representing four major types of field data: 1) reference information, including numbering systems; 2) location and landowner information; 3) litho- and chronostratigraphic information, including section thickness and elevation data; and 4) sample and specimen information. A general review of these major field types is given in the following paragraphs. Note that a number of the following *MNOS fields are designed to use restricted-value internal lookup tables (see discussion under Q&A® file modifications).

General reference information fields (see Appendix I) contain data on the source of the information (i.e., citation), including 1) authorship and pagination; 2) project chief and institutional or agency affiliation; 3) individual, and affiliation, responsible for section interpretation; 4) name (if any) of geological observation (e.g., Tepee Buttes section); 5) type of geologic observation (e.g., surface or subsurface); 6) type of subsurface logs (e.g., gamma log); 7) whether photographs of the surface section, core, or of general location are available; and 8) the location of geologic observation in cross section panels. Reference numbering systems include 1) UND-EERC-MMRRI "M-number"; 2) reference number(s), associated with the source of information, such as a number specifically associated with the publication or in-house report of the geologic section; 3) original field number, usually referring to the original number used during field work; 4) institutional number, referring to numbering systems employed by various agencies or institutions (e.g., NDSWC 4252 = North Dakota State Water Commission Number 4252); and 5) any other number that might be applied to the observation. Record management fields, associated with basic reference information, are used to 1) code the primary or unique form for each M-number, 2) code data types, 3) note when and who entered data, 4) note if data has been changed since the last recorded input, 5) code utility fields which indicate the use of the data (e.g., NCRDS), 6) note whether the observation has been plotted on topographic maps, and 7) note how the information has been filed (for hardcopy records).

*MNOS file location fields contain information ranging in scale from general political boundaries to site-specific coordinate systems. Location fields include 1) nation, 2) state, 3) county, 4) region, 5) field area, 6) map reference (e.g., U.S. Geological Survey 7.5-minute, 1:24,000-scale topographic quadrangles and associated data), 7) township and range location, 8) footage and/or meters from section lines, 9) longitude and latitude (in decimal format or as degrees, minutes, and seconds), 10) UTM coordinates, 11) state land grid coordinates, and 12) general location comment field. *MNOS files use the MAPS file as an external lookup table to import map reference information. Fields containing distances can be entered either as English or metric units, with automatic conversions to respective fields.

*MNOS litho- and chronostratigraphic information is contained in fields that reference 1) the section thickness, 2) the elevation of the section at its top and base, 3) the geologic age of the measured section or observation, 4) the formations represented in the section, 5) the thickness of the formations represented in the section, 6) whether or not the formation is complete at this location, 7) a general listing of the named beds in the section, 8) the primary formation (used for bed-specific observations), 9) specific reference to a particular bed, 10) the original name of the bed (many bed names are revised), 11) the unit number for the bed in the geologic section, and 12) a general stratigraphic comment field. *MNOS files use the EPCODES and FMCODES files as external lookup tables to import chrono- and lithostratigraphic reference information directly into an *MNOS database. Fields containing thicknesses can be entered either as English or metric units, with automatic conversions to respective fields. The *MNOS form also contains fields for information on lithic and fossil samples.

The companion file to the *MNOS database is the *UNIT database (see Appendix II). Like *MNOS files, a number of *UNIT databases use fields designed for restricted-value internal lookup tables (see discussion under Q&A® file modifications). *UNIT files have 77 fields specific to the reference, measurement, and description of a unit (or bed) in a geologic section. A "unit" is a stratigraphic interval, identified by the geologist, that is sufficiently distinct from lithologies above and below to represent a discrete portion of the overall geologic section. *UNIT databases can be related to *MNOS databases through the creation of derived fields in the Report Module of Q&A®, thus expanding the capability of sorting *UNIT files on additional reference and location information.

Reference fields include general citation data, MMRRI M-number numbering system, and record management fields. General location information for easy reference purposes is also provided in state and region fields.

The majority of the *UNIT fields concern the naming, measurement, and description of unit data. The unit (bed) name and formational assignment is given also with necessary comments on revised lithostratigraphy. The unit thickness can be directly inputted in English (including nondecimal entries) or metric units, with automatic conversion to respective fields, or the thickness can be calculated from scaled measurements taken from drawings or photographs. Unit thickness can also be calculated from original structural data (e.g., pace and compass method) associated with the measurement of either the unit itself or section in which it is found (SECTION STRUCTURAL INFORMATION).

The unit (or bed) description can be quoted in full from the original source (REF), and can be separated into its component parts to permit uniform interpretation and sorting on specific data types. Standard lithic field types include 1) primary rock type, 2) rock-type modifiers, 3) fresh and dry colors (GSA rock color chart), 4) sedimentary structures, 5) grain size sequencing, 6) weathering profile, 7) interpretation of the sedimentary depositional environment, and 8) interpretation of fossil-indicated environment. *UNIT files use the COLOR and STRATCOL/STRATA files as external lookup tables to import color values, and graphic and weathering symbol codes directly into a *UNIT database.

Other fields manage information to provide uniform coding procedures for specific projects (e.g., NCRDS data fields) or computer programs (e.g., STRATCOL/STRATA). For example, the *UNIT database is designed to generate reports for the program STRATCOL/STRATA. With only minor modifications, these files can be directly read by STRATCOL/STRATA, thus quickly producing a graphic representation of the geologic unit.

*LOC files contain records on the location of fossil localities and is specifically designed for micro- and macrofossil specimens (see Appendix III). The *LOC file is similar to *MNOS files in general design, containing the nearly the same fields for reference and location data. Like the *MNOS form design, *LOC files contain a number of coding fields that are used for sort routines of age-related information and uses the MAPS file as an external lookup table for map reference information. Also like *MNOS databases, *LOC databases use fields designed with restricted-value internal lookup tables (see discussion under Q&A® file modifications). *LOC files contain 138 fields organized into the following major field types: 1) reference information, including numbering systems; 2) location systems, including elevation data; 3) litho- and chronostratigraphic information; and 4) paleontologic data. A general review of these major field types is given in the following paragraphs.

Specialized reference information includes the following record management fields: 1) unique L-number (UNQ), 2) field trip code (FY), and 3) fossil category code (FS). The unique L-number field is a combination of the L-number and the primary form field (P) and is inputed automatically. This unique number permits other databases (e.g., *SPP) to construct derived fields utilizing *LOC locality and stratigraphy data. The field trip code provides an additional means of sorting locality data on the basis of when the information was taken. The importance of this field is that it permits sorting across project categories and data entries in different field books. The fossil category code permits a retrieval and sort on a selected major taxonomic category. For example, a retrieval could be made on only microfossils from any of the stratigraphic or location fields in the *LOC database.

The *LOC database stratigraphically oriented fields differ from *MNOS databases in that fields are designed to permit precise reference of a fossil locality to an intra- or extraformational stratigraphic marker or horizon. In addition, a locality can be placed in reference to the base or top of the enclosing formation. Various code fields document the predicted error associated with the placement of a locality relative to any of these horizons. Besides these "relative" stratigraphic fields, the elevation of a locality, and its interpreted error, can also be inputted. All of these fields can be entered in either English or metric units, with automatic conversion to respective fields.

Additional stratigraphic field types include 1) the formation and member to which the locality can be assigned, 2) the general level of the locality within the formation (e.g., upper, top), 3) the original formation used by the discoverer of the locality, 4) the measured section and unit numbers (i.e., *MNOS and *UNIT) to which the locality belongs, 5) the age of the locality (i.e., Tiffanian Stage), and 6) an extended comment field for additional stratigraphic considerations. As with the purpose of similar general fields, the reference source can be quoted (at length) to document the exact meaning of the original author.

*LOC database fields specific to paleontology are primarily concerned with the record of fossil discovery, collection, and identification. These topics are covered in the following fields: 1) discoverer(s), date of discovery, and comments on how the discovery occurred; 2) field crew chief and affiliation; 3) collector(s), date of collection, and comments on the contributions of the collectors; 4) the collection repository and comments on the quality (preservation) of the collections; 5) faunal comments on the assemblage of fossils collected and their significance; and 6) a list of the fossils identified, and the name (and year) of the person responsible for their identification. The *SPP database is a companion to *LOC files and records detailed information on the identification of taxa from a particular locality. The *SPP database can be used as an external lookup table to combine taxon identifications with stratigraphic and location data. Although not discussed at length in this report, the following field types constitute the *SPP database: 1) taxon identification, 2) a simplified classification of the taxon, 3) repository and specimen numbers, 4) number of specimens, and 5) identification comments. Both old and revised identifications are recorded to provide a history of study on specific specimens and taxon names. *SPP uses the database MCLASS as an external lookup table to extract classification data. With *SPP, *LOC, and MCLASS data bases, the stratigraphic range of taxa can be determined through a merge of the data from the three files.

Q&A® File Modifications. A number of database design modifications were anticipated and were produced as a result of the Release 4 of Q&A®. Some of the form design differences, compared to previous reports (Hartman, 1990b, 1991a, 1992a), are evident in the new designs of the databases themselves, as can be examined in Appendices I (*MNOS), II (*UNIT), and III (*LOC). However, substantial changes were also made in the functioning of the geological and paleontological databases, as it pertains to the File, Report, and Write modules of Q&A®. Important program features include 1) extended relational data management capabilities; 2) extended programming language; 3) increased (effectively unlimited) field length, with the capability of designing forms with portions of lengthy entries "hidden," which permits a more streamlined database design; and 4) the ability to select data for database entry from prescribed internal and external databases (lookup) tables. Important secondary features include 1) word-processing capabilities in the file module (e.g., within a given field), 2) spell-checking in the file module, 3) the ability to change field names (Set Field Names) for the purposes of programming and designing new forms in the Write module, 4) expanded macro program facilities, 5) new export and import capabilities with other database managers, 6) greater font control in the various modules, and 7) a new compression backup utility. Although the physical appearance of the database design has, in some ways, changed substantially, these changes are a natural outgrowth of the functionality and basic purpose of the earlier designs.

The results of these module improvements can be seen in 1) the additional ease in which data can be entered through copy and insert file functions in the update mode in the File module; 2) the enhanced ability to restrict data entry, reducing, if not eliminating, incorrect input (see below); 3) substantially fewer errors in the entry of information in comment-type fields (e.g., LOC, STRAT, FAUNAL, COM) as a function of a spell-check facility; 4) increased flexibility to redesign and program databases with editing functions in the design and program modes of the File and Write modules; and 5) the ability to control database form design in the Write module with the use of scalable fonts tied to absolute ("real") tab settings. Of particular importance is the upgraded ability to import data (from other databases) to serve as a lookup file for data entry. Through a specific function key combination, a lookup window appears over the database form, from which the appropriate entry can be selected and automatically inputted in the database. Along with custom-designed help-lookup windows, editing time and quality of the inputted data are substantially reduced and improved, respectively. With the more refined control of scalable fonts, the *MNOS, *UNIT, and *LOC databases were redesigned (see relevant appendixes). These changes, which are in part cosmetic in nature, permit some additional database design refinements through the ability to precisely select the needed point size. As a result, most field names in database forms produced using the Write module can be written in full, reducing the number of somewhat cryptic field labels. In addition, extended comment fields require substantially less space with the use of proportional fonts.

Selected Q&A® database modifications include the following programming statements: 1) a check for the existence of a primary form between *UNITS and *MNOS databases, 2) a comparison of identical quadrangle names (in an *MNOS or *LOC database) found in more than one state in the MAP database, 3) a thickness value comparison between the related *MNOS and *UNIT databases, and 4) an approximation of quarter sections derived from original footages from a section. The first three programming statements provide safeguards or checks on appropriate inputting between related databases. As an example, a U.S. Geological Survey topographic quadrangle name is unique to a state, but may be used in another state (e.g., the map name Black Butte is used both in North Dakota and Montana). Because each map name must be unique in a database for accurate external lookups, a map name must be modified by adding the state abbreviation (e.g., "Black Butte (ND)"). A person that is inputting a map name is not expected to know which map names are in common between states, so the program routine prompts the inputer with an appropriate choice. The last programming statement, mentioned above (no. 4), is used to aid in plotting of geographic locations on varying scale maps (particularly 1:100,000). The approximation of a quarter-quarter section permits a quick method for placing a location on a small-scale map. The conversion from a footage given location to a legal location is completed automatically.

Besides the *MNOS, *UNIT, and *LOC file modifications mentioned above, database "form" design modifications were made to a number of Write module output forms. Also, a new database, SPEC, was constructed for the purpose of controlling data associated with collected samples and for printing collection labels. The greater font control, available with Version 4 of Q&A®, makes possible the printing of the necessarily small form designs and associated data. Multiple copies of appropriate forms (for samples from the same location) are then easily produced in the merge-data portion of the Write module.

Design modifications were also implemented for *UNIT databases to permit the output of data in NCRDS, STRATIFACT® (by GRG), and LOGGER® (by Rockware). See Appendix II for examples of *UNIT database form design and the outputted data format (e.g., NCRDS).

2.2 Database Augmentation (Task B)

Data Input. The geologic exposures of far-western North Dakota are largely derived from the drainage patterns produced by the Little Missouri and Missouri Rivers. The relatively good outcrops along these rivers, and some of their tributaries, have been the source of many independent coal and noncoal studies. Much of this data has never been assimilated for the purposes of detailed coal correlation, and is, for the most part, not part of any database system.

As part of this Coal Science database design and management program, Williston Basin stratigraphic data were cataloged and computerized from data sources relevant to exposures along the Little Missouri and Missouri Rivers in western North Dakota, and adjacent areas in the drainage of the Yellowstone and Missouri Rivers in eastern Montana. Input study areas in North Dakota included 1) Bowman and Slope Counties, 2) Billings and Golden Valley Counties, and 3) McKenzie and Williams Counties. These county-based areas represent, to a certain extent, well-defined input data sets, based on the nature of available outcrops and county surface and subsurface studies. The input coverage in the adjacent counties in Montana is less comprehensive, which simply reflects project goals focused in North Dakota. Coverage in Montana included Roosevelt, Richland, Dawson, Wibaux, and Fallon Counties. The stratigraphic data inputted for North Dakota represents primarily the Fort Union Group, which includes the Ludlow, Cannonball, Slope (upper Ludlow of some authors), Bullion Creek (= Tongue River in adjacent Montana), and Sentinel Butte Formations. To date, the following M-number geological observations have been recorded in North Dakota: 1) 609 in Bowman County, 2) 49 in Adams County, 3) 1664 in Slope County, 4) 63 in Hettinger County, 5) 421 in Golden Valley County, 6) 344 in Billings County, 7) 171 in McKenzie County, and 8) 199 in Williams County. In Montana, M-number geological observations have been inputted as follows: 1) 64 in Roosevelt County, 2) 72 in Richland County, 3) 146 in Dawson County, 4) 110 in Wibaux County, and 5) 56 in Fallon County. As part of this research, an annotated bibliography of unpublished and published coal-related observations has been compiled to facilitate computerization (Appendix VI). Publications included in the last reporting period include (See Appendix VI bibliography) Anna (1980), Archibald (1982), Benson (1953), Bluemle (1971), Carlson (1973), Denson and others (1959), Fisher (1954), Flores and Lepp (1983), Gregory Drilling, Inc. (unpublished drilling logs), Hartman (1991 unpublished field notes), Jacob (1976), Kroeger (1988 unpublished field notes), Pipiringos and others (1965), Steiner (1978), Stevenson (1956), and U.S. Geological Survey Open-File Report 76-888. Some geologic data was also previously entered for stratigraphic studies of relevant comparable summary sections in the coal-bearing strata of Harding County, South Dakota.

During January-May, effort was been extended to produce a paper-based "library" of computerized data. This entails assembling the original published and unpublished source of the M-numbered sections (*MNOS database) and ordering them in a set of ring binders for archival purposes. Although this compilation has been ongoing, an attempt was made to bring the catalog up to date, which involves the copying of thousands of records. An archived "hard copy" system provides a permanent method of verifying the use of the M-number assigned to a particular geological observation. The process of back-logging previously M-number geological observations is effectively complete for current considerations.

Stratigraphic and paleontologic data were also computerized for studies in the Bighorn Basin of northwestern Wyoming and south-central Montana. This work is directed towards establishing nonmarine molluscan criteria for recognizing Clarkforkian (Paleocene)-age strata in the Williston and Powder River Basins. This interval represents important coal-bearing sequences in the upper part of the Tongue River Member of the Fort Union Formation and in the lower part of the Wasatch Formation in the Powder River Basin. This time interval cannot be precisely correlated into the stratigraphic section of the Williston Basin, but must, in part, be correlative with the Sentinel Butte and Golden Valley Formations.

Stratigraphic and paleontologic data were also computerized for the Powder River Basin of northeastern Wyoming and southeastern Montana. This data will augment substantially the database previously compiled for the temporal control of coal-bed correlations in the basin (Hartman, 1990a, 1992d). At present, approximately 300 nonmarine molluscan localities have been used to chronostratigraphically organize the coal beds of the Powder River Basin. Newly available unpublished data will approximately double this number of localities, increasing the number of new control points, probably by about 30 to 50 percent.

Additional unpublished stratigraphic coal-based data was acquired for a number of areas in the Williston Basin in Montana and North Dakota through the courtesy of Mr. John Spencer of the Billings office of the Bureau of Land Management. This material was produced by the U.S. Geological Survey, primarily for the purposes of coal land classification and was never published or open-filed. Areas of study represented by these data include 1) the Yellowstone and Missouri River confluence area of Montana and North Dakota (including the Culbertson and Girard coal fields, and route of a portion of the northern tier pipeline); 2) the Nesson coal field of Williams and McKenzie Counties; and 3) the Jordan coal field of Garfield County, Montana. Selected geologic and paleontologic data of the Jordan coal field were incorporated in studies on the biostratigraphy of the Hell Creek/Tullock Formation transition in Garfield and McCone Counties, Montana (Hartman, 1991b).

Additional database augmentation incorporated unpublished, computerized, coal-related databases constructed by LeFever and Murphy (1983) in a project entitled "Mining Resources and Potential Problems Associated with Mining of Cenozoic Rocks of the Williston and Powder River Basins, Northern Great Plains." These databases have not been utilized since their compilation. They were constructed on an IBM mainframe computer utilizing the program system SAS (SAS Institute, Inc.) before the advent of powerful microcomputers. Downloading these files, from an old version of SAS, proved to be tedious, and exemplifies the need for data to be stored in a manner that permits their transfer between computing systems. All of the files from the LeFever and Murphy (1983) project were downloaded as ASCII files and subsequently inputted into Q&A® databases. Additional effort will be required to decode data originally encrypted to circumvent storage and line length limitations imposed on the IBM system. When completely upgraded, the LeFever and Murphy (1983) files will be imported into the Williston Basin MNOS database. Incorporation of these data into currently maintained databases will provide an excellent opportunity to test present database designs.

Video Imaging. The video imaging of small but macrofossil-size specimens was undertaken for the purposes of morphometric analysis and illustrations for presentations. The video imaging system has been used extensively in the studies of Mr. Timothy J. Kroeger for microsized palynomorph samples, and in this writer's studies of small, macrosized bivalves and snails. Morphometric techniques developed utilizing this system provide considerable additional rigor in discriminating between taxa of mollusks. This ability thus enhances the opportunity for highly resolved interpretation of time through coal bed sequences to interpret their environmental history. Numeric data derived from these studies are maintained in Q&A® databases and Quattro Pro® spreadsheets.

Recent video-imaging considerations to enhance sample image quality have focused on an attempt to implement greater gray-scale control to improve resolution. A meeting with a representative of Leeds Precision Instruments resulted in the purchase of software capable of externally controlling the gray scale range (gain and offset) of the system's Cohu camera outside of the environment of the video imaging software. Software acquired from Computer Imaging Applications significantly improved gray scale control thus affording an improved image for video capture.

This writer attended a "Video Imaging and Analysis Seminar" sponsored by Leeds Precision Instruments. Presenters included the manufactures of the hardware and software utilized in Coal Science projects. As a consequence of these meetings, and previous considerations as to the needs of ongoing data management and project needs, new hardware and software was ordered to upgrade the current operating system to a Microsoft Windows environment. The hardware order represents an upgrade to the CFG VisionPlus-AT framegrabber by Imaging Technology, Inc. This board will permit greater resolution without loss of overlay capabilities used in more sophisticated video capture programs and applications. The software order is an upgrade to the video capture program Optimas by Bioscan. Besides its enhanced analytic capabilities, Optimas permits a far better environment to exchange captured images with other Windows graphic drivers and related programming and should permit a far wider range of data management applications.

2.3 Geochemical Database Design (Task C)

In the context of the present Coal Science program, the purpose of designing a coal geochemical database, or any other similar analysis-type database, is to place such observations in a geologic framework. Thus geochemically oriented data can be integrated with stratigraphic and paleontologic databases to better facilitate the reconstruction of paleoenvironments and produce more definitive coal-related stratigraphic correlations. Such abilities thus afford a more comprehensive and meaningful interpretation of geologic history. Isolated coal analyses, without geologic context, have limited value in providing a means to correlate coal beds and coal-forming environments or to interpret depositional or diagenetic histories.

For the purposes of present database considerations, coal and rock geochemical data was downloaded from a mainframe database constructed for another project by LeFever and Murphy (1983). This data set was chosen because it was originally constructed for the purpose of posing questions of concern to individuals in coal resource assessment. These databases incorporate standard analytical data (e.g., Btu value, sulfur content, etc.) along with stratigraphic data, utilizing Q&A®, *MNOS, and *UNIT files and formats (see Appendix IV). All of the available data, representing several thousand initial observations, has been incorporated into specifically designed Q&A® databases. Unfortunately, very few chemical observations can be tied to specific stratigraphic sections, let alone their placement relative to specific horizons. The use of the LeFever and Murphy (1983) database clearly illustrates the problems attendant in the taking, recording (in the field), and tracking of geochemical data by earlier coal-oriented projects. A very low percentage of the "coal geochemistry" data can be specifically tied to a specific coal bed or even to a specific point on the ground. Thus, much good geochemical data is of immediately limited value, beyond its original intent. Appendix IV provides a detailed account of the geographic, geologic, bibliographic, lithologic, and coal chemistry data given by LeFever and Murphy (1983). As noted, all of their data has been inputted into specially designed Q&A® databases. These databases are related to one another through unique locality numbers.

2.4 Data Presentation (Task D)

Display of information in maintained databases is an important aspect of database utilization for the research scientist. Database management programs, such as Q&A®, provide a means to show data in various output formats. Data is most commonly displayed in tables, as rows and columns of observations, or as forms, depending on the nature of the intended use. In addition, graphical representation of data is particularly important where data is inherently visual (e.g., geologic sections) or numeric (e.g., analyses). Of considerable importance to data visualization is the ease with which the data can be displayed. The visualization of data should be used as a tool in data analysis and not an end in itself. The more easily data can be viewed, the more likely it will be used as a tool to permit the researcher to make better interpretations.

The program STRATCOL/STRATA (derived from a public domain program by Peter Guth) produces a graphic presentation of geologic logs from *UNIT databases. Through the use of Q&A® and STRATCOL/STRATA, a graphic representation of a geologic column can be produced with a laser printer in a matter of a few minutes. Additions to the *MNOS and *UNIT files also include entries specific to STRATCOL/STRATA (see Appendix II). Thus any geologic section inputted into the *UNIT database can be conveniently graphically represented for research studies.

A *MNOS base map reference system was initiated during Year Two of the Coal Science project and continues to be used for the plotting of the location of geologic observations. This system employs U.S. Geological Survey 1:24,000- and 1:100,000-scale maps. Surface and subsurface sections are plotted on the 1:24,000-scale maps with as much precision as is available. Elevations of the top and bottom of surface sections are compared with original data, or a "best fit" is determined if elevation data is not available. Paleontological observations are similarly plotted on the same maps. These maps will be used as the basis for digitizing coal and related geological observations for use in geographic information system programming and geologic software. In addition, *MNOS data is also plotted on a set of linen-backed topographic 1:100,000-scale maps. These maps have been put together to form a mosaic of far-western North Dakota and easternmost Montana. Essentially all of the M-number and L-numbered localities housed in Coal Science databases for easternmost Montana and far-western North Dakota have been plotted on 1:24,000 and 1:100,000-scale maps.

2.5 Database Implementation

Implementation or utilization of a database is the best means to realize the requirements for its effective use. The databases so far constructed and augmented have been used in research projects that test database design. These projects are discussed in the following section.

Research Studies. Field, laboratory, and computer-based activities have greatly facilitated the diverse requirements for the construction of database systems that can be used as a tool in research, rather than as a means to gather data. The following section represents studies undertaken with the purpose to fully test and implement databases constructed under the Coal Science program. To indicate the continuity of these studies, as part of the overall approach to this report, most of the research studies undertaken during the 1991-1992 fiscal year have been included.

Abstracts previously submitted for publication were presented to the Geological Society of America (GSA) and Society of Vertebrate Paleontology (SVP) for presentations at their annual meetings in San Diego in October. The GSA abstract summarizes research conducted on the stratigraphy and molluscan paleontology across the Cretaceous-Paleocene boundary in the northern Great Plains (Hartman, 1991b). Information utilized in the preparation of this paper was derived from databases maintained in Q&A® for the Williston, Powder River, and Crazy Mountains Basins in the northern Great Plains of the United States and Canada. The abstract delimits the occurrence of certain taxa through the uppermost Cretaceous Hell Creek and Lance Formations and Paleocene Ludlow, Tullock, and Bear Formations, providing biochronologic control for temporal correlations across North Dakota, Montana, Wyoming, and Saskatchewan. This abstract was submitted by invitation for a theme session on the "Fossil Record at the Cretaceous-Tertiary Boundary."

The SVP abstract summarizes research conducted on the stratigraphy and mammalian and molluscan paleontology of the Paleocene Sentinel Butte Formation in the North Dakota portion of the Williston Basin (Kihm and Hartman, 1991). Field work conducted over the last two summers relocated all of the previously known mammalian localities and rigorously defined their geographic and stratigraphic positions. These data were substantially revised from previously published reports. The coal-bearing strata of this formation can be shown to be somewhat older than previously considered, and is equivalent in age to the important coal-bearing sequence of the Tongue River Member of the Fort Union Formation in the Powder River Basin of northeastern Wyoming and southeastern Montana. All data associated with this effort, including both historic and modern stratigraphic and paleontologic observations, were maintained in databases designed under the Coal Science program.

A paper submitted for publication was presented as a poster session with Dr. Allen J. Kihm, in October, at the Sixth International Williston Basin Symposium (and Fourth Saskatchewan Petroleum Conference) in Regina, Saskatchewan. This paper concerns the stratigraphic and biochronologic context of pantodonts (vertebrates) in North Dakota. By more rigorously defining the stratigraphic and geographic position of a number of localities, the stratigraphic distribution of this group has been shown to be more temporally restricted than previously understood. This type of information permits more precise temporal (biochronologic) correlation of the coal-bearing strata of the upper Bullion Creek (Tongue River) and Sentinel Butte Formations. All of the stratigraphic and paleontologic data used to construct this paper, and associated figures, was organized through Q&A® databases developed and tested through Coal Science field and laboratory research.

Research was undertaken on the freshwater and terrestrial molluscan fauna of the Riverdale Locality, on the eastern bank of Lake Sakakawea, McLean County, North Dakota. Previously collected snails were curated for the purposes of morphometric and photographic study. The terrestrial snails, so far processed, were examined by Dr. Barry Roth, a consulting paleontologist from San Francisco, California. This material, along with the freshwater taxa, will form the basis of a publication on the most diverse nonmarine faunule of the Paleocene in North Dakota, and possibly in North America.

A Symposium on the *Paleontology in North Dakota: Fossils as a Resource in Research, Education, and Economics* was held April 30th at the 84th annual meeting of the North Dakota Academy of Science (Hartman, 1992b, c). This symposium was convened by Dr. Allen J. Kihm of Minot State University and this writer to provide a public forum for relating matters of statewide concern in regards to the fossil resources of the state (Hartman and Kihm, 1992). Nine presentations were given encompassing the entire exposed bedrock and Quaternary fossil fauna and flora of North Dakota. The presentations were followed by a group discussion in which the more than 50 people who attended the symposium participated. The symposium was covered by the Grand Forks Herald and the Associated Press wire service. Preparations for this event included mailings to various federal and state agencies and committee representatives.

Collaborative research, undertaken with Dr. David Krause of the State University of New York at Stony Brook, has resulted initially in the acceptance of an abstract to the annual meeting of the Society of Vertebrate Paleontology (Krause, et al., in press, 1992) on the "Latest Cretaceous and early Paleocene mammals from Makoshika State Park, Williston Basin, eastern Montana." This study, representing one of a number of site-based projects, is on the vertebrate paleontology and stratigraphy of Makoshika State Park, Dawson County, Montana. This research specifically pertains to the early Paleocene Hiatt Locality, which was discovered by Dr. Robert Hiatt, of Glendive, many years ago. The value of this research is in that temporal data is being documented for the base of the coal-bearing sequence in an area of the Fort Union Lignite Region where no such data was previously available. Such information bears on developing an understanding of the chronology of the Cretaceous/Tertiary transition, representing a shift in paleoenvironments from noncoal to coal-dominated settings. This research ties in directly with studies underway in southwestern North Dakota by Kroeger (dissertation project mentioned below), Hartman and Cvancara (in preparation, 1992), and Hartman and Krause (in preparation), in the western Williston Basin of Garfield and McCone Counties, Montana, by Hartman (1991a, 1992d) and Hartman and Rolland (in preparation), and in the Crazy Mountains Basin of Sweet Grass and Wheatland Counties, Montana, by studies of Hartman, Krause and others.

Samples of North Dakota tuffs, collected by Dr. Nels Forsmen of the University of North Dakota Department of Geology and Geological Engineering, were sent for age and geochemical analysis. One tuff, referred to as the Marmarth tuff, is from uppermost Cretaceous strata in southwestern North Dakota. The other tuff is the well known (but poorly documented) "blue bed" of McKenzie County, North Dakota. The tuffs will be age dated by Dr. Carl Swischer of the Institute of Human Origins. Very few isotopic dates are known for bedrock North Dakota strata. This information will place the section of strata represented between these two tuffs in an entirely new context permitting continental and global scale comparisons of previous continental configurations hypothesized for this interval. These analyses will be paid for by Dr. Malcolm C. McKenna of the American Museum of Natural History. Dr. George Shaw, of Union College, Schenectady, New York, will use an inductively-coupled plasma quadrapole mass spectrometer to fingerprint the tuffs for future lithostratigraphic correlation projects to fully utilize the poorly known volcanic record as preserved in North Dakota.

Research has commenced to published the stratigraphic distribution of historically important fossil mollusk localities in the coal-bearing strata of the Upper Cretaceous Fruitland and Kirtland Formations on various mine leases in the western portion of the San Juan Basin in northwestern New Mexico and southwestern Colorado. The field research undertaken for this project was supported by the New Mexico Bureau of Mines and Mineral Resources. Data analysis extensively utilizes databases constructed for Q&A® *MNOS, *UNIT, and *LOC databases. Although undertaken separately, this work will provide needed context for interpreting the biostratigraphic range of Upper Cretaceous molluscan taxa elsewhere in the western interior of North America. Results of this research will form the basis for systematic studies undertaken by Ms. Rolland mentioned below.

At the end of June and in early July, the results of stratigraphic and paleontologic studies on the "Biochronology of uppermost Cretaceous and lower Tertiary nonmarine Mollusca of the northern Great Plains, U.S.A. and Canada" were presented at the Fifth North American Paleontological Convention held in Chicago (Hartman, 1992d). The convention is held every four years, and on this occasion was attended by over 500 paleontologists from around the world.

Field Research. Field research represents the applied connection between data gathering, its management, and subsequent implementation and revision. A utilitarian database design is forged through use having specific goals and applications. The field research and database implementation discussed below have resulted in significant improvements in the approach to database management. Field research undertaken during the last summer field season was fully summarized in a previous technical report (Hartman, 1992a).

Field work recently undertaken includes the study of fossils and strata of the uppermost Cretaceous Hell Creek Formation of the Missouri and Little Missouri Rivers in southern North Dakota. This research concerns documenting the Hell Creek stratigraphic distribution of molluscan taxa in the North Dakota portion of the Williston Basin. Other research in the western portion of the Williston Basin in Garfield and McCone Counties, Montana (Hartman, 1991b; 1992d) has delineated the biostratigraphic ranges of most Lancian taxa known in the northern Great Plains. Studies in North Dakota provide the necessary biochronologic continuity to interpret the temporal history of the easternmost extent of Upper Cretaceous strata.

Research of T.J. Kroeger. Mr. Kroeger, a Ph.D. candidate in the University of North Dakota Department of Geology and Geological Engineering, is in the later stages of his dissertation studies entitled "Paleoecology of palynomorph assemblages in the upper Ludlow Formation (Paleocene), southwestern North Dakota." Mr. Kroeger is in the process of analyzing and interpreting the palynomorph-bearing sediment samples for brackish and marine indicators to provide greater resolution in interpreting these environments in the western Slope and southwestern Golden Valley Counties, North Dakota, and in Dawson County, Montana. In addition to his dissertation studies, his research has identified the Cretaceous-Tertiary boundary in surface and subsurface samples in Slope County, North Dakota, and in surface samples from Makoshika State Park, Dawson County, Montana. This information will be used in conjunction with age information interpreted from the nearby Hiatt mammal locality for the purposes of establishing a chronostratigraphic framework for the transition between largely nonlignite-bearing to lignite-bearing strata along the Yellowstone River and elsewhere. Mr. Kroeger's research makes extensive use of Q&A® "coal science" databases including the *MNOS and *UNIT databases, as well as other that have been specifically designed for sample record keeping in the laboratory and as accession records into the collections of the University of North Dakota.

Research of W.D. Peck. Mr. Peck, a Master's student in the University of North Dakota Department of Geology and Geological Engineering, is in the final stages of completing his project entitled "The stratigraphy and sedimentology of the Sentinel Butte Formation (Paleocene) in south-central Williams County, North Dakota," and will defend his effort in July. As a part of current related studies, Mr. Peck, with Dr. Allen J. Kihm and this writer, has attempted to construct a coal-based correlation framework for the area between the Nesson Anticline and Fort Union. This effort utilizes the relatively numerous isolated reports of coal along the Missouri River that have been computerized into *MNOS and *UNIT databases. Aspects of our study have been incorporated into Mr. Peck's thesis research. A final thesis manuscript has been submitted to his graduate committee.

Research of M.M. Rolland. Ms. Rolland has undertaken a senior thesis project, under this writer's supervision, in the University of North Dakota Department of Geology and Geological Engineering. The project is entitled "A faunal comparison of selected freshwater mollusks from the Upper Cretaceous (Edmontian?) Fruitland Formation of the San Juan Basin, New Mexico, with the Hell Creek Formation (Lancian) of the Williston Basin, Montana-North Dakota." Ms. Rolland's study, which is being partially supported by a grant from the local chapter of Sigma Gamma Epilson, a National Honorary Society for the Earth Sciences, involves the paleontologic and stratigraphic study of nonmarine mollusks from the coal-bearing strata of the Williston Basin of North Dakota and Montana and the San Juan Basin of New Mexico. Research will be directed towards understanding the evolutionary history of selected nonmarine molluscan taxa to provide a more rigorous biochronologic framework for the correlation and paleoenvironmental interpretation of nonmarine strata in the Upper Cretaceous strata of the western interior of the United States. Studies to date have utilized Coal Science data management systems (i.e., *LOC database) to revise geologic and paleontologic data concerning relevant strata in North Dakota. Field work undertaken in June specifically dealt with the stratigraphy and molluscan fauna of the Hell Creek Formation in Morton and Bowman Counties, North Dakota, representing the two main areas of exposures of Hell Creek strata in the state.

2.7 Other Research Travel

During the last fiscal year professional presentations and poster sessions were given in Regina, Saskatchewan (Hartman and Kihm, 1991), San Diego, California (Hartman, 1991b; Kihm and Hartman, 1991), and Chicago, Illinois (Hartman, 1992d). Other research travel for the July-December portion of the year has been previously fully summarized (Hartman, 1992a).

In addition, this writer attended the geographic information system (GIS) meetings in Bismarck, North Dakota, and Overland Park (Kansas City), Kansas. As previously noted, the map presentation and map analysis of geological and paleontological data is an important means to convey significant amounts of data conveniently to a large and varied audience. GIS represents a technology specifically designed to manage information that can input, manipulate, and analyze geographically referenced data. GIS programming represents a set of tools to organize, edit, analyze, display, and illustrate geographically referenced data. As essentially all of the constructed "coal science" databases represent geographically referenced information, GIS technology represents a natural extension of developing extended analytical and display capabilities for earth resource characterization and evaluation. GIS as a data systems architecture or methodology is clearly developing rapidly, with a large number of state and federal government agencies promoting its use through their own programs. The meeting in Bismarck was entitled "North Dakota GIS Short Course," and was sponsored by the North Dakota Geological Survey. In Overland Park, I attended the "Mid-America GIS symposium." As part of this symposium, I participated in the short courses "Methods for data capture and data management" and "An overview of GIS hardware and software."

In June, this writer attended a "Video Imaging and Analysis Seminar" sponsored by Leeds Precision Instruments in Minneapolis. The results of this trip are summarized above under "Video Imaging."

Also in June, as part of results obtained through Coal Science data management studies, this writer was invited and presented a talk on the "Uppermost Cretaceous and Paleocene nonmarine molluscan and mammalian studies in the Williston Basin" at the dedication of the paleontological laboratory of the Pioneer Trails Museum in Bowman, North Dakota.

2.8 Computer Hardware and Software

As previously noted, during September, a Gateway 2000 486/33 computer was acquired (through other funding) and installed, and Coal Science database systems were transferred to this machine. The main benefit of the 486 computer is its larger (650 MB) hard drive. The 486/33, and the previously purchased Coal Science Gateway 2000 386/25, will serve as the main database management computers. Expanded database needs, focused primarily on additional staff involvement in data management and use, have resulted in the need for additional computers and, eventually, the means to connect (i.e., network) them. To date, two machines, a Standard 286 and Gateway 2000 386sx, are used specifically for data input. Although this system of four computers functions well, as databases become larger, a significant increase in efficiency could be achieved through a computer network. Installing a network, however, is currently beyond the scope of committed financial resources.

Also during September, a 150-MB hard drive was replaced (through other funds) on the Gateway 2000 386/25 computer. Hard drives do not appear to have a long half-life, which emphasizes the necessity of regular backups. In this totally unexpected hard drive crash, no information was lost as all of the data on the 300 MB of the 386/25 computer had been backed up on streamer cassettes using an Everex external drive backup system. Both the 486/33 and 386/25 computers use the Everex system. The 486/33 is routinely backed up on a weekly basis, while the 386/25 is backed up by database as needed. In January, the Gateway 2000 386/25 experienced enigmatic computer hard drive problems, which were only resolved with a new hard drive transfer cable. No data was lost as a result of these machine problems.

The upgrades to various programs were acquired throughout the year. These programs include Release 4.0 of Freelance Graphics® by Lotus Development Corporation, Release 4.0 of Quattro Pro® by Borland Corporation, Release 2.0 of Axum® by Trimetrix, Inc., Release 3.1 of Windows® by Microsoft, Release 1.0

of WordPerfect for Windows® by WordPerfect Corporation, QEMM 386® by Quarterdeck Office Systems, and Release 2.1 of F-Prot Antivirus by Fridrik Skulason (site license by the University of North Dakota Computer Center).

2.9 Sample Processing

Surface and subsurface lithic and micro- and macrofossil samples collected from coal-bearing strata from the Little Missouri River drainage of southwestern North Dakota, Yellowstone, and Missouri drainages of the Williston Basin in eastern Montana, and Crazy Mountains Basin of south-central Montana were processed, curated, and analyzed during the last year. The data derived from these samples have been and will be in the study of the biostratigraphy and event-lithostratigraphy for the temporal interpretation of uppermost Cretaceous Paleocene strata in the northern Great Plains.

Microfossil samples, consisting largely of pollen, spores, and dinoflagellates, largely comprise the dissertation studies of Mr. Timothy J. Kroeger (see under Database Implementation). Samples to be used for dissertation studies and related papers (e.g., Krause et al., in press, 1992) have been fully processed and are under analysis towards completion of dissertation studies in about 18 months.

Rotary mud samples derived from the 1990-1991 drilling project (holes M2187 and M2188) and other related lithic samples were cataloged and labeled for archival storage. The drill hole samples were described as part of DOE database management studies. Various samples were also analyzed for the purposes of coal correlation and paleoenvironmental interpretation (Hartman and Cvancara, in preparation, 1992). As determined through the archiving process, certain samples are subject to bacterial decay. Although the likelihood of decay was previously known, the speed and number of samples to be effected was not. To avoid this problem in the future, a small refrigerator was purchased to house the few samples likely to be effected that would be processed for palynomorph studies. Once these samples have been processed, the remaining material will be dried for archival storage.

Surface lithic and macrofossil samples were processed by Mr. Johnathan M. Campbell, an undergraduate student at the University of North Dakota, for biochronologic studies in the Crazy Mountains and Williston Basin. These efforts are directed towards the construction of a unified temporal framework for the northern Great Plains. In addition, Ms. Michelle M. Rolland has begun to process macrofossil samples from the western portion of the Williston Basin to compare the systematic validity of the biochronologic range of selected nonmarine molluscan taxa in the western interior of the United States.

3.0 SUMMARY AND CONCLUSIONS

The general Coal Science objective of the Mining and Mineral Resources Research Institute (MMRRI) is directed towards more effective use of geologic observations specific to the correlation and assessment of coal-bearing strata. The effective and efficient utilization of these observations requires streamlined but flexible user-oriented data management programs incorporating straightforward data inputting and summary data output in the form most convenient to the user. Substantial amounts of currently useful and historically invaluable geologic data bearing on the correlation of coal beds is available for most coal-bearing areas. This is certainly the case in the lower Tertiary strata of the northern Great Plains in general and in western North Dakota specifically. This information exists as published and unpublished but accessible documents. The specific objective of this project is to implement, through computer-based data management systems, specific test area field studies that utilize all currently available information for the assessment of efficient database management techniques in the evaluation of specific coal correlation problems. This project is specific to fundamental coal resource and geologic studies undertaken by MMRRI. There is no attempt to duplicate the general needs of a national database resource management program, which, by its very nature, must approach coal correlation at a more general level, dependent entirely on the nature of data inputted to it. The databases described above are multidisciplinary and aimed at resolving specific questions of a litho-, bio-, and chronostratigraphic correlation.

The focus of the first phase of this project was to establish the computerized basis for reevaluating North Dakota's lignite resource in a stratigraphic and paleontologic context. The goal of the second phase of the project was to establish more realistic database case studies, including surface and subsurface data specifically taken with the design and construction of stratigraphic and paleontologic databases as a resulting product. The third phase continues to set new and greater demands on the stratigraphic database design. Several thousand surface and subsurface data entries have been compiled from the uppermost Cretaceous and Paleocene Fort Union coal region of the Williston Basin, far-western North Dakota and adjacent easternmost Montana. Database designs have continued to be modified to reflect a greater knowledge on the demands and needs of the end-user. Unlike other databases that are constructed to summarize the data compiled, database research under the Coal Science program has attempted to design a flexible data management system that serves an ongoing interactive need to answer previously unconsidered resource-based questions.

Coal Science data management research will continue into the next biennium to conclude tasks concerning database programming. A number of new programming techniques have been developed that will significantly increase the relational power of existing databases, reducing the redundancy of forms for certain data retrieval operations. These database design improvements will be accomplished as an extension of the current cooperative agreement (as per the April 1992 monthly report) with existing funds.

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APPENDIX I

Document 1

*MNOS Database Form
(Q&A® File Module)

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Mno:          REF:                                            DATE:
  P:          PAG:                                             LOG:
ent:      refBOSS:                       from:
dFU:    secDONEon:                         by:
UNQ:        intBY:                       from:
OFno:                         NAME:                       Last Modified
REF#:                         ADD#:                     (Date)      (Time)
INST:                         #:                  24K:     100K:
LOGt:      U:      LOGcom:               NCRDS:    SUMc:    HEADc:    LOGc:
--------------------------------------------------------------------------
NAT:     REG:         FIELD:                         ldg:         I#:   O:
 ST:    CO:              QD:                          YR:         SR:   CI:
BLM:       QQ:                SEC:    T:     NS:   R:     EW:  SC:  TC:  RC:
TK/ft:          /m:           S/:    LG:                LT:
ELtop:         T/m:           X:     gd:     gm:    gs:   td:    tm:     ts:
ELbot:         B/m:           Z:     Ng:   UTM:           Eg:  UTM:
EL+/-:        +/-m:                 CNS:   CO1:          CEW:  CO2:
  INT:                             ftNS:    #3:         ftEW:   #4:
                                    mNS:    #5:          mEW:   #6:
FS:     Lno :
LS:     RK-S:
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End of first screen

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--------------------------------------------------------------------------
 :                  :

SE4:        FM:                TK:         TKm:          4:   S:      F:
SE3:        FM:                TK:         TKm:          3:   S:      F:
SE2:        FM:                TK:         TKm:          2:   S:      F:
SE1:        FM:                TK:         TKm:          1:   S:      F:

  PRIMARY FM:
ORG BED NAME:                  U#:         U-TK/ft:          U-TK/m:
REVISED NAME:                  BEDc:       FD:  XS:      CL:

NAMED BEDS:


STRAT:
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End of second screen

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LOC:



COM:


PROPowner:

PICTURES:
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APPENDIX I

Document 2

*MNOS Database Form with Data
(Q&A® File Module)

```
Mno: M2253       REF: Hartman (1990u, v. 18)                   DATE: 1990/09/05
  P:             PAG: p. 67, 106, 107-111, 112-115, 118-119, 124  LOG: 1990/10/02
ent: JHH    refBOSS: Hartman, J.H.           from: UND-EERC-MMRRI
dFU:        secDONEon: 1990/09/08              by: Kroeger, T.J., Peck, W.D., Har
UNQ: M2253P   intBY: Hartman, J.H.           from: UND-EERC-MMRRI
OFno: No. 1-DH surface section NAME: M2187-DH surface sect   Last Modified
REF#: M2253                  ADD#:                        1992/01/15  15:25 p.m.
INST:                           #:                     24K: Y   100K: Y
LOGt: MS    U:       LOGcom:                NCRDS:    SUMc:    HEADc:    LOGc:
-------------------------------------------------------------------------------
NAT: USA  REG: WB-LMR FIELD: Brown Ranch              ldg: 46103     I#: E7 O: m
ST: ND CO: Slope          QD: Three V Crossing        YR: 1979    SR: 7.5 CI: 20
BLM:        QQ: about C E SE   SEC:  9 T: 135 NS: N R:  105 EW: W SC:  TC:  RC:
TK/ft:  211.939  /m:   64.600 S/:    LG:                      LT:
ELtop: 2857.743 T/m:  871.051  X:    gd:     gm:     gs:     td:     tm:     ts:
ELbot: 2645.785 B/m:  806.445  Z:    Ng:   UTM:                Eg:  UTM:
EL+/-: 10.0    +/-m:  3.0           CNS:   CO1:               CEW:  CO2:
  INT: JHH                         ftNS:    #3:              ftEW:   #4:
                                    mNS:    #5:               mEW:   #6:
FS: B/? Lno : L5605 L5606 (Cannonball, upper tongue); L5607 (upper tongue?)
LS:     RK-S:
-------------------------------------------------------------------------------
: M2253           : Hartman (1990u, v. 18)

SE4: PAL     FM: Slope              TK:  106.626 TKm:   32.500 4:   S: E1A  F: T2
SE3: PAL     FM: Cannonball-Upper? TK:   14.764 TKm:    4.500 3:   S: C1A  F: T2
SE2: PAL     FM: Cannonball-Upper  TK:   16.404 TKm:    5.000 2: C S: E1A  F: T2
SE1: PAL     FM: Slope              TK:   80.708 TKm:   24.600 1:   S: E1A  F: T2

  PRIMARY FM: Cannonball
ORG BED NAME: upper tongue       U#: 029-031    U-TK/ft:  16.404  U-TK/m:  5.000
REVISED NAME: Three V Tongue     BEDc:          FD:  XS:      CL:

NAMED BEDS: Lower Coal Pair; Upper Coal Pair; Glasswort? clay; West Yellow
Marker; upper tongue; upper tongue?; No. 1 coal; Yule coal; ESB Channel 12


STRAT: This section plots on the location of M320 of Moore (1976).
Comparable sections include M40 and M51 by Belt.  This section includes the
upper tongue (unpublished Three V Tongue) of the Cannonball Formation and a
number of coal beds.

-------------------------------------------------------------------------------
: M2253           : Hartman (1990u, v. 18)

LOC: M2253, measured more or less due south of the drilling site M2187, is
located on generally south-facing exposures on a major bluff face and
associated tributary trending northwest to southeast.  Section M2253a was
measured by Wes on the walls of the drilling mud pit.


COM: This surface section was measured to permit a direct comparison (by the
same geologists) with the upper portion of drill hole section M2187.


PROPowner: U.S. Forest Service.

PICTURES: C1737-C1745, C1746-C1749 (localities), C1750-C1755
```

APPENDIX I

Document 3

*MNOS Database Form (Q&A® Write Module)

WILLISTON BASIN M-NUMBER LOCALITY FORM

Joseph H. Hartman, UND-EERC-MMRRI
data entered on: ; form printed on: 1992/01/15

Example

LOG TYPE:

REFERENCE	: ,		
REFERENCE BOSS	: ()		
OBSERVATION BY	: ()		
INTERPRETED BY	: ()		
REFERENCE #	:	**ADDITIONAL #**	:
ORGINAL FIELD#	:	**LOCALITY NAME**	:
INSTITUTION #	:	**PANEL DATA**	: AREA CROSS SEC COLUMN
DRILL LOG TYPES	:	**NCRDS RELATED**	: NCRDS: SUMc: HEADc: LOGc:
FOSSIL L-numbers	: ()		

M-number LOCATION DATA

GENERAL LOCATION : , , County **STUDY AREA:** region, field area
QUADRANGLE DATA : Quad., , series, foot contour interval (map location: ,)
LEGAL LOCATION : sec. , T. ., R. . (CODES- sec: ; TWP: ; RGE: ; X: ; BLM:)
FROM SECTION LINE : feet , feet ; meters , meters
ILLUSTRATIONS : **PLOTTED (Y/N)- 24k: 100k:**
SITE DESCRIPTION :

STRATIGRAPHIC DATA

Litho- and Chronostratigraphy of Section (1 to 4 = bottom to top)

SERIES4:	**FORMATION:**	**THICKNESS:**	**feet;**	**meters**	**C4:**
SERIES3:	**FORMATION:**	**THICKNESS:**	**feet;**	**meters**	**C3:**
SERIES2:	**FORMATION:**	**THICKNESS:**	**feet;**	**meters**	**C2:**
SERIES1:	**FORMATION:**	**THICKNESS:**	**feet;**	**meters**	**C1:**

Section Thickness and Elevations

SECTION THICKNESS : feet; meters
ELEV TOP OF SECTION : feet; meters **ELEVATION +/-** : feet; meters
ELEV BASE OF SECTION : feet; meters **INTERPRETED BY** :

Bed Nomenclature and Data

PRIMARY FORMATION : **LITHIC COLLNS** :
ORIGINAL BED NAME : **UNIT #** : **BED Code:**
REVISED BED NAME :
NAMED BEDS IN SECTION :

Stratigraphic Correlation and Description

GENERAL M-number COMMENTS

APPENDIX I

Document 4

*MNOS Database Example (Q&A® Write Module)

WILLISTON BASIN M-NUMBER LOCALITY FORM

Joseph H. Hartman, UND-EERC-MMRRI
data entered on: 1990/10/02; form printed on: 1992/01/15

M2253

LOG TYPE: MS

REFERENCE : Hartman (1990u, v. 18), p. 67, 106, 107-111, 112-115, 118-119, 124-128, 148-150, 155-157
REFERENCE BOSS : Hartman, J.H. (UND-EERC-MMRRI)
OBSERVATION BY : Kroeger, T.J., Peck, W.D., Hartman, J.H. (1990/09/08)
INTERPRETED BY : Hartman, J.H. (UND-EERC-MMRRI)
REFERENCE # : M2253 **ADDITIONAL #** :
ORGINAL FIELD# : No. 1-DH surface section **LOCALITY NAME** : M2187-DH surface section
INSTITUTION # : **PANEL DATA** : AREA CROSS SEC COLUMN
DRILL LOG TYPES : **NCRDS RELATED** : NCRDS: SUMc: HEADc: LOGc:
FOSSIL L-numbers : L5605-L5606 (Cannonball, upper tongue); L5607 (upper tongue?) (B/?)

M-number LOCATION DATA

GENERAL LOCATION : USA, ND, Slope County **STUDY AREA:** WB-LMR region, Brown Ranch field area
QUADRANGLE DATA : Three V Crossing Quad., 1979, 7.5 series, 20 foot contour interval (map location: 46103, E7)
LEGAL LOCATION : about C E SE sec. 9, T. 135 N., R. 105 W. (CODES- sec: ; TWP: ; RGE: ; X: ; BLM:)
FROM SECTION LINE : feet , feet ; meters , meters
ILLUSTRATIONS : C1737-C1745, C1746-C1749 (localitie **PLOTTED (Y/N)-** 24k: Y 100k: Y
SITE DESCRIPTION : M2253, measured more or less due south of the drilling site M2187, is located on generally south-facing exposures on a major bluff face and associated tributary trending northwest to southeast. Section M2253a was measured by Wes on the walls of the drilling mud pit.

STRATIGRAPHIC DATA

Litho- and Chronostratigraphy of Section (1 to 4 = bottom to top)

SERIES4:	PAL	**FORMATION:**	Slope	**THICKNESS:**	106.626	feet;	32.500	meters	C4:	
SERIES3:	PAL	**FORMATION:**	Cannonball-Upper?	**THICKNESS:**	14.764	feet;	4.500	meters	C3:	
SERIES2:	PAL	**FORMATION:**	Cannonball-Upper	**THICKNESS:**	16.404	feet;	5.000	meters	C2:	C
SERIES1:	PAL	**FORMATION:**	Slope	**THICKNESS:**	80.708	feet;	24.600	meters	C1:	

Section Thickness and Elevations

SECTION THICKNESS :	211.939	feet;	64.600	meters		
ELEV TOP OF SECTION :	2857.743	feet;	871.051	meters	**ELEVATION +/-** :	10.0 feet; 3.0 meters
ELEV BASE OF SECTION :	2645.785	feet;	806.445	meters	**INTERPRETED BY** :	JHH

Bed Nomenclature and Data

PRIMARY FORMATION : Cannonball **LITHIC COLLNS** :
ORIGINAL BED NAME : upper tongue **UNIT #** : 029-031 **BED Code:**
REVISED BED NAME : Three V Tongue
NAMED BEDS IN SECTION : Lower Coal Pair; Upper Coal Pair; Glasswort? clay; West Yellow Marker; upper tongue; upper tongue?; No. 1 coal; Yule coal; ESB Channel 12

Stratigraphic Correlation and Description

This section plots on the location of M320 of Moore (1976). Comparable sections include M40 and M51 by Belt. This section includes the upper tongue (unpublished Three V Tongue) of the Cannonball Formation and a number of coal beds.

GENERAL M-number COMMENTS

This surface section was measured to permit a direct comparison (by the same geologists) with the upper portion of drill hole section M2187.

APPENDIX I

Document 5

*MNOS Database Fields Organized by Topic
(Q&A® File Module)

See Document 6 for full Field Names and Explanations

REFERENCE RELATED INFORMATION

Numbering Systems Fields
Mno:
OFno:
REF#:
ADD#:
INST: #:

Reference (Citation) Fields
REF:
PAG:
refBOSS: from:
secDONEon: by:
intBY: from:
NAME:
LOGt: LOGcom:
FD: XS: CL:
COM:
PICTURES:

Record Management Fields
DATE: (of Reference)
LOG: (of entry)
P:
UNQ:
ent:
LAST MODIFIED Fields – Date and Time of modification
24K: 100K:
U: (utility)
NCRDS: SUMc: HEADc: LOGc:
O: (original unit of measure)

Screen Management Fields
[Mno]: [REF]: (for screens 2 and 3)

LOCATION FIELDS

General Location
NAT: ST: CO:
REG: FIELD:
QD: YR: SR: CI: ldg: I#:
LOC:
PROPowner:

*MNOS Database FIELDS ORGANIZED BY TOPIC, continued

LOCATION FIELDS, continued

Legal Location

BLM:
QQ: SEC: SC: T: NS: TC: R: EW: RC:
ftNS: #3: ftEW: #4:
mNS: #5: mEW: #6:
S/:
X:

Longitude and Latitude Coordinates

LG: LT:
gd: gm: gs: td: tm: ts:
X:

UTM Coordinates

Z: Ng: UTM: Eg: UTM:
X:

State Land Grid Coordinate System

CNS: C01: CEW: C02:
X:

STRATIGRAPHY FIELDS

Section Elevations

TK/ft: /m:
ELtop: T/m:
ELbot: B/m:
EL+/-: +/-m: INT:

Chronostratigraphy

SE4: S:
SE3: S:
SE2: S:
SE1: S:

Lithostratigraphy and Formation Thickness

FM: F: 4: TK: TKm:
FM: F: 3: TK: TKm:
FM: F: 2: TK: TKm:
FM: F: 1: TK: TKm:
PRIMARY FM:
NAMED BEDS:
STRAT:
dFU:

*MNOS Database FIELDS ORGANIZED BY TOPIC, continued

STRATIGRAPHY FIELDS, continued

Unit (Bed) Nomenclature and Basic Data

ORG BED NAME:
REVISED NAME:
U#:
U-TK/ft: U-TK/m:
BEDc:
dFU:

SAMPLE COLLECTION FIELDS

Fossil Collections

FS: Lno:

Rock Collections

LS: RK-S:

APPENDIX I

Document 6

*MNOS Database Field Names and Explanations

The following list contains the explanations of the typically abbreviated field names used in *MNOS databases in the File Module of Q&A®. The unabbreviated form of the field name is given parenthetically, followed by an explanation and/or examples of entry input to show the appropriate type of field information and style. This explanatory information is available to the Q&A® user through customized HELP fields while inputting or editing data. The fields are ordered as per row in *MNOS databases (see Appendix Document 4.2.1 for example).

Mno (M-number)
EERC MMRRI section or geological observation number (e.g., M1000, M2345a). If this M-number entry (of the first screen or page) is inadvertently changed, the M-number entry of the second screen is not affected.

REF (Reference)
Primary reference information; examples of preferred formats: Hares (1928), Hartman (1986u), Hartman (1991u, v. 12) [u = unpublished]; U.S. Geological Survey OFR (for Open-file Reports); North Dakota Geological Survey; North Dakota State Water Commission. The primary reference information for this form is automatically entered on the second and subsequent pages (screens) in the ADD and UPDATE modes.

DATE (Date of Reference)
The date of the reference (REF) (e.g., 1978). Enter also the month and day if the reference is unpublished and the information is available (e.g., 1978/10/12).

P (Primary form)
Enter "P" for all primary forms. Leave empty for all other (duplicate = other use) forms.

PAG (Pagination)
Secondary reference information. For typical references, enter pagination, such as page (p.), plate (pl.), etc. The letters "m" and "p" adjacent to page numbers stand for "map" and "photo" (the pagination "p. 34p, 35, 36m" indicates that a photo and map of the section is found on pages 34 and 36, respectively). For drill holes use this line for source of information, such as "NCRDS summary form," "drilling form," etc.

LOG

Represents data of first or subsequent revisions of M-number data on computer. The date is automatically entered in the ADD mode when entering data to a new form. Major revisions to a previous form should receive a new date. Save an old form as a hard copy or as secondary forms (non-"P" forms).

ent (Enterer)
Enter the initials of person who is responsible for filling in form. Note the source of interpretations (location information, etc.) in fields **INT**, **STRAT**, **LOC**, or **COM**.

refBOSS (Reference boss)
Enter the last name and initials of the person in charge of the reference (e.g., Hares, C.J.). This entry may be the same as given under **REF**.

from
Enter the institutional affiliation of the **refBOSS** (e.g., University of North Dakota, U.S. Geological Survey, North Dakota Geological Survey).

dFU (Duplicate form)
This form is used to integrate the presence of partially "duplicate" forms in the database for use with data specific to formations and units. Enter "F" or "U" for use of same M-number for descriptions of formation or unit thicknesses within this section (this approach avoids duplication of an M-number in sort routines in general reference to location or other information about the section).

secDONEon (Date section was done)
Enter the date section was measured or drilled (e.g., month/day/year).

by
Enter the name of the person who measured the section (e.g., Powell, L.M.).

UNQ (Unique M-number)
This field is automatically entered combining fields **Mno** and **P** to make **LnoP** (e.g., M2187P). The purpose of this addition is to create a unique M-number for a variety of external lookup files.

intBY (Interpreted by)
Enter the person responsible for interpreting the section as given in this form. This may be the same person as given in fields **REF** (reference source) and **by** (section measurer). This use of this field is meant particularly for the subsequent interpretation of subsurface geophysical logs.

from
Enter the institutional affiliation of the **intBY** (e.g., University of North Dakota, U.S. Geological Survey, North Dakota Geological Survey).

OFno (Original field number)
Enter the number originally applied to the section. This number usually is the number (or name) assigned to the section during field work.

NAME (Name of section)
Enter the name of the section (e.g., Red Hills).

REF# (Reference number)
Enter the number applied to section in **REF**. This may or may not be the original field number (**OFno**). Both the original field number (**OFno**) and the reference number (**REF#**) should be entered even if they are the same.

ADD# (Additional number)
Enter any additional numbers that may have been used by **REF** to refer to this section. This field may also have a "constructed" number to use to help refer to a section that cannot otherwise be conveniently differentiated from another section.

Last Modified See DATE and TIME of last modification.

(DATE of Last Modification)
If ANY changes are made to this form, the date that those changes were made will automatically be entered in this field. The DATE field is otherwise invisible.

(TIME of Last Modification)
If ANY changes are made to this form, the time that those changes were made will automatically be entered in this field. The TIME field is otherwise invisible.

INST (Institution)
Enter the institutional acronym for use with a formalized numbering system (e.g., USGS, NDGS, NDSWC), and enter number in next field (#).

 # (Institutional number)
The identification number used in a formalized numbering system.

24K
Enter "P" if the locality has been plotted on 1:24,000-scale map.

100K
Enter "P" if the locality has been plotted on 1:100,000-scale map.

LOGt (Type of section)
Enter one of the following two-letter log codes: MS = measured section; DH = drill hole section; RR = rock record (single bed or rock sample occurrence); PM = paleomagnetic reading. A paleomagnetic section is a measured section if encompassing more than a single bed.

U (Unit type)
Enter one of the following user-specified unit type codes for reference to a bed or bed complex: BT = bed thickness (unspecified bed type); CB = Cannonball Formation (tongue); CS = coal section (coal thickness); PM = paleomagnetic (detail); QU = quarry section (fossil deposit) (limited use); SI = silcrete; WM = white marker.

LOGcom (Log comment)
Enter the appropriate geophysical log codes (e.g., 07, 08, 10, 11): 01 (core), 02 (drill hole), 03 (rotary), 05 (electric), 06 (geophysical), 07 (gamma), 08 (density), 09 (neutron), 10 (resistivity), 11 (spontaneous potential), 12 (sonic), 13 (laterlog), 14 (seismic), 15 (caliper), 16 (coal test), 17 (oil and gas), 18 (water well).

NCRDS (National Coal Resources Data System)
Enter "Y" (yes) to indicate that this M-number is to be used in the NCRDS program.

SUMc (NCRDS summary form copied)
Enter "C" (copied) to indicate if the associated NCRDS summary sheet(s) has(have) been copied and filed (this use is in reference to geophysical logs). Enter "P" to indicate that a photocopy has been made of a nongeophysical log record (this use is in reference to surface sections).

HEADc (Original header copied)
Enter "C" (copied) to indicate that the original header from the geophysical log has been copied and filed.

LOGc (Geophysical or other log copied)
Enter "C" (copied) to indicate that the entire geophysical log has been copied and filed.

NAT (Nation)
Enter a three-letter abbreviation for the nation of the locality (e.g., USA, CAN).

REG (Region)
Enter a regional designation for the locality. These designations are predetermined; examples for the Williston Basin are as follows: WB-NDC = central North Dakota; WB-LMR = Little Missouri River; WB-FTU = Fort Union; WB-W = Garfield and McCone Counties; WB-N = northern Montana; WB-SK = Saskatchewan.

FIELD (Field or study area)
Enter the name of the field or study area (if available) in which the locality occurs (e.g., Williston lignite field, Charlson oil field). The field area is an area smaller than a region (**REG**) and generally is an area designated by the reference (**REF**).

1dg (1 degree)
Enter the 1 x 1-degree reference number cited by USGS in state quadrangle booklets (automatically entered after leaving field **QD**).

I# (Map Index number)
Indexes quadrangles within 1 x 1-degree areas by the USGS methods. This field is automatically filled upon leaving the **QD** field.

O (Original units of measure)
Enter "ft" or "m" to indicate in what units the original section was measured.

ST (State or Canadian Province)
Enter the two-letter designation for the state or province as per U.S. Postal standards.

CO (County)
Enter the name of the county in which the section occurs.

QD (Quadrangle)
Enter the name of USGS 7.5-minute quadrangle on which the section is located.

YR (Year quadrangle was published)
This field is automatically filled upon leaving the field **QD**.

SR (Map series)
The appropriate U.S. Geological Survey map series (e.g., 7.5, 15) (7.5-minute = 1:24,000; 15-minute = 1:62,500 (not typically used) will be automatically entered upon leaving the **QD** field.

CI (Contour interval)
The contour interval for all 7.5-minute maps is presently in feet. This field is automatically entered upon leaving the **QD** field (if the data has been inputted in the MAPS database).

BLM (Bureau of Land Management [and others])
Enter, if used in the original reference, the section subdivision system with letters to refer to quarter section areas (cartesian quadrants) (e.g., ADC). Entered subdivisions will automatically be converted to quarter-quarter (**QQ**) nomenclature (e.g., SW SE NE).

QQ (Quarter section subdivisions)
Enter the quarter section subdivision (e.g., SW SE NW) for the location of the locality. Use other descriptive terms as necessary, e.g., C west edge (C = center); near; about; central.

SEC (Section)
Enter the section number in which the M-number occurs. If the M-number occurs in more than one section (as with a measured section), place the appropriate code in the field **SC**.

T (Township)
Enter the township number in which the section occurs (e.g., 124). Enter the number only. Do not enter the preceding "T" or the subsequent "N" or "S."

NS (North/South)
Enter **N** or **S** in reference to townships north or south of the base line.

R (Range)
Enter the range number in which the locality occurs (e.g., 84). Enter the number only. Do not enter the preceding "R" or the subsequent "E" or "W."

EW (East/West)
Enter **E** or **W** in reference to townships east or west of the principal meridian.

SC (Section code)
Enter "?" if there is uncertainty in the section designation (used primarily for historical records with inspecific data). Enter "/" if a locality occurs in more than one section, and enter this additional section in the field **S/**.

TC (Township code)
Enter "?" if there is uncertainty in the township designation (used primarily for historical records with inspecific data). Enter 2pm (2nd principal meridian), 3pm (3rd principal meridian), etc., for reference to Canadian principal meridians.

RC (Range code)
Enter "?" if there is uncertainty in the range designation (used primarily for historical records with inspecific data).

TK/ft (Section thickness in feet)
Enter the thickness of the section in feet. If section thickness was originally measured in meters, this field will be inputted automatically upon leaving the field **TK/m**.

TK/m (Section thickness in meters)
Enter the thickness of the section in meters. If section thickness was originally measured in feet, this field will be inputted automatically upon leaving the field **TK/ft**.

S/ (Additional township and range section number)
Enter the additional section number (e.g., 24) in which the locality occurs. This section is in reference to the section number given in field **SEC**.

LG (Longitude)
Enter longitude of the locality in the following format: ###.####.

LT (Latitude)
Enter the latitude of the locality in the following format: ##.####.

ELtop (Elevation at top of section or unit in feet)
Enter elevation (in feet) at the top of the geologic section or unit. If the elevation was originally entered in meters, leave this field blank. The conversion from meters to feet will be done automatically.

T/m (Elevation at top of section in meters)
Enter, in meters, the elevation of the top of the section (if interpreted originally in meters). The elevation in feet will be automatically entered in field **ELtop** upon leaving **T/m**.

X (Coordinate location code)
Enter "X" to indicate that the coordinate system location was based on an arbitrarily plotted point (where the locality was only known to an area).

gd (Longitude value for degrees)
This value is automatically extracted from the longitude value.

gm (Longitude value for minutes)
This value is automatically extracted from the longitude value.

gs (Longitude value for seconds)
This value is automatically extracted from the longitude value.

td (Latitude value for degrees)
This value is automatically extracted from the latitude value.

tm (Latitude value for minutes)
This value is automatically extracted from the latitude value.

ts (Latitude value for seconds)
This value is automatically extracted from the latitude value.

ELbot (Elevation at bottom of section in feet)
Enter elevation (in feet) at the bottom of the geologic section. If the elevation was originally entered in meters, leave this field blank. The conversion from meters to feet will be done automatically.

B/m (Elevation of bottom of section in meters)
Enter, in meters, the elevation of the base of the section (if interpreted originally in meters). The elevation in feet will be automatically entered in field **ELbot** upon leaving **B/m**.

Z (Zone of UTM coordinate system)
Enter the zone number (e.g., 12) for the following UTM coordinate.

Ng (Northing for UTM coordinate system)
This value is preset for northing (N).

UTM (Universal Transverse Mecator coordinate system easting number)
Enter the easting number; commas are automatically emplaced.

Eg (Easting for UTM coordinate system)
This value is preset for easting (E).

UTM (Universal Transverse Mecator coordinate system northing number)
Enter the northing number; commas are automatically emplaced.

EL+/- (Elevation accuracy in feet)
Enter the letters "A" (= approximate) or "vA" (= very approximate) as estimates of the locality's elevation, or enter the footage value based on an interpretation of contours on a topographic map (e.g., "10" = +/- 10 ft).

+/-m (Elevation accuracy in meters)
Enter the letters "A" (= approximate) or "vA" (= very approximate) as estimates of the locality's elevation, or enter the metric value based on an interpretation of contours on a topographic map (e.g., "3" = +/- 3 m). As most elevation contour lines on U.S. Geological Survey topographic maps are in feet, a numeric value given in field "EL+/-" will automatically be converted to meters in this field ("+/-m).

INT (Interpreter of elevation)
Enter the initials of person making the interpretation of the elevation.

CNS (North/south code)
As appropriate, enter "N" (north) or "S" (south) zone code for the 10,000-ft state plane coordinate system.

C01 (10,000 ft coordinate number)
Enter the 10,000-ft coordinate number appropriate for the location of the locality. This number is read from a USGS quadrangle (commas are applied to this number automatically).

CEW (East/west code)
As appropriate, enter "E" (east) or "W" (west) zone code for the 10,000-ft state plane coordinate system.

C02 (10,000 ft coordinate number)
Enter the 10,000-ft coordinate number appropriate for the location of the locality. This number is read from a USGS quadrangle (commas are applied to this number automatically).

ftNS (Feet north or south of section line)
Enter "N" or "S" to indicate in which direction the distance from a section line was measured. This field is automatically filled if the metric value is entered in Field **#5**.

#3 (Number of feet north or south of a section line)
Enter the distance in feet north or south of a section line.

ftEW (Feet east or west of a section line)
Enter "E" or "W" to indicate in which direction the distance from a section line was measured. This field is automatically filled if the metric value is entered in Field **#6**.

#4 (Number of feet east or west of a section line)
Enter the distance in feet east or west of a section line.

mNS (Meters north or south of a section line)
Enter "N" or "S" to indicate in which direction the distance from a section line is measured. This field is filled automatically if **ftNS** is entered.

#5 (Number of meters north or south of a section line)
Enter the distance in meters north or south of a section line. This field is automatically filled if **#3** is entered.

mEW (Meters east or west of a section line)
Enter "E" or "W" to indicate in which direction the distance from a section line is measured. This field is filled automatically if **ftEW** is entered.

#6 (Number of meters east or west of a section line)
Enter the distance in meters east or west of a section line. This field is automatically filled if **#4** is entered.

FS (Fossil samples)
Enter "Y" (yes) if fossils have been collected from this section (locality numbers are entered in field **Lno**). Enter "x" (= yes) if fossils were collected but no L-number has yet been assigned.

Lno (L-number)
Enter **L-numbers** assigned to this section. The **L-number** represents a paleontological locality numbering system initiated and maintained by Joseph H. Hartman.

LS (Lithic cutting or samples)
Enter "Y" (yes) if sample has been numbered and then see field **RK-S**.

RK-S (Lithic sample number)
Enter rock sample numbers assigned to this section.

SE4 (Epoch)
Enter the series abbreviation applicable to formation #4 (**FM4**) (e.g., EOC = Eocene; PAL = Paleocene; UK = Upper Cretaceous).

FM (Formation)
Enter a formation name occurring in the section. Formations are ordered as per their stratigraphic superposition (see **SERIES1-SERIES4**), with **SERIES1** (or Formation 1) as the oldest and **SERIES4** as the most recent.

TK (Formation thickness in feet)
Enter the thickness, in feet, of Formations 1-4, respectively. If the original measurement was in meters, a conversion to feet is automatically done upon leaving the appropriate **TKm** field.

TKm (Formation thickness in meters)
Enter the thickness, in meters, of Formations 1-4, respectively, if the section was originally measured in meters. The calculation to meters from feet is done automatically after the footage is entered in field **TK**. If the original measurement was in meters, a conversion to feet is automatically done upon leaving the appropriate **TKm** field.

4 (Formation code)
Enter the formation code ("C)" for Formations 1-4, respectively, if the formation is complete in this section.

S (Series code)
The series code for Formations 1-4 (**FM**), respectively, is automatically entered upon leaving the **SE(1-4)** fields.

F (Formation code)
The formation code for Formations 1-4 (**FM**), respectively, is entered automatically upon leaving the **FM** fields.

PRIMARY FM (Primary Formation)
Enter the name of the primary formation in the section.

ORG BED NAME (Original bed name)
Enter the original name of the bed or unit (if the purpose of the form is to consider individual units).

U# (Unit number)
Enter the unit number of a specific bed in the section. Refer to the *UNITS file for more complete information on this unit.

U-TK/ft (Unit thickness)
Enter the thickness, in feet, of the unit referred to in field **U#**.

U-TK/m (Unit thickness)
Enter the thickness, in meters, of the unit referred to in field **U#**. This value is automatically derived from the field **U-TK/ft** if the value was originally measured in feet.

REVISED NAME (Revised bed name)
Enter the revised name of the bed referred to in **ORG BED NAME**. Include the initials of the person making the revision along with the year (if necessary) and the lithology (e.g., lignite Bed B-FAH 1928).

BEDc (Bed code)
Enter one of the following bed codes: ? = questioned correlation; + = bed thicker than given (bed not totally exposed); T = possible stratotype (TYPE) for bed; C = clinker bed representing the product of a burned named bed; P = parting > or = to 10% or < 25% of bed thickness (otherwise no "P"); S = split - parting > or = 25% of bed thickness.

FD (Project number)
The project field represents a subdivision of the field **REG**, as used in Hartman (1984) for the location of cross section panels and corresponds to the "zone" field area.

XS (Cross section or panel identifier)
Enter the number of the cross section in which the geologic section has been illustrated.

CL (Column number)
Enter the number of the column in the cross section (**XS**) that refers to a particular M-number geologic section.

NAMED BEDS
Enter the names (formal or informal) of beds occurring in this section.

STRAT (Stratigraphy)
Enter, preferably as a quote, any general stratigraphic comments.

LOC (Location)
Enter, preferably as a quote, any general location comments.

COM (Comments)
Enter any general comments about the section that do not fit well into any other field.

PROPowner (Property owner)
Enter the name of the owner of the property on which the section is located.

PICTURES
Enter the catalog number of photographs of the section or unit (taken in the field or lab).

APPENDIX II

Document 7

*UNIT Database Form
(Q&A® File Module)

Mno: REF: DATE:
SC: PAG: LOG:
ST: REG: PJC: mod: (Date) (Time) ent:

U#: M#+U#: O: BED:
DV: x: SCALE: FM:
+: COM:
TK/ft: SC-EL/Top: SC-TK/ft: Lnos:
TK/m : SC-EL/Bot: SC-TK/m : RK-S:

DESC:

STRATCOL-LITH : SYMBOL: RESISTANCE VALUE:
LITHOLOGY: modifier:
COLOR: FRESH/DRY: GSAcolor: NUM:
COLOR(COM):
SEQU : S/S :

End of first screen

M#: REF:

F-ENVIR:
S-ENVIR: COM2:

SECTION STRUCTURAL INFORMATION
fct:
DIP: DIPrad:
PACE: fctval:
SURF: U-TK:
SURF-T: SC-TK:

STRATIFACT/LOGGER FIELDS
M#-U#:
U-top: U-top-EL:
U-bot: U-bot-EL:

NCRDS DATA FIELDS UQ:
priLITH: modLITH:
COLOR:
GRsize: GRshape:
MINERALS:
BEDDING: CONTACT:
FOSSILS:
FRACTURES: JOINTS:
CLEATS:
WILD1: WILD2:
COMMENT:

APPENDIX II

Document 8

*UNIT Database Form with Data
(Q&A® File Module)

```
Mno: M2253         REF: Hartman (1990u, v. 18)                  DATE: 1990/09/09
SC: MS             PAG: p. 148-150 (see v. III, p. 33-41, 48-61) LOG: 1990/09/12
ST: ND REG: WB-LMR PJC: Slope       mod: 1992/01/15  15:25 p.m. ent: JHH
-----------------------------------------------------------------------------
   U#: 043        M#+U#: M2253-043       O: m          BED: Yule coal-JHH
   DV:            x:             SCALE:                 FM: Slope
    +:            COM:
TK/ft:     3.937  SC-EL/Top: 2857.724  SC-TK/ft:  211.939  Lnos:
TK/m :     1.200  SC-EL/Bot: 2645.785  SC-TK/m :   64.600  RK-S:
-----------------------------------------------------------------------------
DESC: "lignite, black (N 1)"



-----------------------------------------------------------------------------
STRATCOL-LITH : lig            SYMBOL: LIG  RESISTANCE VALUE:  1
LITHOLOGY: lignite    modifier:
COLOR: black                    FRESH/DRY: F  GSAcolor: N 1       NUM: 11.50
COLOR(COM):
SEQU :             S/S  :
-----------------------------------------------------------------------------
M#: M2253          REF: Hartman (1990u, v. 18)

F-ENVIR:
S-ENVIR: coal swamp              COM2:

+----------------------------------+ +---------------------------------------+
|  SECTION STRUCTURAL INFORMATION  | |       NCRDS DATA FIELDS  UQ:          |
|   fct:                           | |  priLITH:            modLITH:         |
|   DIP:          DIPrad:          | |    COLOR:                             |
|  PACE:          fctval:          | |   GRsize:            GRshape:         |
|  SURF:            U-TK:          | | MINERALS:                             |
|SURF-T:           SC-TK:          | |  BEDDING:            CONTACT:         |
+----------------------------------+ |  FOSSILS:                             |
+----------------------------------+ |FRACTURES:             JOINTS:         |
| STRATIFACT/LOGGER FIELDS         | |   CLEATS:                             |
|M#-U#:                            | |    WILD1:              WILD2:         |
|U-top:           U-top-EL:        | |  COMMENT:                             |
|U-bot:           U-bot-EL:        | +---------------------------------------+
+----------------------------------+
```

APPENDIX II
Document 9
*UNIT Database Report (Q&A® Report Module)

Units Summed from Base with Elevations & Descriptions: M2253
(Hartman, 1990u, M2187-DH surface section)

MMRRI Sect. No.	Sect. Unit No.	Unit THICK ft	Feet Above Base of Section	Elevation ABV Base of Section	Bed Name	Formation	Fossil LOC #	
M2253	057	0.000	211.939	2857.763				Top of section.
	056	8.202	211.939	2857.724		Slope		"covered interval of siltstones and claystones to highest ground on plateau (west of well)" See M2253a for mud pit section through this interval.
	055	2.953	203.737	2849.522		Slope		"deeply weathered silty claystone, bentonitic; ironstone concretion on surface; dusky yellowish brown (10 YR 2/2)"
	054	10.663	200.784	2846.569	ESB Channel 12-JHH	Slope		"siltstone to very fine-grained sandstone; includes concretion horizon near top (better lithified lens); small ripples; root traces; pale yellowish orange (10 YR 8/2)"
	053	4.921	190.121	2835.906		Slope		"silty claystone, somewhat fissile; plant fragments; discontinous concretionary zone at top; dark yellowish brown (10 YR 4/2)"
	052	0.984	185.200	2830.985	unnamed lignite-JHH	Slope		"lignite, black (N 1)"
	051	0.656	184.216	2830.001		Slope	plants	"Carbonaceous shale; extenstively rooted; abundant plant fragments; dusky yellowish brown (10 YR 2/2)"
	050	9.186	183.560	2829.345		Slope		"light olive gray (5 Y 6/1) clayey siltstone in lower part coarsening upwards in middle with 3 or 4 thin (5 cm) beds of fine-grained sandstone, fining upwards in upper part to silty claystone; dark yellowish brown (10 YR 4/2); 20 cm thick concretionary bed 1 m above base " Uppermost horizon of bentonitic slope wash.
	049	2.625	174.374	2820.159		Slope		"organic rich silty claystone; bentonitic, crumbly; upper and lower contacts are gradational; slickensides; root traces; pale yellowish brown (10 YR 6/2) to dark yellowish brown (10 YR 4/2)" Photos lateral to bentonitic slope wash, including units 45 to near top.
	048	0.984	171.749	2817.534		Slope		"carbonaceous shale, slightly lignitic; brownish black to grayish black (5 YR 2/1 to N 2); lignite clasts are black (N 1)" Slope is covered by popcorn clay.
	047	2.297	170.765	2816.550		Slope		"silty claystone to claystone (fining upwards), silty at base; extensively rooted; slickensides; organic laminae at bottom; large horizon roots (rhizomes);

APPENDIX II
Document 10
NCRDS *UNIT Database Form with Data (Q&A® Write Module)

USGS NATIONAL COAL RESOURCES DATA SYSTEM - STRATIGRAPHIC DATA FORM - USTRAT
printed: 1992/01/15

POINT ID: M2688 **GEOLOGIST**: Schmit, C.R. **DATE**: 1977 **CONFID**:

QUAD+SER: Scranton NE 7.5 **SOURCE**: NCRDS summary form **PRIN MERIDIAN**: 07

STATE: ND **SURF-ELEV**: 2809.000 **EST-RANK**: lignite **QUARTERS**: NW NW SE

COUNTY: Bowman **ELVPREC**: **STR-DIP**: **SECTION**: 21

PROVINCE: N Great Plains **THICKNESS**: 236.000 **LATITUDE**: 46 14 **TOWNSHIP**: 132 N

REGION: Fort Union **DESCR-LOG**: **LONGITUDE**: 103 4 **RANGE**: 99 W

FIELD: **WEATHERING**: **LLPREC**:

COMMENT1: B077-105

HYDRO CD: **FILEPOINTER**: **OWNERSHIP**:

UNIT DATA

Explanation:

U# = Unit
UQ = Unit qualifier
TK/Ft = Thickness (ft)
priLITH = Primary lithology
modLITH = Lithology modifier
grSIZE = Grain size
grSHAPE = Grain shape
A = Contact
B = Fossils
C = Fractures
D = Joints
E = Cleats
WC1 = Wild card 1
WC2 = Wild card 2

U#	UQ	TK/FT	Formation	Name	priLITH	modLITH	Color	grSIZE	grSHAPE	Minerals	Bedding	A	B	C	D	E	WC1	WC2	Comment2
001		20.500			NR														
002		0.500			NR	CARB													
003		1.500			NR														
004		0.500			NR	CARB													
005		13.500			NR														
006		1.500			NR	CARB													
007		39.000			NR														
008		2.000			NR	CARB													
009		4.000			NR														
010		3.000			NR	CARB													
011		1.000			NR														
012		2.500			NR	CARB													
013		1.000			NR														
014		2.000			NR	CARB													
015		10.000			NR														
016		1.000			NR	CARB													
017		2.500			NR														
018		3.500			LIG														
019		35.500			NR														
020		2.000			NR	CARB													
021		24.500			NR														
022		8.500			LIG														
023		7.000			NR														
024		0.500			NR	CARB													
025		1.000			NR														
026		4.000			LIG														
027		6.500			NR														
028		2.000			NR	CARB													
029		7.500			NR														
030		2.500			NR	CARB													
031		25.000			NR														

APPENDIX II

Document 11

*UNIT Database Fields Organized by Topic
(Q&A® File Module)

See Document 12 for full Field Names and Explanations

REFERENCE RELATED INFORMATION

Numbering Systems Fields
Mno:
U#:
Reference (Citation) Fields
REF:
PAG:
SC:

Record Management Fields
DATE:
LOG:
PJC:
mod:
ent:
M#+U#:
O:

Screen Management Fields
[Mno]: [REF]: (for screen 2)

LOCATION FIELDS

General Location
ST:
REG:

STRATIGRAPHY

Unit Thickness Calculations
DV: x: SCALE:
+:
TK/ft: TK/m:
SC-TK/ft: SC-TK/m:
SC-EL/Top: SC-EL/Bot:

Unit (Bed) Nomenclature and Basic Data

BED:	Bed name (plus who assigned name)
FM:	Formation (plus who assigned name)
COM:	Comment
DESC:	Unit description

*UNITS Database FIELDS ORGANIZED BY TOPIC, continued

STRATIGRAPHY, continued

Unit (Bed) Data Categorization

LITHOLOGY: modifer:
COLOR: FRESH/DRY: GSAcolor: NUM: COLOR(COM):
SEQU: S/S:
F-ENVIR: S-ENVIR: COM2:

STRATCOL/STRATA Fields

STRATCOL-LITH: SYMPOL: RESISTANCE VALUE:

Section Structural Information Fields

fct: fctval:
DIP: DIPrad:
PACE:
SURF: SURF-T:
U-TK: SC-TK:

SAMPLE COLLECTION FIELDS

Fossil and Rock Collections

Lnos: RK-S:

NCRDS-SPECIFIC FIELDS

UQ: Unit Qualifier
priLITH: modLITH: primary lithology and lithic modifier
COLOR:
GRsize: GRshape: grain size and shape
MINERALS: BEDDING: CONTACT:
FOSSILS:
FRACTURES: JOINTS: CLEATS:
WILD1: WILD2:
COMMENT:

STRATIFACT/LOGGER FIELDS

M#-U#: M-number plus unit number
U-top: U-top-EL:
U-bot: U-bot-EL: