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Energy and Environmental Research Emphasizing Low-Rank Coal -- Task 7.2 Resource Data Evaluation

Topical Report
July 1994 - May 1995

Joseph H. Hartman

June 1995

Work Performed Under Contract No.: DE-FC21-93MC30097

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
University of North Dakota
Grand Forks, North Dakota

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Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
University of North Dakota
Energy and Environmental Research Center
P.O. Box 9018
Grand Forks, North Dakota 58202-9018

June 1995

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7.2 RESOURCE DATA EVALUATION

1.0 INTRODUCTION

The Resource Data Evaluation subtask of the U.S. Department of Energy (DOE) base program represents an Energy & Environmental Research Center (EERC) initiative to promote the integration of geographic information system (GIS) technologies with other ongoing and planned EERC research in the areas of resource utilization, remediation, land use planning, and regulatory and policy assessment. Significant demand for GIS-based information already exists for energy resource evaluation, interpretation of remote sensing data, environmental assessment at the state and local levels, and use in strategic planning. Through sound data-taking procedures and wise data management policies, a GIS approach can serve an integral function in permitting cross-disciplinary uses of information by many EERC researchers. The use of GIS methodologies will expand the potential for interaction between the researcher, governmental agencies, and private companies.

The objective of this task was to determine the appropriate platform and approach upon which to develop GIS applications for optimizing resource evaluation and integrating this information with related areas of interest.

To review, GIS specifically refers to computer-based methodologies that manipulate, analyze, and portray information derived or summarized from specific geographically referred observations. The geographic reference can be any number of earth-based coordinate systems (e.g., latitude and longitude, Universal Transverse Mercator [UTM], state plane coordinate) or generalized to any number of political (e.g., counties) or other types of boundaries (e.g., zip codes). Different types of information are effectively layered, each layer representing a vector-based map with associated discrete attribute information (Hartman, 1994). For example, the map portrayal of the interpreted occurrences of a particular coal bed throughout its extent might include political boundaries, selected cultural features, the geology of the region, and the specific surface and subsurface coal observations being investigated. The political aspect of the map could consist of several layers including federal, state, county, and township boundaries. Cities of a certain population range, roads of a certain type, and drainage systems of a certain size could be added to provide potential market and environmental considerations. Subsurface water interests could be applied if considered potentially significant. The geologic map could consist of layers representing selected geologic contacts and occurrence of relevant marker beds. The portrayal of the coal occurrences of a particular coal bed could be keyed to 1) surface versus subsurface observations, 2) coals greater than a certain thickness, 3) coals with selected analytical properties, or 4) estimates of coal reserves. As each data type is represented by a different database or file, data can be edited and integrated with existing databases.

2.0 ACCOMPLISHMENTS

Activities associated with Task 7.2, Resource Data Evaluation, were conducted primarily during the first half of the project year. These activities included tasks associated with the development and implementation of GIS databases and construction of digitized files for research pertaining to energy studies. As previously noted, database design was undertaken for two EERC projects: 1) coal occurrence in Bowman and adjacent counties in the Fort Union Coal Region of southwestern North Dakota and 2) energy resource utilization concerns for selected sites in Alaska.

Subsequently, the coal studies in southwestern North Dakota were expanded to include the adjacent Slope County. Also, additional projects were undertaken that employed GIS methodology to determine the timing of coal correlation within the Fort Union Coal Region of the Williston Basin.

These projects involved the development of GIS applications using Atlas GIS® 2.0 by Strategic Mapping, Inc., and Access® by Microsoft Corporation. The projects also employed location and coal-related databases designed in Q&A® 4.0 by Symantec Corporation. However, the advantages of GIS technology are more fully realized through fully relational database designs, where files can be maintained in various environments (such as those specifically associated with Atlas GIS® and those in Access®) and directly linked to provide seamless implementation of queries and table (report) construction. Because of limited funding to develop programming applications in Access®, databases were frequently maintained in Q&A® and exported as dBase® (Borland International, Inc.) files that can be read directly by Atlas GIS®.

2.1 Bowman and Slope County Studies

In the Bowman County area, the North Dakota project involved approximately 700 surface and subsurface geological observations related to coal bed stratigraphy (Figure 1). The digitized records in Atlas GIS® were shared through a dBase® file format with attributes maintained in Access®. Previously, the graphical depiction of coal-bearing stratigraphic geologic sections was accomplished via a multistep procedure involving Q&A®, a DOS editor, such as Norton Commander® by Symantec Corporation, and a modified public domain program known as STRATCOL/STRATA. With the use of a relational data manager, such as Access®, the procedure to produce a graphic representation of a geologic column can be greatly simplified for the general user. The revised procedure, however, does require a number of programming steps to facilitate this approach. The following discussion illustrates the type of database management and programming considerations followed to simplify the production of a selected type of graphical image.

Previous discussions on the management of coal-related geologic observations (Hartman, 1992) have reviewed Q&A® database file structure. Two databases were maintained for geologic observations, MNOS and UNIT files. In Access®, the functioning of these two files can be combined into one database. More importantly, the implementation of the UNIT file can be altered significantly by relating specific UNIT fields in a one-to-many relationship. This relationship is well documented in Figure 2 (Summary Subform), where a summary of the units in a particular measured section (M2253) can be depicted simultaneously.

Previously, in Q&A®, a separate report would have to have been written to tabulate this subform information. The entry of information to produce a graphic file is as before. A primary lithology is entered into the field "StratColLith," and fields "Symbol" and "Resistance Value" are automatically filled by reference to a lookup table. To produce a data file in Q&A® for graphic image construction, a report (from the Report Module) would have been written that would contain the appropriate columnar data to load into STRATCOL/STRATA. Table 1 represents a portion of a UNIT file (Units 50 to 56) for measured Section M2253 (see also Figure 4). The second column (e.g., 2.500) represents the metric thickness of the unit, while the third column gives the thickness in feet. The fourth column is the graphic symbol name (e.g., COV = covered interval), while the fifth

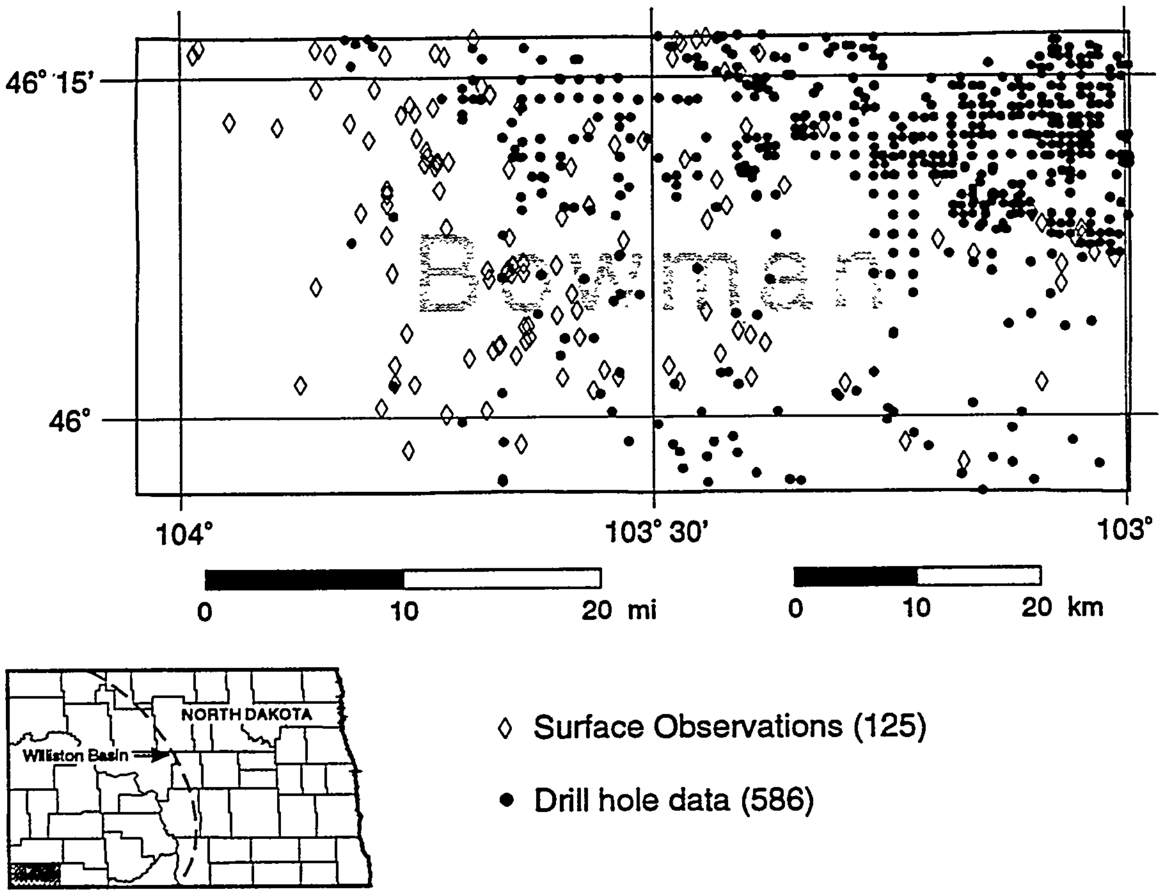
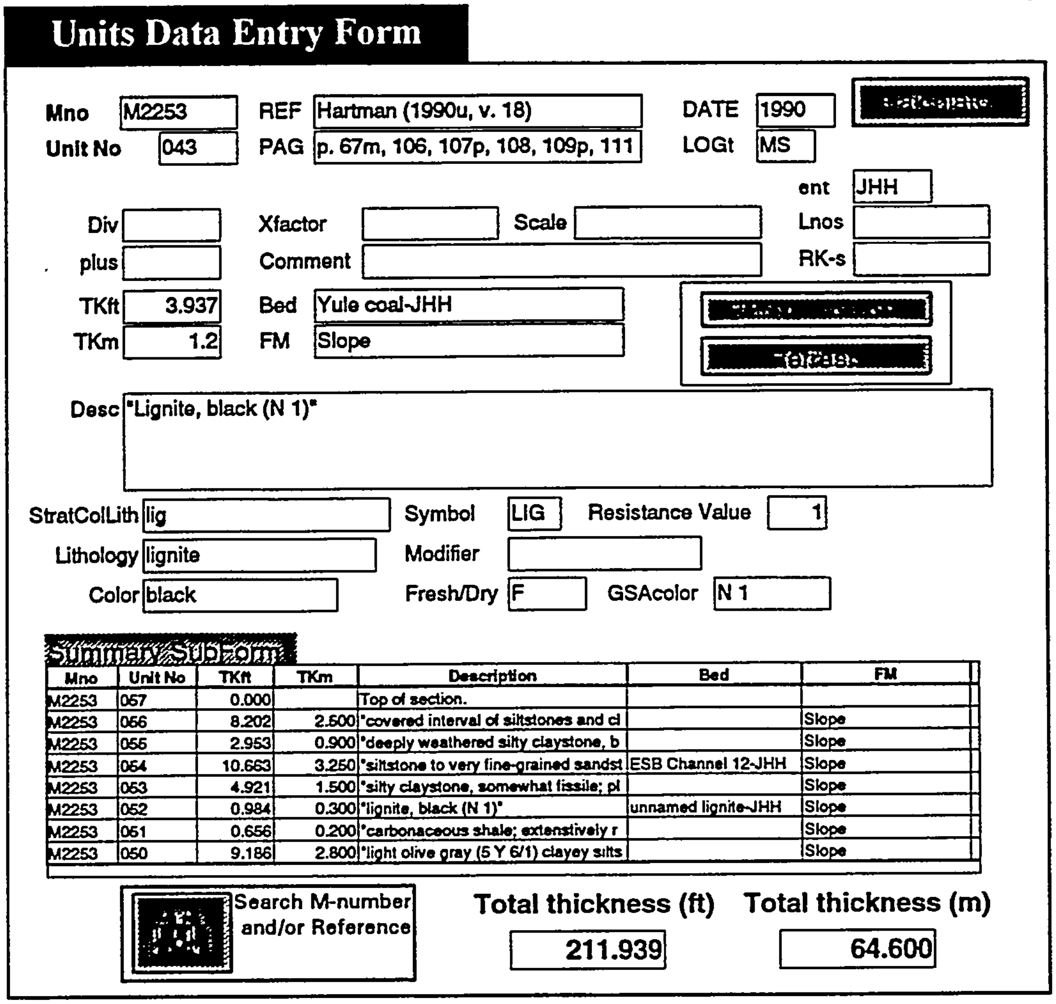


Figure 1. Distribution of geological observations (M-numbers) in Bowman County, North Dakota. Numerous subsurface and surface coal-related observations have been made in Bowman County. The density of data increases from west to east, away from the drainage of the Little Missouri River, where predominantly noncoal-bearing strata of uppermost Cretaceous and lowermost Paleocene age are exposed. The surface mines near Gascoyne are the largest coal-producing operations in southwestern North Dakota.

column is the resistance value for the weathering profile. Two descriptive fields are available to add comment to the unit. In the example in Table 1, fossil information is included in Column 6, while names of key beds are reported in Column 7. A precise spacing between columns (fixed format) is required for use by STRATCOL/STRATA. The same file must be generated by Access®, but can be accomplished directly and more simply for the uninitiated user through the use of an Access® custom toolbar and associated programming.


Units Data Entry Form

Mno M2253 | REF Hartman (1990u, v. 18) | DATE 1990
Unit No 043 | PAG p. 67m, 106, 107p, 108, 109p, 111 | LOGt MS
ent JHH
Div | Xfactor | Scale | Lnos
plus | Comment | RK-s
TKft 3.937 | Bed Yule coal-JHH
TKm 1.2 | FM Slope
Desc "Lignite, black (N 1)"
StratColLith lig | Symbol LIG | Resistance Value 1
Lithology lignite | Modifier
Color black | Fresh/Dry F | GSAcolor N 1

Summary SubForm

Mno	Unit No	TKft	TKm	Description	Bed	FM
M2253	057	0.000		Top of section.		
M2253	056	8.202	2.500	"covered interval of siltstones and cl		Slope
M2253	055	2.953	0.900	"deeply weathered silty claystone, b		Slope
M2253	054	10.663	3.250	"siltstone to very fine-grained sandst	ESB Channel 12-JHH	Slope
M2253	053	4.921	1.500	"silty claystone, somewhat fissile; pl		Slope
M2253	052	0.984	0.300	"lignite, black (N 1)"	unnamed lignite-JHH	Slope
M2253	051	0.656	0.200	"carbonaceous shale; extensively r		Slope
M2253	050	9.186	2.800	"light olive gray (5 Y 6/1) clayey silts		Slope

Search M-number and/or Reference

Total thickness (ft) 211.939 | Total thickness (m) 64.600

Figure 2. Units Data Entry Form. The UNIT table, containing the field entries describing the observations for a particular geologic unit, are entered in this form design. The summary subform displays a selected number of unit descriptions and related information. Important abbreviations include TKft (thickness feet) and TKm (thickness meters) (see text for additional discussion).

TABLE 1

Geologic Section M2253

M2253

056	2.500	8.202	COV	3		
055	0.900	2.953	BEN	2		
054	3.250	10.663	ETA	3		ESB Channel 12-JHH
053	1.500	4.921	SH2	3		
052	0.300	0.984	LIG	1		unnamed lignite-JHH
051	0.200	0.656	CM4	1	plants	
050	2.800	9.186	SH2	3		

In Access®, the buttons on the custom toolbar (as shown in Figure 3) activate associated macros, which in turn, run the proper modules. The toolbar can be set to be present on the screen at all times in UNIT applications. By clicking on the "Run StratOut(DH) Macro" button, the following module is run:

```
Function StratOut_DH ()

On Error GoTo ExitThisFunction DoCmd OutputTo A_Report, "StratCol Report
(DH)", A_Formattxt

Exit Function

ExitThisFunction:
  Exit Function

End Function
```

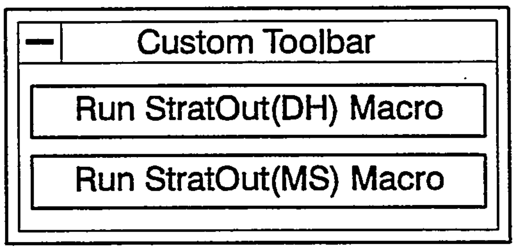


Figure 3. Access® custom toolbar for the construction of geologic columns.

If no error is detected, such as not finding the M-number requested (see below) or the process is canceled, a report (A_Report) is written in a form (StratCol Report), which is exported in a text format (A_Formattxt). Depending on the type of geologic column to be printed in STRATCOL/STRATA, either drill hole (DH, representing measurements from the top down) or measure section (MS, representing measurements from the bottom up), the user clicks the appropriate toolbar button. The following code was written as the control source for an "unbound text box" in the "StratCol Report (DH)" report for fixing the format in the data file for use in STRATCOL/STRATA.

```
=Format([Unit_no],"@@@@@") & "   " & Format([TKm],"0000.000")
& "   " & Format([TKft],"0000.000") & "   " & [Symbol] & Space(4) &
[Resistance Value] & Space(16) & [Bed]
```

After the button is clicked, the programming is activated and the user is prompted for the name (and path, if necessary) of the data file to be created. Next, the user is prompted to fill in a value for the parameter requested by the underlying query. In this case, the parameter value is the M-number (Figure 2), and the data file is then automatically created. The extra steps formerly required in Q&A® to produce a specific report and eliminate unwanted leading headers and trailing blank lines at

STRAT3 OUTPUT: SECTION M2253

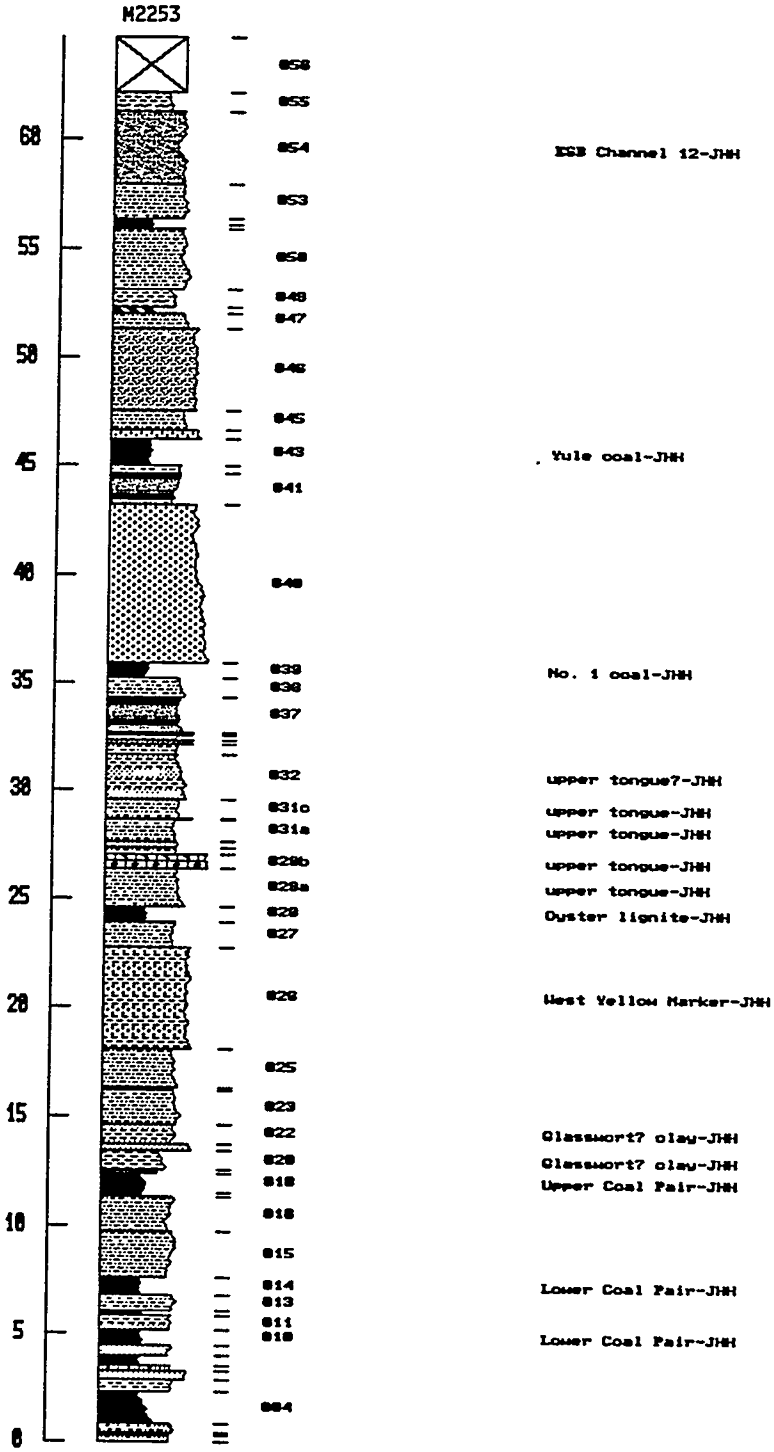


Figure 4. Geologic Section M2253. This geologic column is produced from the program STRATCOL/STRATA and is a measured section of 64.6 m in length. The symbols making up the units of the column describe the lithology of the rock. A black fill represents a lignite, dot patterns represent sandstone or sandy textures, and dashes and lines represent claystones, shales, or clayey textures. Named or significant beds are labeled to the right.

the end of the data file are unnecessary. This method for creating STRATCOL/STRATA data files also has the advantage of being available to create a data file for any M-number at anytime while in the UNIT database. The resulting output from STRATCOL/STRATA is shown in Figure 4.

The coordination of geologic sections and their geographic location is depicted in Figure 5. This figure illustrates the correlation of coal beds across T. 135 N., R. 105 W., on the west side of the Little Missouri River. The relative geographic location of the surface and subsurface geologic sections is shown in the inset map. The tongues of the Cannonball Formation intercalate with progradational sequences of nonmarine strata. All of these occurrences are digitized for use and interpretation with GIS technology. This type of information can be easily maintained in a program of the sophistication represented by Atlas GIS®. Utilizing the information derived from the analysis of coal bed correlations in Slope and Bowman Counties, errors were found in the use of coal bed names and stratigraphic thicknesses between the study area. An example of these discrepancies is shown in Figure 6. This diagram shows the relative stratigraphic placement of the significant lignite and marker beds in Bowman County, North Dakota, along with the lower portion of the section represented in Slope County. The base of the Harmon lignite bed serves as a datum to compare the two columns. Although the coal strata of both counties were investigated by the same researches at approximately the same time, their inability to directly correlate surface exposures produced stratigraphic nomenclatural problems that persist to this day. Rigorous use of GIS technology, along with the use of subsurface geophysical logs, would largely resolve existing correlation problems.

As part of coal correlation studies, a general geologic base map was constructed for the Williston Basin, which represents a significant portion of the Fort Union Coal Region. The construction of this map severely tested the limitations of Atlas GIS®. As an example, Figure 7 depicts selected geologic units that are represented by a number of polygons instead of one per unit (i.e., the Hell Creek Formation is shown by compositing a number of polygons instead of one). This limitation results in complications for depiction and export, but more importantly, modification and export to other graphic programs. Thus, particularly for geological applications, Atlas GIS® poses important restrictions to full functionality.

Column B shows a current reinterpretation of the stratigraphic placement and nomenclature of these beds. Column B is a composite section derived mainly from observations in Slope County (M2187, M321, M341; see Figure 5), where exposures are more continuous, especially between the Cannonball and T Cross lignite (after Moore, 1976) beds. The great difference in thickness between these lignites in the two columns is difficult to understand, but may be due to the relative miscorrelation of the Cannonball and T Cross lignite beds from their respective type areas to Slope County.

Figure 7 is a good example of the value of GIS to data presentation and manipulation. As mentioned, Figure 7 represents a general geographic and geologic base map for an important coal-bearing area. The depiction of any of the information portrayed on this map can be turned on or off or filtered to form a base map for any number of other applications. The following is a brief discussion of the layers represented in the diagram. To begin with, this map can be viewed as representing international, state, and county boundaries. These features can be treated either as one or three independent layers. The river systems represent another layer independent of their role as

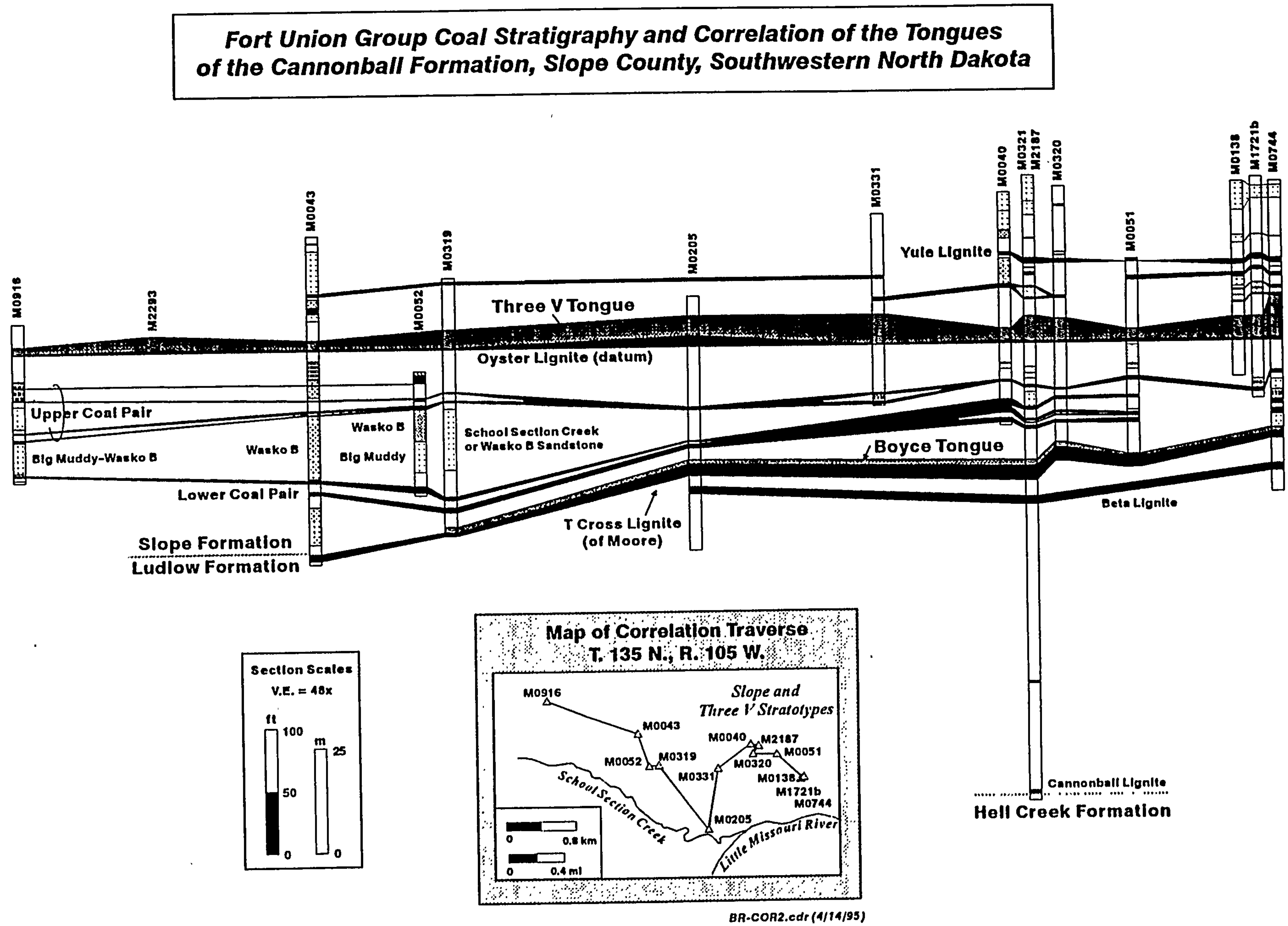


Figure 5. Fort Union Group coal stratigraphy and correlation of the tongues of the Cannonball Formation, Slope County, southwestern North Dakota.

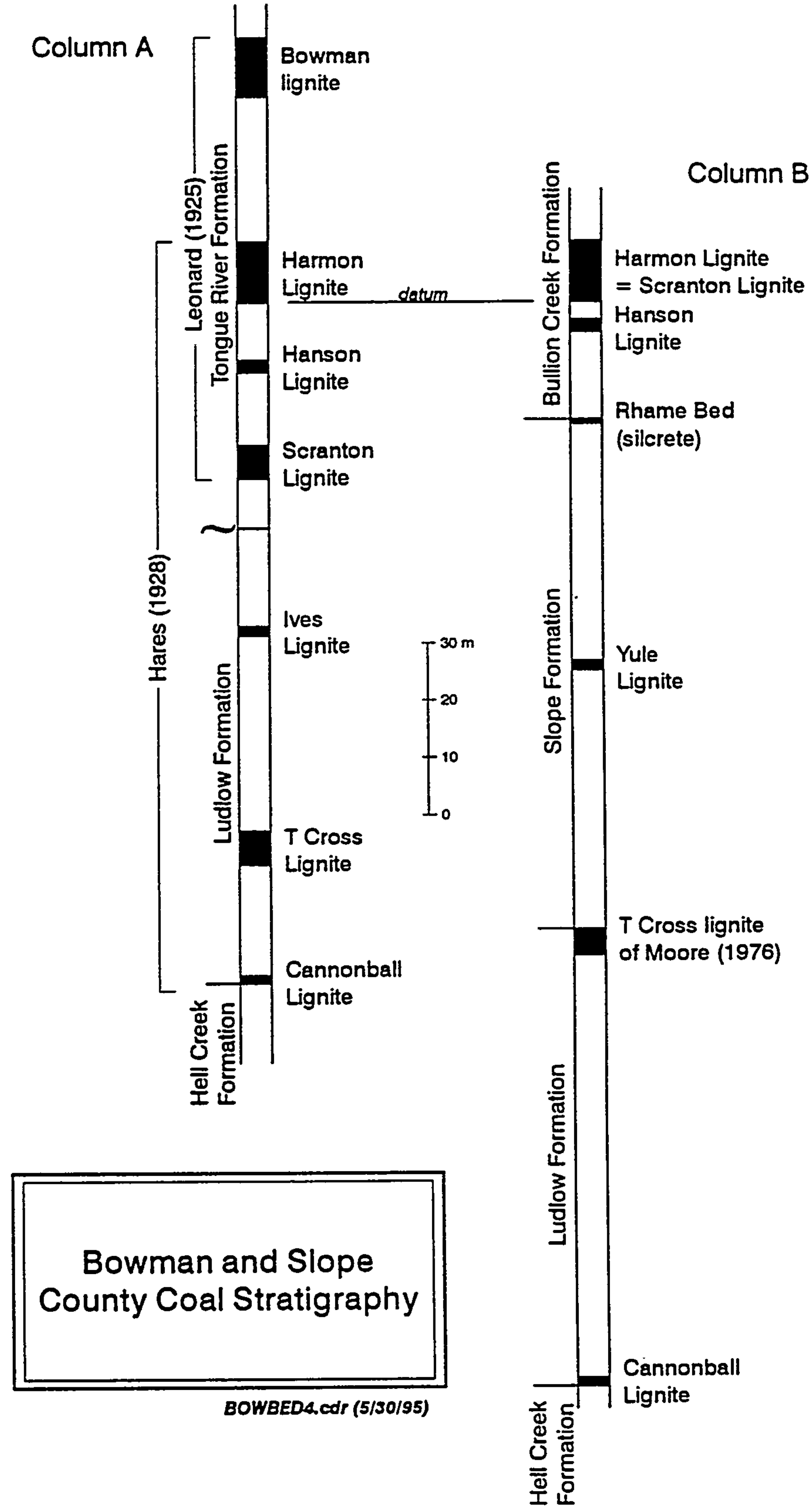


Figure 6. Bowman County coal stratigraphy. Column A represents the placement of the lignite beds as interpreted by Leonard and others (1925) and Hares (1928). As defined by Hares (1928), the Hell Creek and Ludlow were originally included as members of the Lance Formation, while the Tongue River was a member of the Fort Union Formation. The lignites of the Ludlow Formation are part of a lignite sequence that Leonard and others (1925) referred to as the "Yule Coal Group," while the lignites of the Tongue River Formation were assigned to the "Great Bend Coal Group."

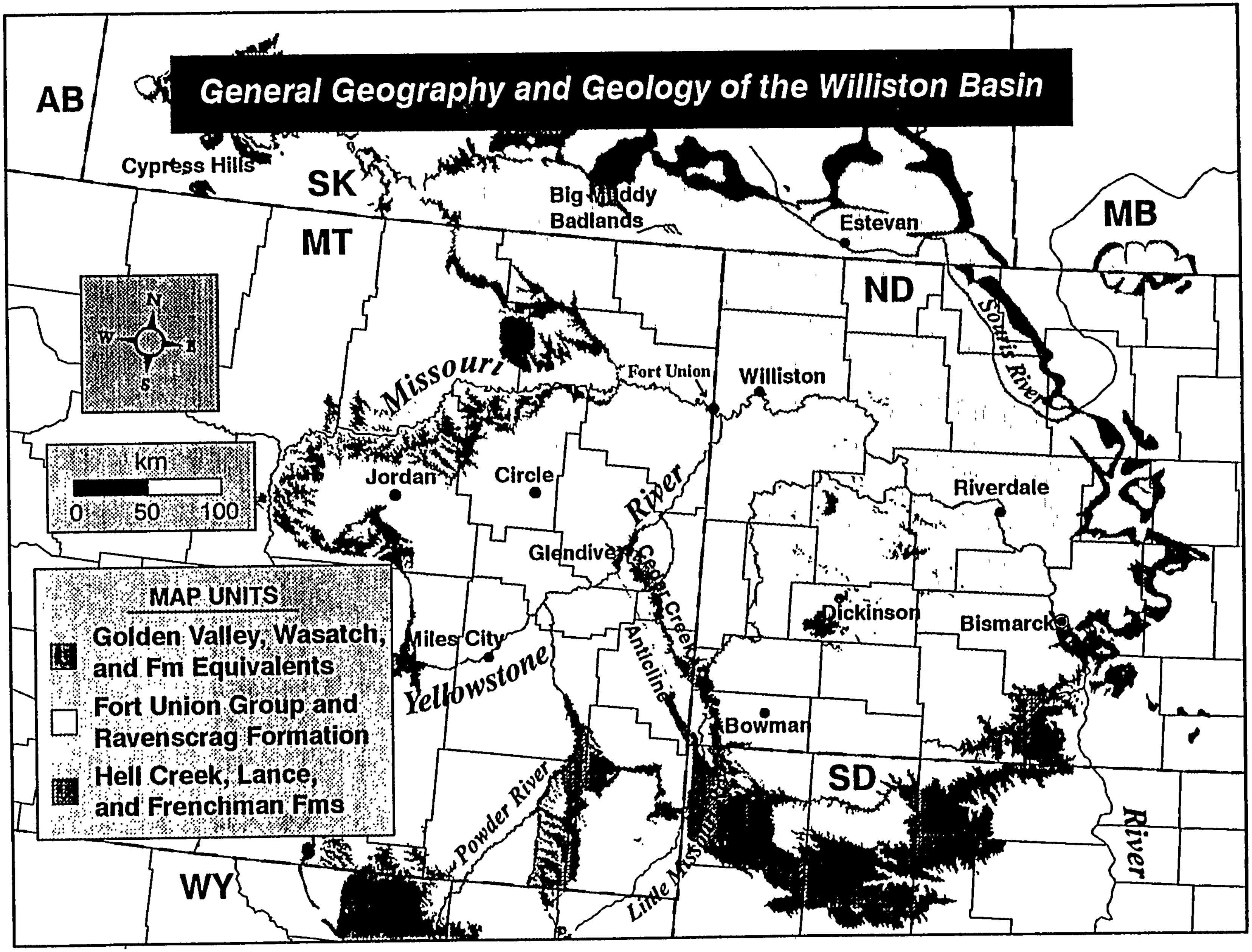


Figure 7. General geography and geology of the Williston Basin.

county boundaries. Feature labels, map explanations, and bar scales represent additional layers that can be modified as needed. The remaining layers represent the geologic mapping. Figure 7 was constructed from a wide variety of map sources, including both published and unpublished data from the North Dakota Geological Survey, South Dakota Geological Survey (SDGS), Montana Bureau of Mines and Geology (MTBMG), and Canadian geological entities. The difference in expressed detailed is, to some extent, a function of the map scale from which the geology was digitized. A more important reason, however, is the difference between the detail available from the interpretation of surface and bedrock geology. Thus in the northeastern portion of the Williston Basin in North Dakota, the detail in the unit boundary pattern is obscured by glacial debris. Exposures in badlands terrain permit far greater mapping precision. Throughout most of Montana and South Dakota, the MTBMG and SDGS kindly provided unpublished maps at scales of 1:100,000 to 1:250,000. In both cases, interpreting the geology for use in GIS applications resulted in uncovering significant lithostratigraphic errors, which were reported to the respective agencies. All other areas were digitized from published maps ranging in scale from 1:250,000 to 1:500,000. Although there are significant advantages to combining all geological polygons of the same formation, there is value in maintaining the integrity of geologic information derived from different sources. Thus, although the Hell Creek, Lance, and Frenchman Formations are represented by a single gray shade, they are maintained as separate layers in Atlas GIS®. This procedure permits ease of future unit modifications, as well as circumventing inherent Atlas GIS® limitations.

As a simple application, the geological observations illustrated as Figure 1 earlier in this report, have now been added to the geologic base map illustrated in Figure 7, and the result is shown in Figure 8. The following prefacing comments need to be made. This map is an unmodified map derived directly from Atlas GIS®. All other illustrations were produced by exporting each layer in Atlas GIS® to a layer in the drawing program CorelDRAW© (Version 4 by Corel Corporation). The advantage of this procedure is to produce a somewhat more elegantly drawn and labeled map than was recently available through the DOS version of Atlas GIS®. The latest Windows® (Microsoft Corporation) version of Atlas GIS® does permit greater flexibility for the attractive display of information. In addition, Figure 8 represents the same geologic data as represented in Figure 7 for the county and area containing the town of Bowman. Even at this significant change in map scale, the accuracy of the depiction is well within usable standards for analytic use.

The majority of the observations depicted in Figure 8 are located in the northeastern portion of Bowman County. Most of these represent subsurface holes from which cuttings were taken and geophysical logs made. The feature on the west side of the map is the southern portion of the Cedar Creek Anticline. Strata dip gently away from the anticline roughly at an orthogonal angle. The number of drill records increases in this direction because of the presence of coal-bearing strata higher in the Fort Union Group, representing the Harmon lignite and related beds in the lower portion of the Bullion Creek Formation.

2.2 The Alaskan Project

The Alaskan project incorporated data into Access® from a number of sources, as well as digitizing a number of natural resource features (e.g., coal and gas basins) and political boundaries (Figure 9). Location data were derived in part from U.S. Geological Survey Geographic Names Information System (GNIS) USGeoData. Using magnetic tape media, 25,000 Alaskan place names, locations, and map and civil divisions were downloaded into a Q&A® database and decoded for general use. Relevant project place names and their position, fixed by latitude and longitude, were transferred to Atlas GIS® for graphical output. Attribute files maintained in Access® included given

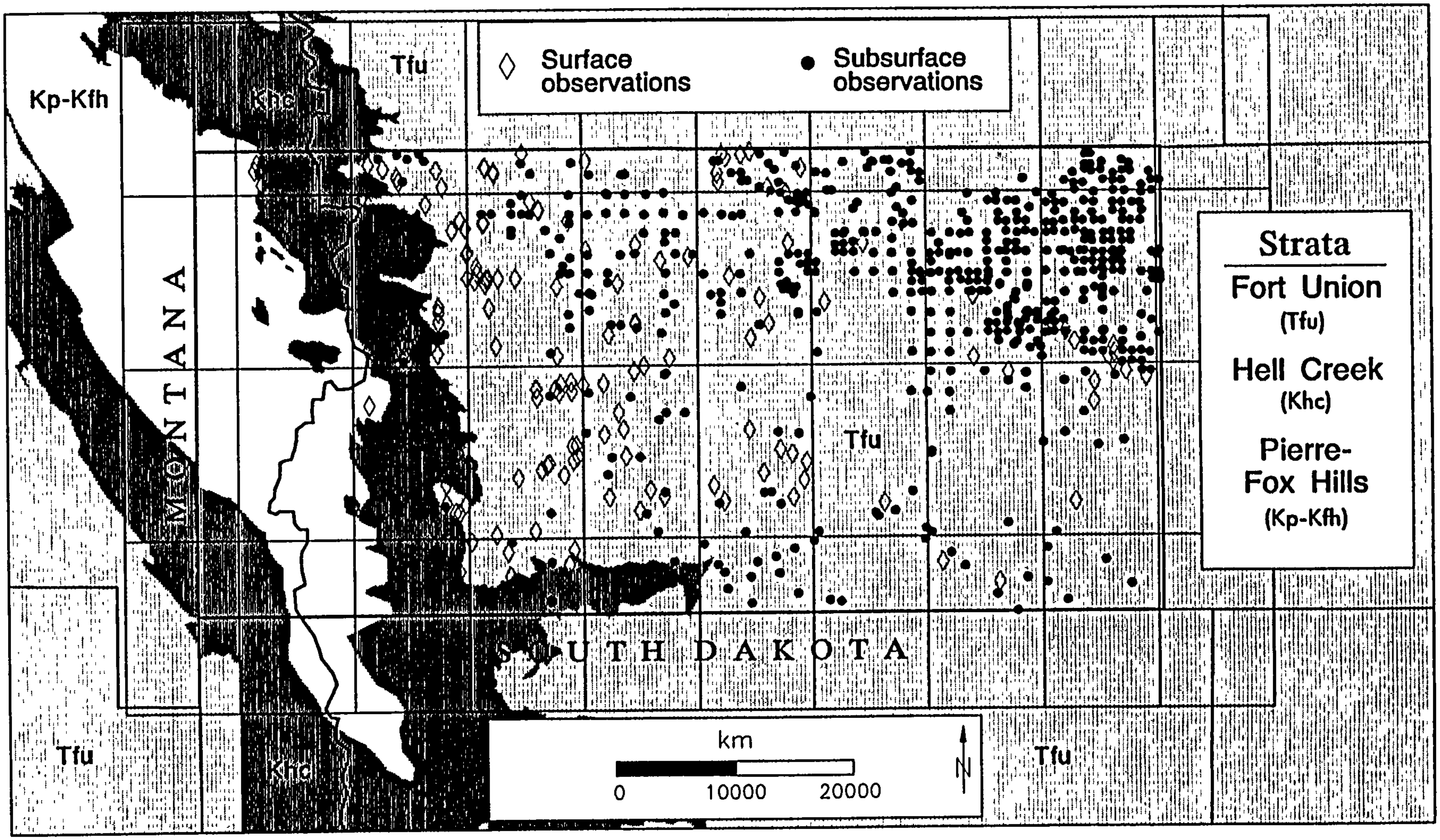


Figure 8. Distribution of Bowman County geological observations (M-numbers) on a general geologic base map (see also Figure 1). This figure illustrates the location of surface and subsurface geologic observations on a generalized geologic map of Bowman County. The quadrangle coverage is superimposed on this map for general reference. All of the records were plotted and subsequently digitized from 1:24,000-scale U.S. Geological Survey topographic quadrangles. The geological map depicts the contact of the largely non-coal-bearing Hell Creek Formation with the significantly coal-bearing Paleocene Fort Union Group. The geologic contact is derived from Clayton (1980).

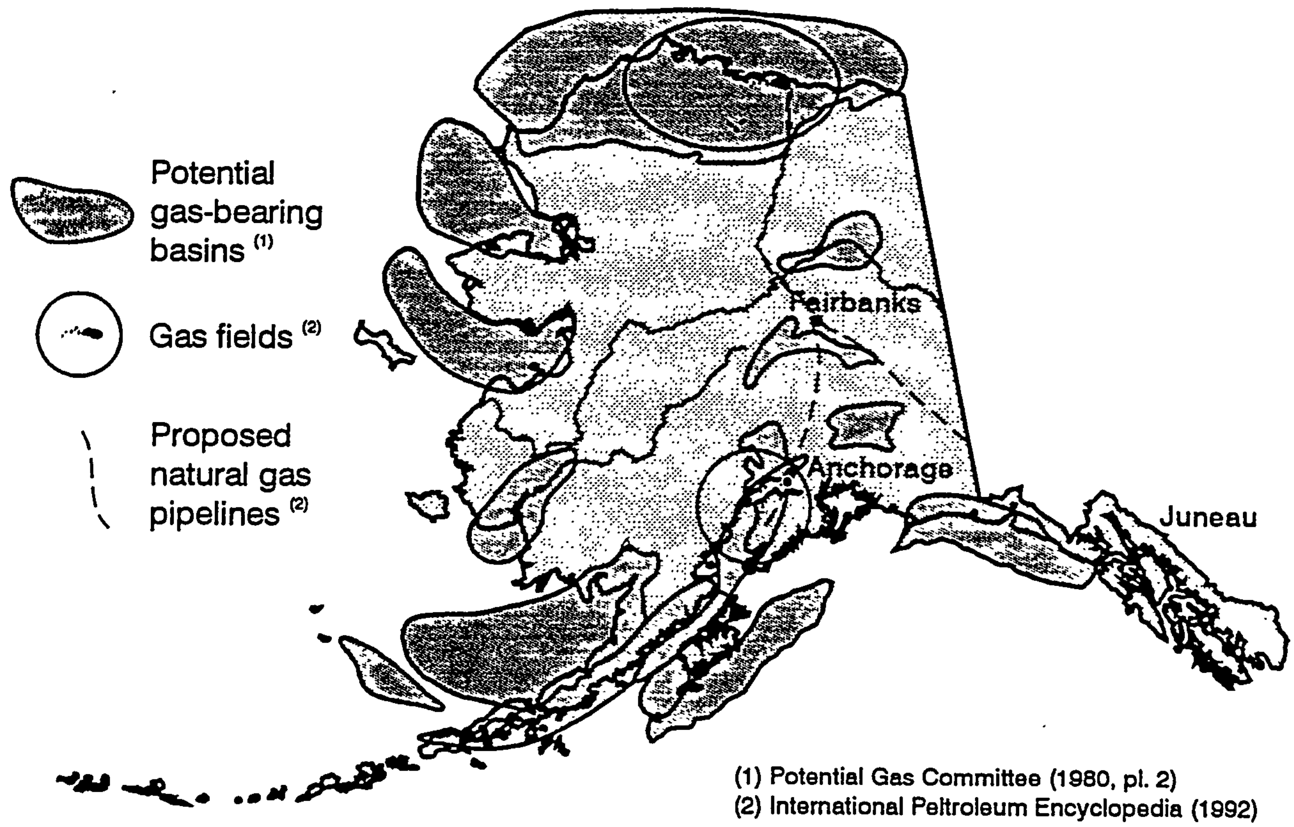


Figure 9. Natural gas resources of Alaska. A number of large potential gas-bearing basins are present in Alaska. Producing gas fields are shown as small dots bounded by an ellipse in the area of the North Slope and southwest of Anchorage.

information on site power generation (e.g., electrical, diesel) and relative costs. Cultural-census information was derived from TIGER files from the U.S. Census. GIS file manipulation resulted in graphical output of site locations (with energy consumption), major coal basins and fields, and indigenous ethnic and general population structure on a digitized map of Alaska. Figure 9 represents a map of potential gas fields in Alaska, along with proposed natural gas pipelines. All of these activities and products were implemented to support the decision-making process in considering additional, more site-specific studies and to draw general and detailed conclusions on coal availability.

3.0 SUMMARY

The use of GIS technology through the course of this study indicates that there is no simple answer to the objective about the appropriate platform and approach upon which to develop GIS applications. The value of GIS to spatial information management and display is considerable. In both short- and long-term research endeavors, there are no good technical reasons for avoiding the development of GIS applications. The major difficulty in implementing a GIS approach at an agency or institution is organizational and financial. GIS methods require a commitment or dedication of a certain amount of human and funding resources. To an important extent, unlike word processing, spread sheets, or simple graphical tools, GIS programming requires the development of a system and concomitant expertise to effectively maintain GIS in the workplace. There can be differing levels of commitment. The results illustrated and described in this report probably represent the least initial investment. The system is personal computer (PC)-based and organized and maintained by two people. Atlas GIS® programming is relatively inexpensive and can be run effectively on 486 machines without difficulty. Additional hardware expenses include a data backup system and digitizing tablet. An initial expenditure of approximately $4000 to $5000 would cover the cost of a system based on a PC, excluding output devices. As noted, the functionality of this system is dependent on the objectives of the user. Atlas GIS® is a highly effectively program to digitize and manipulate data sets for the display and simple analysis of geographically referenced information. There are limitations in terms of the size of digitized files that can be maintained in Atlas GIS® without resorting to less than optimal techniques. Some of these types of limitations may be overcome as the functionality of these types of programs improves, with the ever-increasing power of PCs.

The alternative approach is to utilize a GIS program employing a UNIX operating system. These systems necessarily have higher initial costs, both in hardware and software, quadrupling or more the cost of the initial system. In addition, a UNIX-based system, such as ARC/INFO™ by ESRI, Inc., will require additional training, both in the use of the operating system and the GIS program. If not otherwise available, data management procedures will have to be established, either using the database structure directly utilized by the GIS program or some other database system that can be directly linked to the GIS software. In either case, database expertise will need to be acquired for effective use of the GIS programming. These topics represent investments in personnel which can prohibit entry of organizations with largely dedicated budgets entering GIS from a UNIX-based approach. A partial alternative is the use of GIS software that is part of the public domain. If a commitment has already been made to a UNIX operating system and personnel can be dedicated to the development of public domain applications, some cost reductions are possible. A number of government agencies have taken this approach with some effectiveness.

The advantages to using a UNIX-based GIS system are several. Besides eliminating restrictions placed on a PC platform, analysis capabilities are improved. Gridding and contouring routines permit a wide variety of ways to manipulate and display derived images. Importantly, many data sets are specifically written for UNIX-based systems and, thus, can be used directly without the conversions necessary for use on a PC operating platform. In addition, although representing added costs, memory and processing speed permit large data set manipulation. The use of large graphically based databases posed several problems for the PC-based system employed in the projects mentioned above.

In summary, in these times of tightening budgets but increased demand for analytical capabilities of staff and the push for faster turnaround times, GIS technology provides the opportunity to both reduce costs and increase productivity. The difficulty in establishing a GIS operating system at an organization will be in the reallocation of resources and dedication of personnel to facilitate the development of new techniques for both analysis and publication.

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