# GEOLOGICAL STUDIES OF COAL IN ALBERTA: A STATUS REPORT

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## FOREWORD

This publication is a position paper written during 1986 at the request of the Coal Geology Management Committee which oversees the coal geology program at the Alberta Research Council. The publication aims to provide a framework for management decisions regarding coal geology research in Alberta.

The current coal geology program at the Alberta Research Council is funded on a 50/50 basis by Alberta Energy and the Alberta Research Council. Possible research directions for this program are discussed in the position paper. As a result of recommendations in this paper and through further discussions it was decided by the Management Committee that, in light of the limited financial resources available the program will be predominantly involved with coal quality studies for the next two years.

To provide background data for this position paper, questionnaires were sent to 58 institutions and individuals. We wish to thank the thirty respondants. Their information and suggestions provided important components to the study. We also thank the Coal Management Committee for its constructive comments on a first draft of the publication. Dr. Jan Boon also provided useful editorial comments.

## ACKNOWLEDGEMENTS

We would like to thank Peter McCabe for giving advice and for sharing his expertise in coal geology. Further thanks are due to Maureen FitzGerald for typing, reformatting and editing, and to Andy Bosman for editing.

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## EXECUTIVE SUMMARY


In this paper, a summary and critical account of what is known about the geology of coal in Alberta is given. The paper can provide a basis for management decisions regarding the direction of coal geology studies in Alberta. Information is presented on what 15 geological surveys do in coal geology in other provinces of Canada and areas of the United States of America. Knowledge and opinions of 12 coal mining companies and consultant firms working in Alberta are also presented. From these sources of information, a set of recommendations for future work in coal geology by the Alberta Research Council is presented.

These recommendations are in line with the Alberta Coal Research Strategic Plan (ENR, 1983), which wants to enhance the competitiveness of Alberta coals by improving the quality and developing new uses of the coals. They are also in line with the position of the coal industry (Coal Association of Canada, 1985) which will support research on coal that develops increased coal utilization.

The subject of coal geology is divided into seven research fields, i.e. coal quality, stratigraphy, structural geology, sedimentology, coal databases, geophysics and resource calculations. These research fields are ranked according to five criteria, i.e. benefit to regional exploration, benefit to lease site development, benefit to resource planners, high research pay-off potential (short term) and high research pay-off potential (long term). The ranking obtained in this manner was then compared to the work presently done in the various research fields in other institutions or in other departments of the Alberta Research Council.

The following ranking was obtained. Coal quality is the most important field of research, according to all criteria. Structural geology and coal databases rank as second most important. Stratigraphy and sedimentology rank third. Geophysics and resource calculations fell fourth, because these areas are adequately researched elsewhere.

## COAL QUALITY

A strong need is foreseen for increased research in coal quality and its prediction based on geological models. A better understanding of the factors controlling rank, sulphur, sodium, trace elements, moisture, coking properties and ash contents would be gained through documentation of their regional variations. In addition research should be done on detailed in-seam coal quality variation in selected smaller areas.

## STRUCTURAL GEOLOGY

Detailed mapping in established coal fields of the mountains and foothills needs to continue because of mining problems in structurally complex areas. This position is strongly supported by opinions from the coal mining industry. The areas suggested are the Cadomin-Luscar coal field and the Copton Creek part of the Smoky River coal field. Models developed in these areas will have predictive capabilities elsewhere. These studies could be integrated with regional correlation and mapping of coal seams of foothills and mountains.

## COAL DATABASES

Research into ways to standardize and exchange information through databases and electronic means from a geological perspective is needed. Duplication of effort could be reduced through the development of information systems based on geological expertise.

The full capabilities of a Geographic Information System (GIS) for coal geology could be researched. New ways of looking at coal need to be explored and products presented to researchers, the coal industry and resource managers in government. Co-operative projects between the Alberta Research Council, Energy Resources Conservation Board, Geological Survey of Canada, Alberta Energy and Alberta Forestry could be promoted.

STRATIGRAPHY AND CORRELATIONS

Detailed correlations of all major coal zones in the plains and mountains, on a priority basis, need to take place. At the present time, only the regional correlations of major coal zones are known. Many blank map areas still exist in the mountains and foothills. Detailed studies would allow individual coal seams to be identified and the controlling factors on seam geometry to be determined. Areas where this can be attempted are the Cadomin-Luscar area and parts of the Wapiti map sheet. The Wapiti map sheet will also need regional correlations to be established.

SEDIMENTOLOGY

Sedimentological facies models have predictive applications in the areas of coal occurrence and coal qualilty. Any facies study undertaken needs to be done with an emphasis on user application (i.e coal industry). Facies modelling needs to concentrate on the coal zones with more emphasis on understanding the general geometry of coal seams. For possible future underground mining of plains coal it will be essential that facies models be developed in order to predict variations in roof and floor rock properties.

GEOPHYSICS

Although geophysical research is adequately covered elsewhere, some research might be done by the Alberta Research Council on the accuracy of downhole coal quality determination from geophysical logs. Surface geophysical methods in the plains are adequately covered by an existing joint venture between industry and Alberta Energy. However, when the joint venture starts working in the mountains and foothills, it is strongly recommended that the Alberta Research Council's expertise in these regions of Alberta will be utilized.

## RESOURCE AND RESERVE CALCULATIONS

The calculation of resources and reserves of coal in Alberta is primarily the area of concern of the ERCB. No extensive work by the Alberta Research Council in this research field is proposed at the present time. However, the ERCB foresees a need for additional work on establishing potential coal resources.

## RESEARCH PROJECTS

The present projects of the Alberta Research Council's Coal Geology Group will be focussed in three areas: coal quality, regional coal evaluation and database management. The scheduling and final approval of the projects will be dependent on available manpower and finances.

Aspects of coal quality to be addressed include seam thickness, ash percentage, elemental composition (especially sulphur), maceral content, moisture content and calorific value. Coals of the Horseshoe Canyon Formation and the Ardley coal zone in the plains region will be emphasized. Results from this study would form a basis for future studies in the more complex foothills/mountains area.

The size of the coal resources in the plains region have been well documented on a regional scale by the Alberta Research Council and on a detailed scale in the designated coal fields by the ERCB and the GSC. In large parts of the inner foothills and in the transitional area of the outer foothills and plains, however, the size of the resource is not as well documented. The area suggested must frequently as requiring detailed mapping was the Cadomin-Luscar coalfield. This area has abundant drill hole data and good exposures that would allow a detailed assessment of the resources. Knowledge gained from a study such as this could be applied in areas with less data,but with similar stratigraphic and structural setting.

An efficient database must be established with information on coal geology. This database should be kept in a form that allows for continued use of the data in the future and should be compatible with other Alberta government database systems (particularly the ERCB's). Alberta Research Council data files on the coal resources of the plains region would be used to create this database.

# INTRODUCTION

In order to guide the Coal Geology Group of the Alberta Research Council through a new stage of research, it was felt that a framework for management decisions regarding the direction of research was needed. For this purpose a summary and critical account of what is known about the geology of coal in Alberta is presented in this paper. The subject of coal geology is divided into seven research fields, i.e. coal quality, stratigraphy, structural geology, sedimentology, coal databases, geophysics and resource calculations. Although economic and environmental studies are also important in coal geology, they are not considered in this report as possible research fields for the Coal Geology Group of the Alberta Research Council. They are researched elsewhere. Information will be presented on what geological surveys do in coal geology in other provinces of Canada and areas of the United States of America. Knowledge and opinions of the coal mining industry will also be presented. This information was gathered through a questionnaire (see appendices 1, 2, 3 and 4). From these sources of information, a set of recommendations for future work of the Alberta Research Council in coal geology is presented. It follows the mandate of the Alberta Research Council Coal Geology Program, which is to provide an information base on the geology of Alberta's coal resources.

Coal geology, that is applied to the discovery and evaluation of coal deposits is generally referred to as exploration geology. Data obtained from these exploration programs form the base from which more detailed coal geology studies are done. Geological factors are traditionally also taken into account in the planning of new mines or in modifications of existing mines. This work can be referred to as mining geology. Another application of coal geology is in coal utilization. Preparation plants, power stations and coke ovens are designed to suit the particular type of coal in question, and consequently a study of the coal quality is of great importance. In summary, coal geology plays a critical role in finding the right coal at the right place at the right time.

## COAL FIELDS

In Alberta, 81 coal fields and deposits have been designated by the Energy Resources Conservation Board (ERCB, 1984). A designated coal deposit is an area that contains coal resources of at least one million tonnes. The Energy Resources Conservation Board (ERCB) has divided the coal fields into three broad coal regions, i.e. mountains, foothills and plains. This division is mainly based on physiographic criteria. These divisions do not strictly conform to geological criteria. As a result, several coal fields that belong geologically speaking to the foothills (e.g. Smoky River and Cadomin-Luscar) fall in the ERCB mountain category. Similarly Obed Mountain, which is geologically speaking in the plains, is classed as foothills by the ERCB. In this report the ERCB classification is followed.

## GEOLOGICAL SETTING

The coal-bearing strata of Alberta were deposited in a sedimentary basin along the eastern edge of the evolving Rocky Mountains. They form part of a clastic wedge ranging in age from late Jurassic to mid-Tertiary. In general the source area of the sediments was from the evolving mountains to the west. The coals of this succession occur largely in nine coal zones, which are from bottom to top Kootenay, Luscar/Mannville, McKay, Taber, Lethbridge, Drumheller/Clover Bar, Carbon/Thompson, Ardley/Coalspur and Obed coal zones (figure 1). Economically speaking, the Kootenay, Luscar, Drumheller and Ardley/Coalspur are the most important. In the plains the coal-bearing strata are flat lying, while in the mountains and foothills these strata have been deformed and are generally dipping at varying angles.

The oldest coal-bearing rocks belong to the Jurassic-Cretaceous Kootenay Group of the mountains and foothills. Thick coals are present in the Lower Cretaceous Mannville Group of the plains. They are generally at great depth. Equivalent coal-bearing strata are exposed in the mountains and foothills where they form part of the Luscar Group.

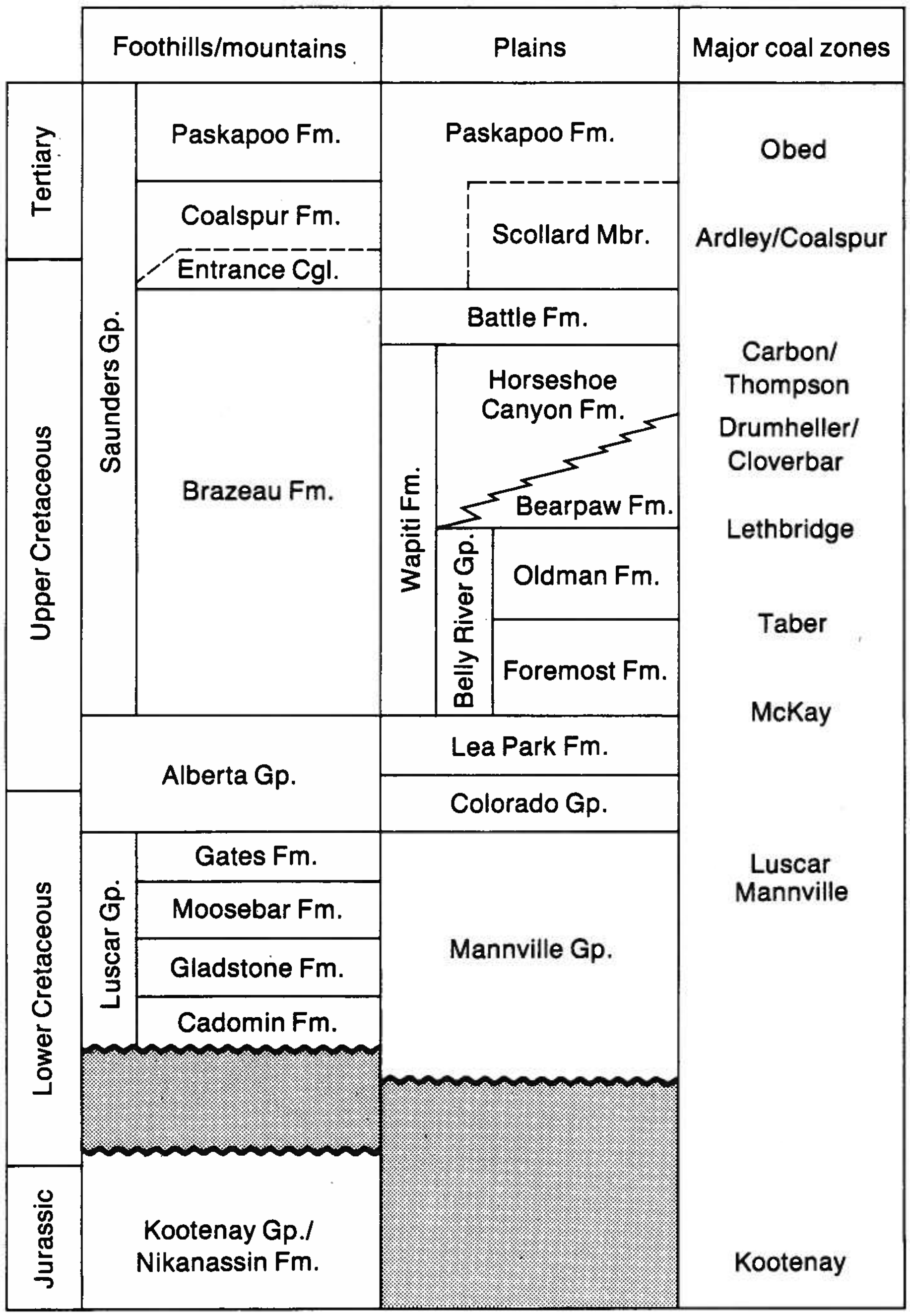



Fig. 1. Table of coal-bearing rock units and coal zones in Alberta.

Late Cretaceous coal-bearing strata are found in the plains. Coal zones are present in the Belly River Group at the base (McKay), middle (Taber) and top (Lethbridge). The Belly River Group is a thick, primarily continental, clastic wedge sequence that was sourced from the west. Marine sediments are known to underlie, overlie and interfinger with the group, becoming more dominant to the east in Saskatchewan.

Two major coal zones are found within the Upper Cretaceous Horseshoe Canyon Formation of the plains; the Drumheller/Clover Bar zone and the Carbon-Thompson zone. No equivalent coal-bearing rocks occur in the mountains and foothills. The Horseshoe Canyon/Bearpaw series is similar to the Belly River Group, being a clastic wedge sequence of continental sediments interfingering with marine and near-shore marine sediments.

There are two major coal zones within the Cretaceous-Tertiary Paskapoo Formation of the plains; one major unit at the base of the formation within the Scollard Member, the Ardley coal zone and one near the top of the formation, the Obed zone. Equivalent coal-bearing strata occur in the Coalspur and Paskapoo Formations of the foothills.

MINING OPERATIONS

Coal has been mined from Alberta's coal bearing strata since the end of the last century. In 1985, about 28 million tonnes of coal was produced from eleven major mines.

In the mountains, metallurgical coal is produced from the Luscar Group. In the Cadomin-Luscar coal field, production is mainly from the 12 m thick Jewel seam. The mining companies are Cardinal River Coals Ltd. and Gregg River Resources Ltd. Coking coal is also produced from the Smoky River coal field, where several seams, ranging in thickness from 2 to 8 m, are mined by Smoky River Coal Limited. Metallurgical coal has been mined in the past from the Kootenay Group of the Coleman-Blairmore coal field. However, there are at present no active mine operators in this area.

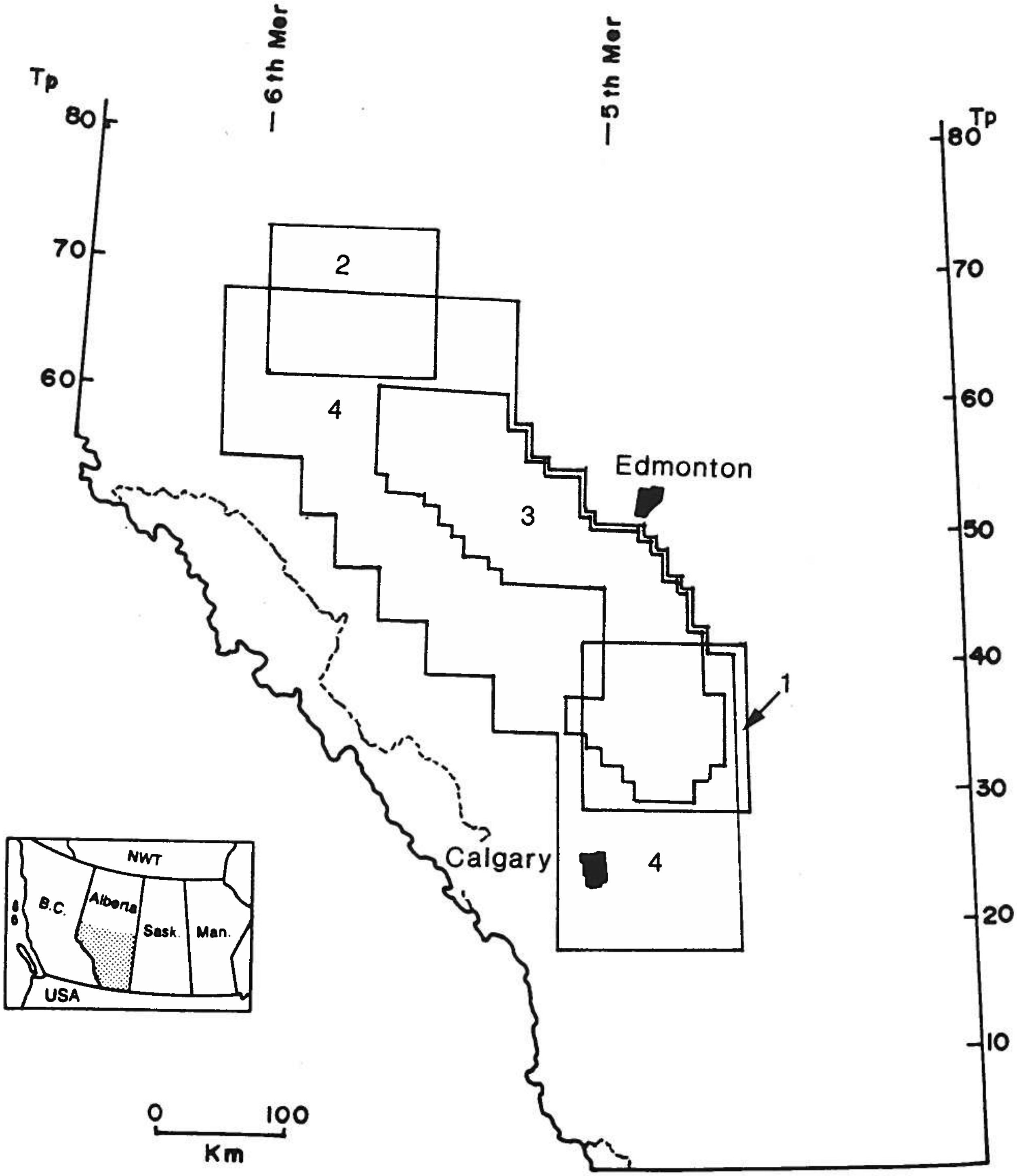
In the foothills, export thermal coal is being mined by Luscar Sterco Ltd. at the Coal Valley Mine, and by Obed Mountain Coal Company Ltd. at the Obed Mine, while the Manalta projects along the McLeod River are on hold until market conditions improve. These mines produce from the Coalspur and Paskapoo Formations.

Major domestic thermal coal production from the Ardley coal zone of the plains comes from the Whitewood and Highvale Mines, owned by TransAlta Utilities. Other major thermal coal producers of the plains are the Diplomat, Paintearth and Montgomery Mines owned by Luscar Ltd. and the Vesta Mine of Manalta Coal. They produce from the Drumheller/ Clover Bar coal zone within the Horseshoe Canyon Formation.

## ALBERTA RESEARCH COUNCIL COAL GEOLOGY PROGRAM

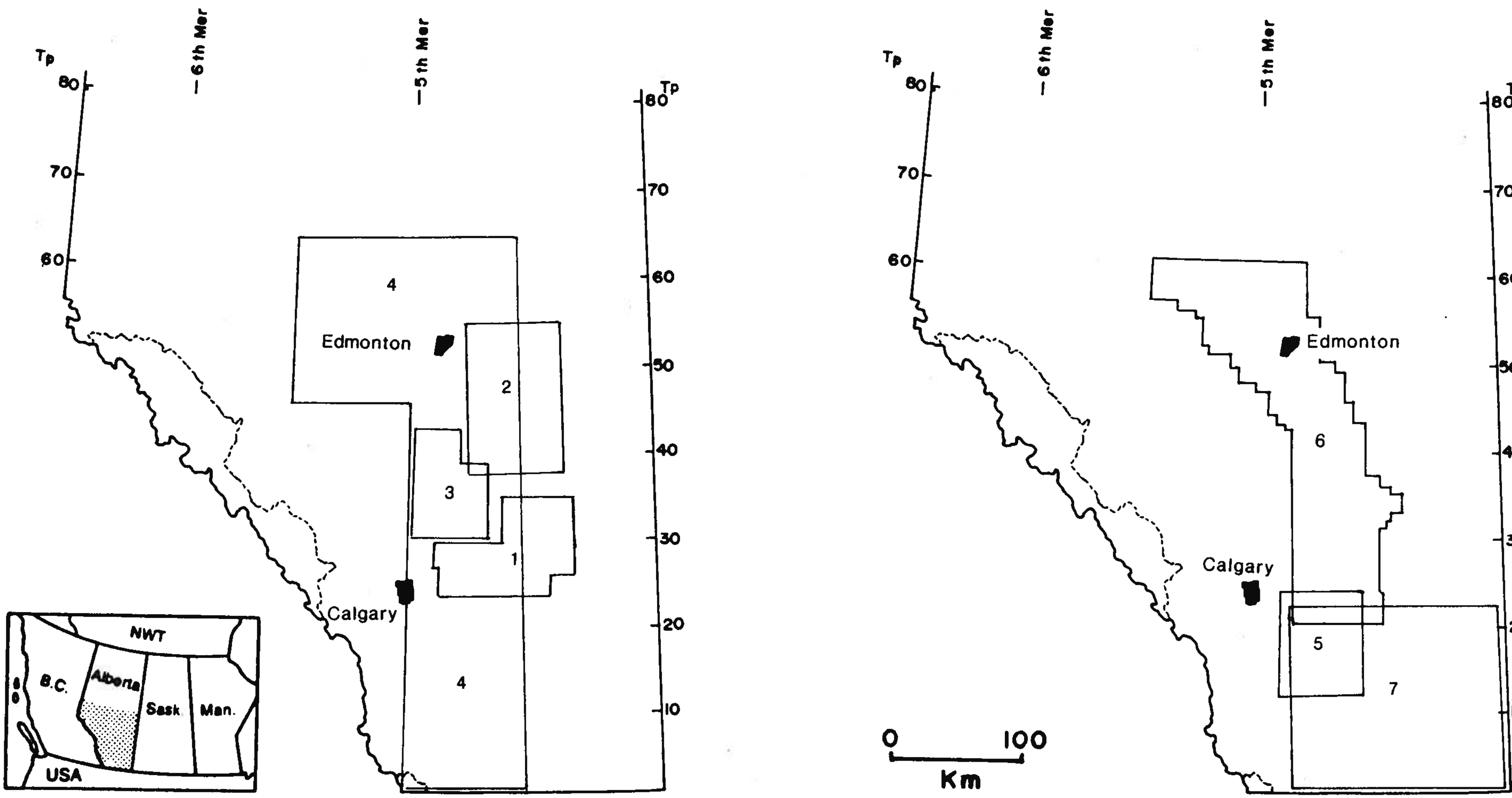
The Alberta Research Council has been involved in coal geology studies since its formation in 1921. From 1961 to 1979 the Alberta Research Council conducted regional coal exploration programs in the plains. The areas studied are shown in figures 2, 3, 4 and 5. The location of wells drilled for these studies in the years 1974 to 1978 are shown in figures 6, 7 8, 9 and 10. These holes were drilled on a one hole per township basis parallel to the outcrop of each coal-bearing formation. From 1979 to 1983 closely spaced holes were drilled in detailed study areas of the plains (figure 11).

Since 1981, research has been done on the structural geology and stratigraphy of foothills coal, with special emphasis on the Grande Cache area (Langenberg et al., in press).




1 Campbell, 1967
2 Campbell, 1972
3 Holter, Yurko and Chu, 1975
4 Richardson et al., 1986

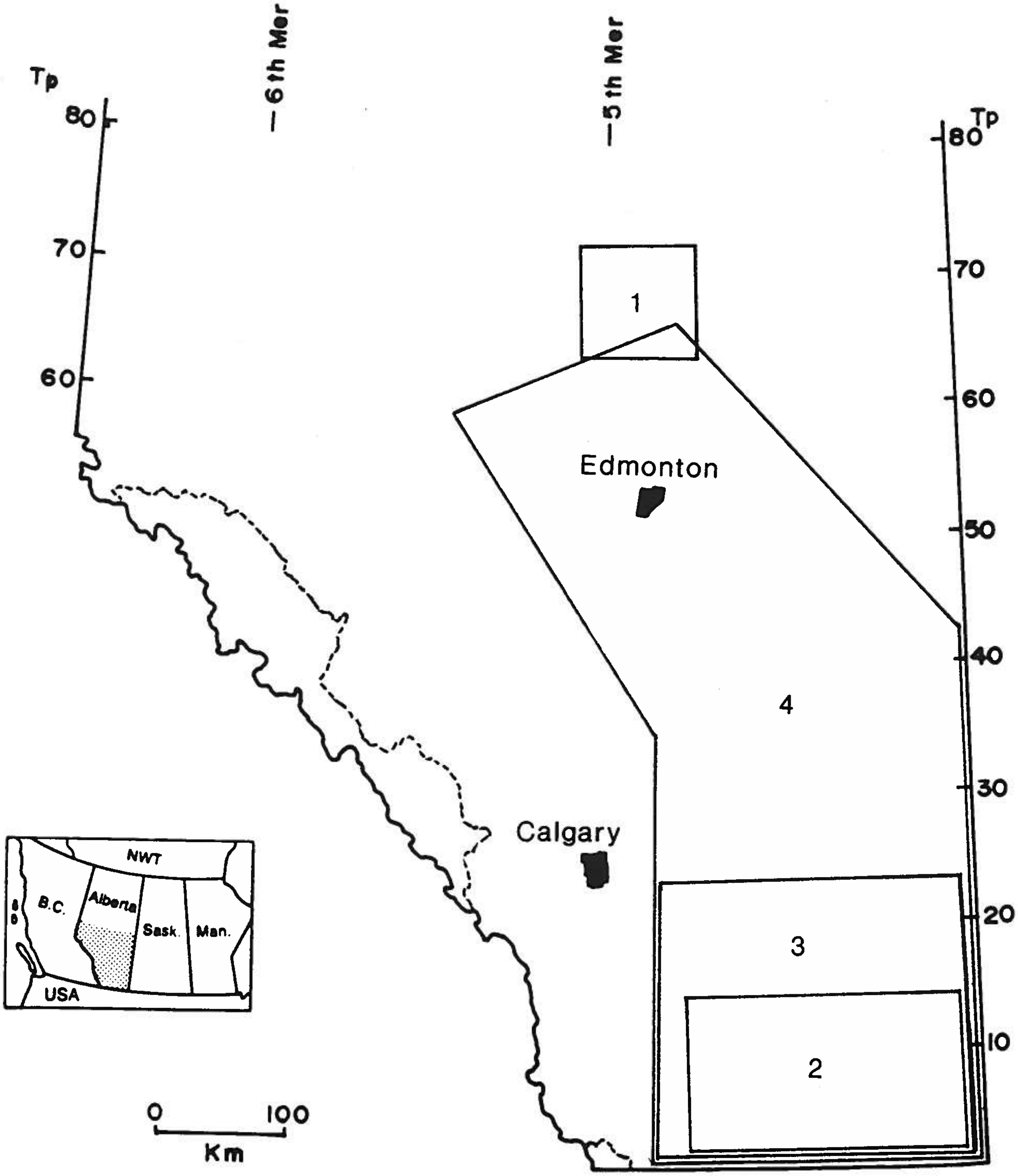
Figure 2. Map showing coal resource studies of the Ardley coal zone (Paskapoo Formation) by the Alberta Research Council.




1 Campbell, 1974
2 Campbell, 1975
3 Nurkowski, 1980
4 McCabe et. al., 1986

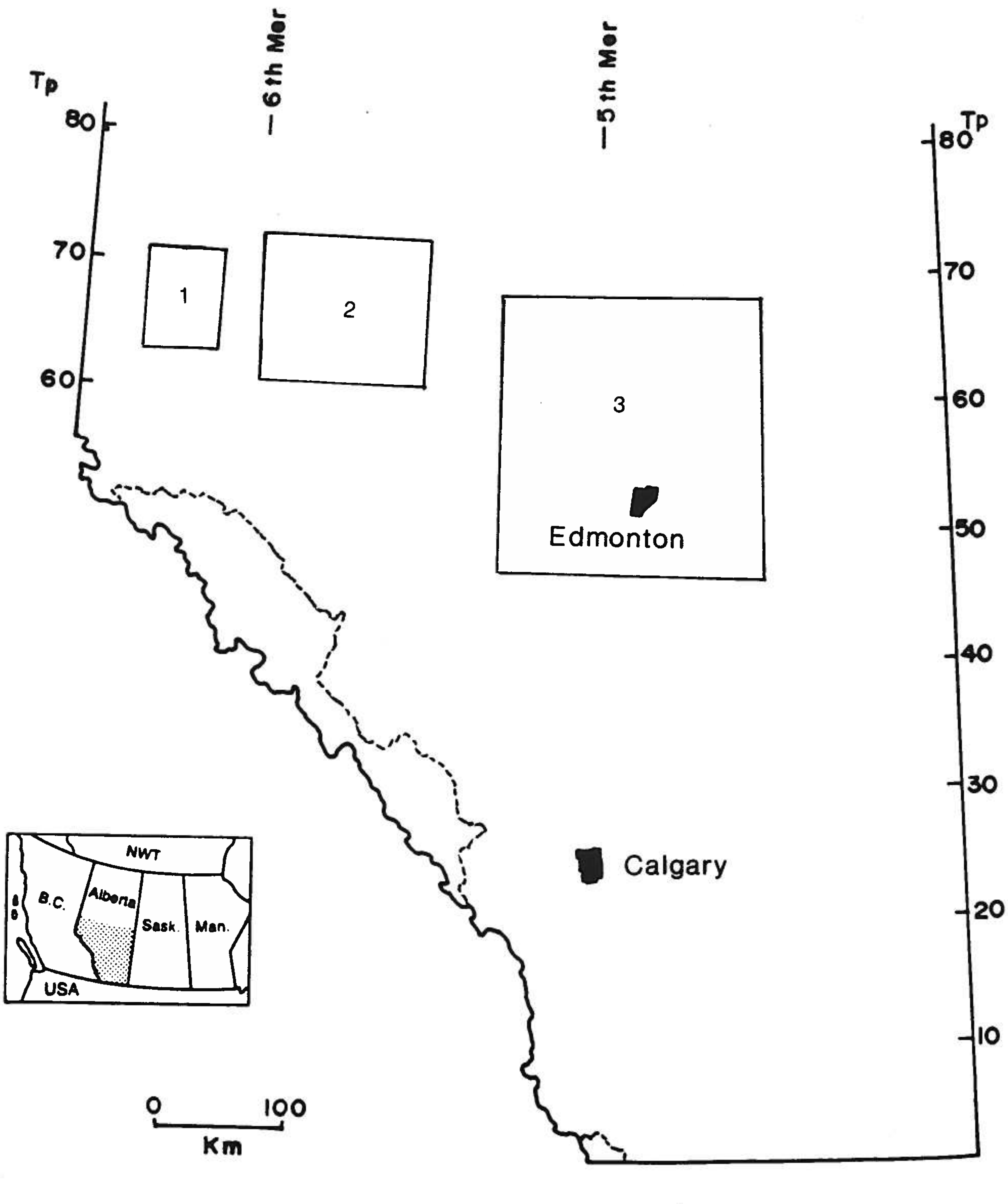
5 Campbell and Almadi, 1964
6 Holter, Chu and Yurko, 1976
7 Holter and Chu, 1978

Figure 3. Map showing coal resource studies of the Horseshoe Canyon Formation and its lateral equivalents by the Alberta Research Council.




1 Campbell, 1972
2 Campbell, 1974
3 Holter and Chu, 1977
4 Macdonald et al., 1986

Figure 4. Map showing coal resource studies of the Belly River Formation and its lateral equivalents by the Alberta Research Council.




1 Allan and Carr, 1946

2 Campbell, 1972

3 Chu, 1978

Figure 5. Map showing coal resource studies of the Wapiti Formation by the Alberta Research Council.

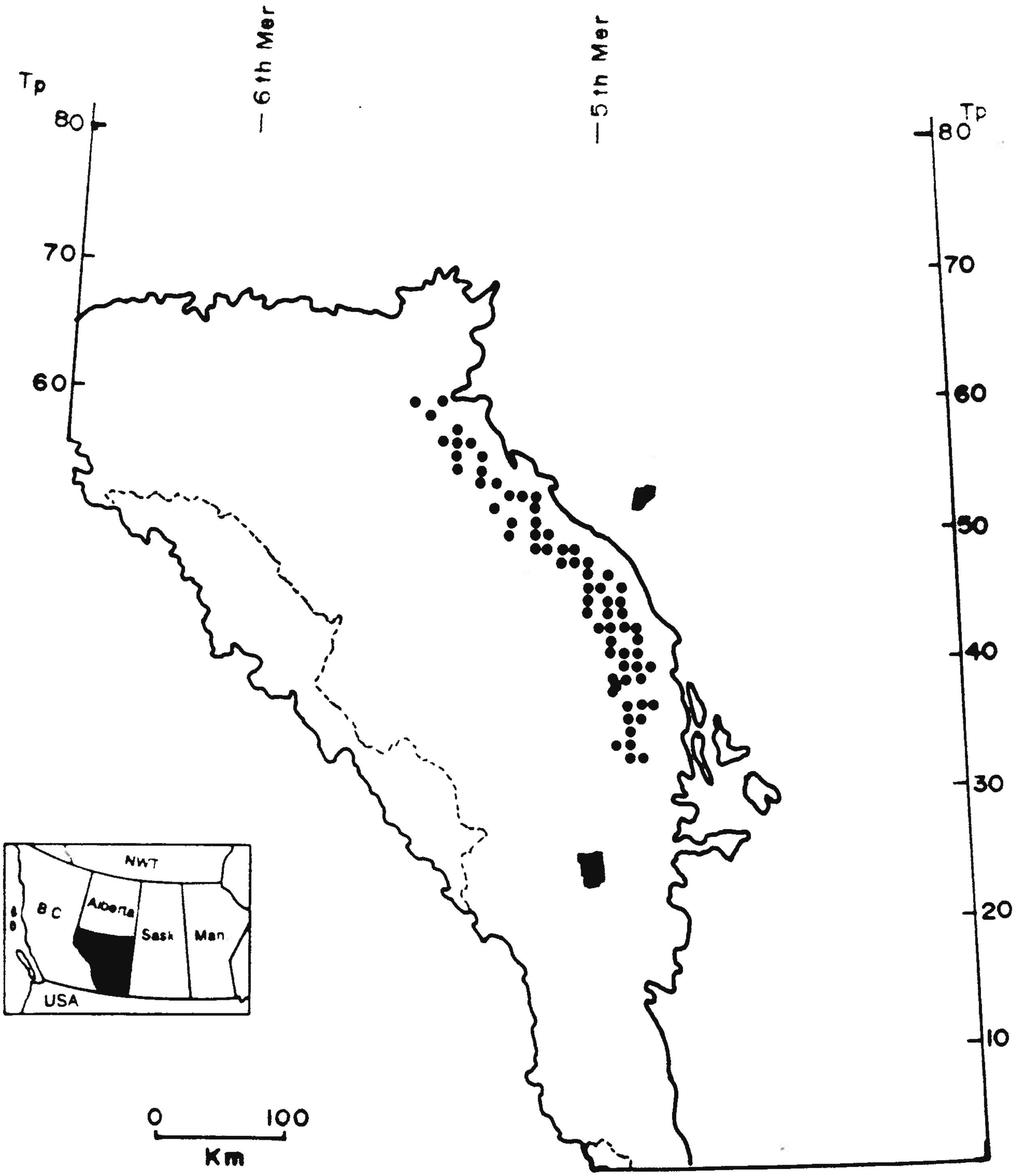



Figure 6. Location of holes drilled in the 1974 Alberta Research Council drilling program in the Ardley coal zone, Paskapoo Formation. Drilling was done on a one hole per township basis. The outcrop of the Paskapoo Formation is shown for reference.

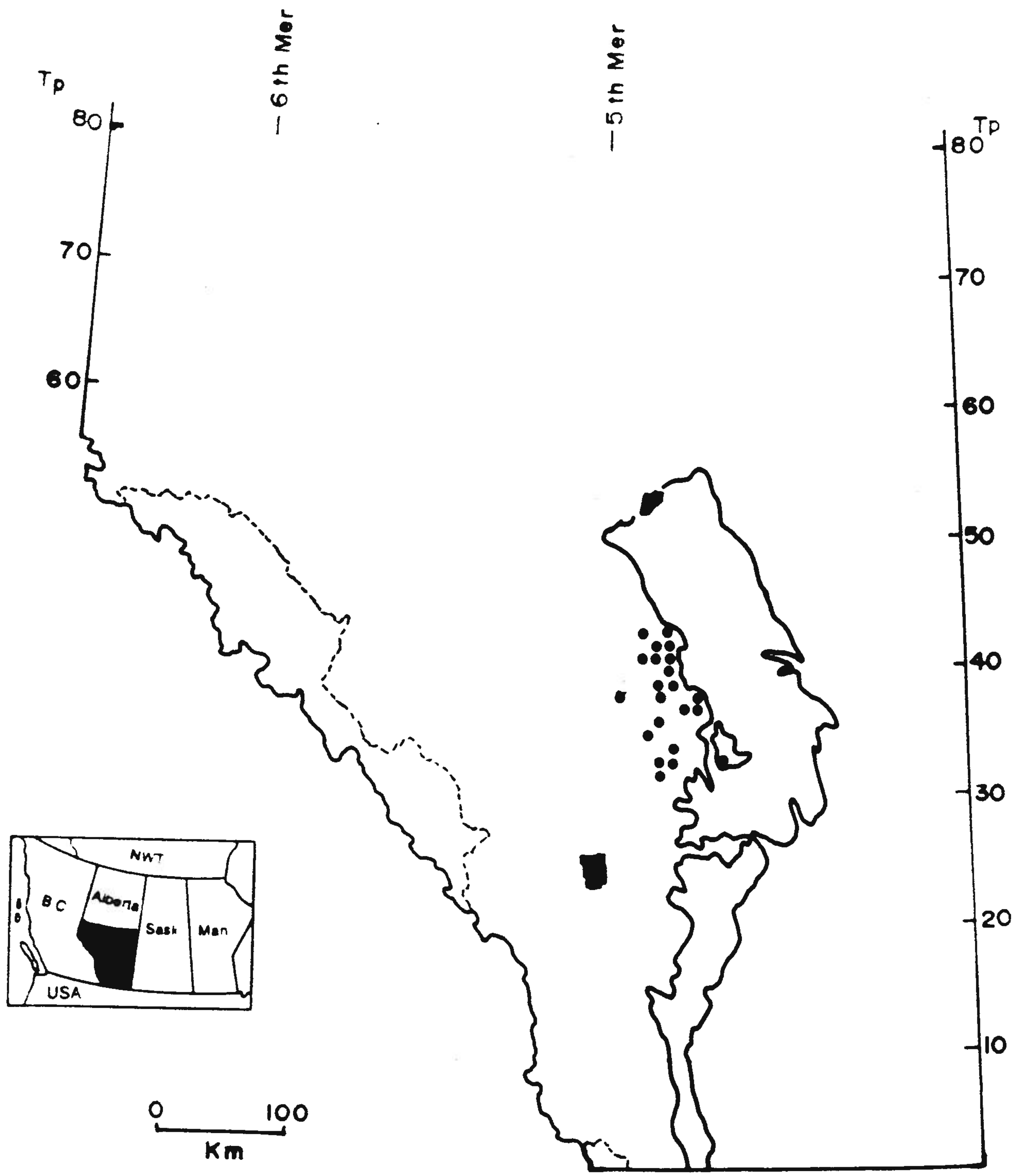



Figure 7. Location of holes of the 1978 Alberta Research Council drilling program in the Carbon-Thompson coal zone, upper Horseshoe Canyon Formation. Drilling was done on a one hole per township basis. The outcrop of the Horseshoe Canyon Formation is shown for reference.

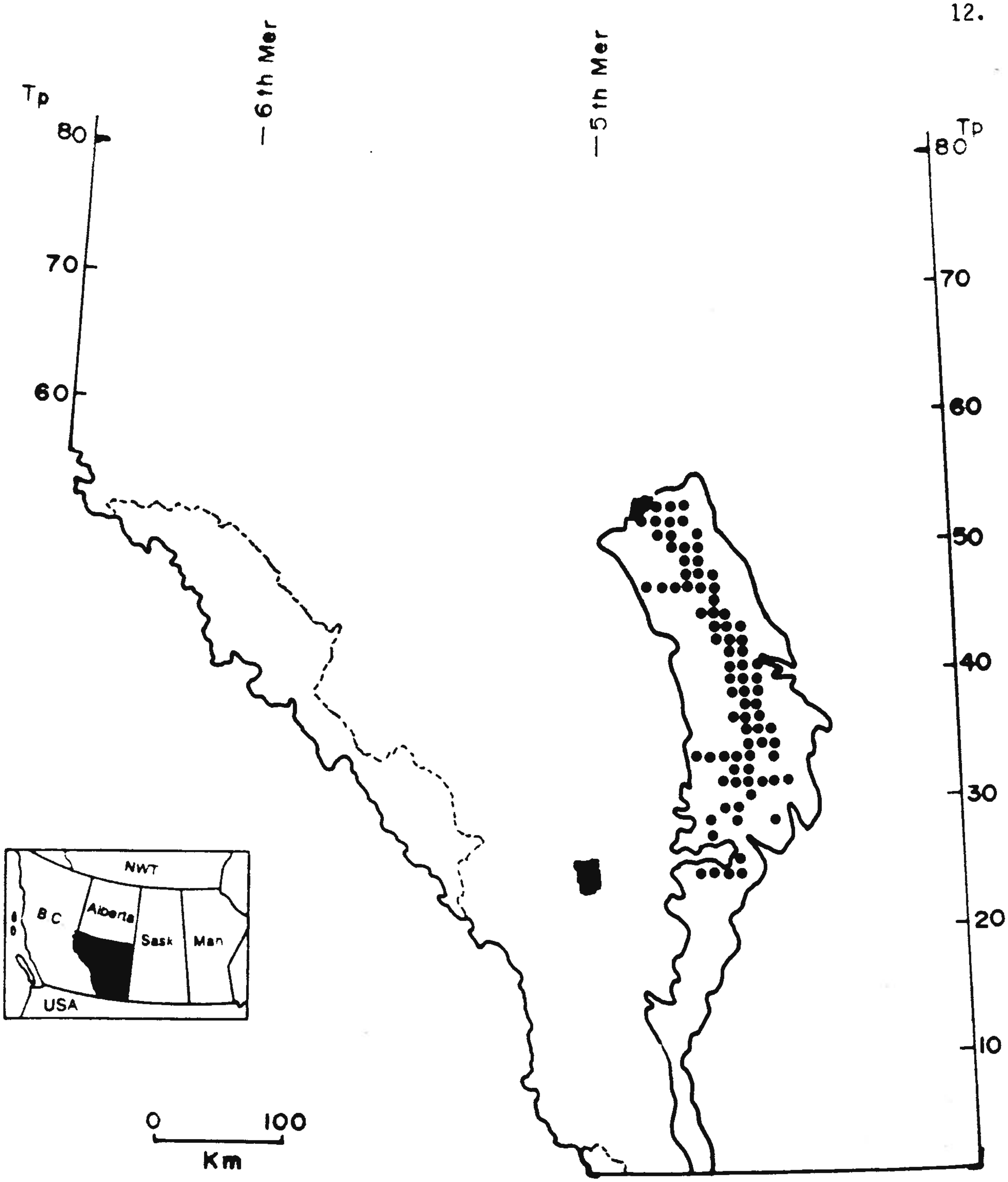



Figure 8. Location of holes drilled of the 1975 Alberta Research Council drilling program in the lower Horseshoe Canyon Formation. Drilling was done on a one hole per township basis. The outcrop of the Horseshoe Canyon Formation is shown for reference.

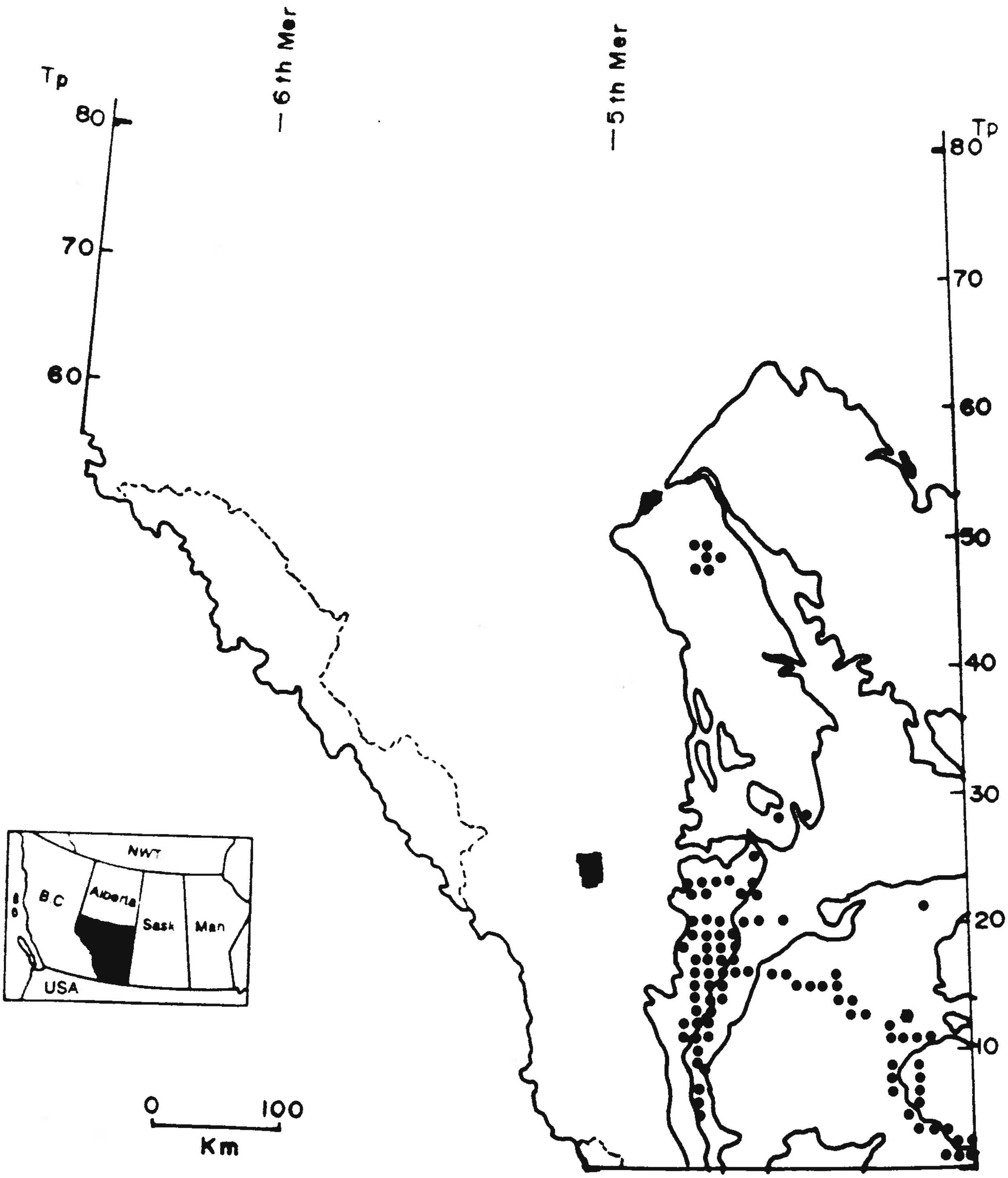



Figure 9. Location of holes drilled in the 1976 combined drilling program in the Horseshoe Canyon and Belly River Formations. Drilling was done on a one hole per township basis. The outcrops of the Horseshoe Canyon and Belly River Formations are shown for reference.

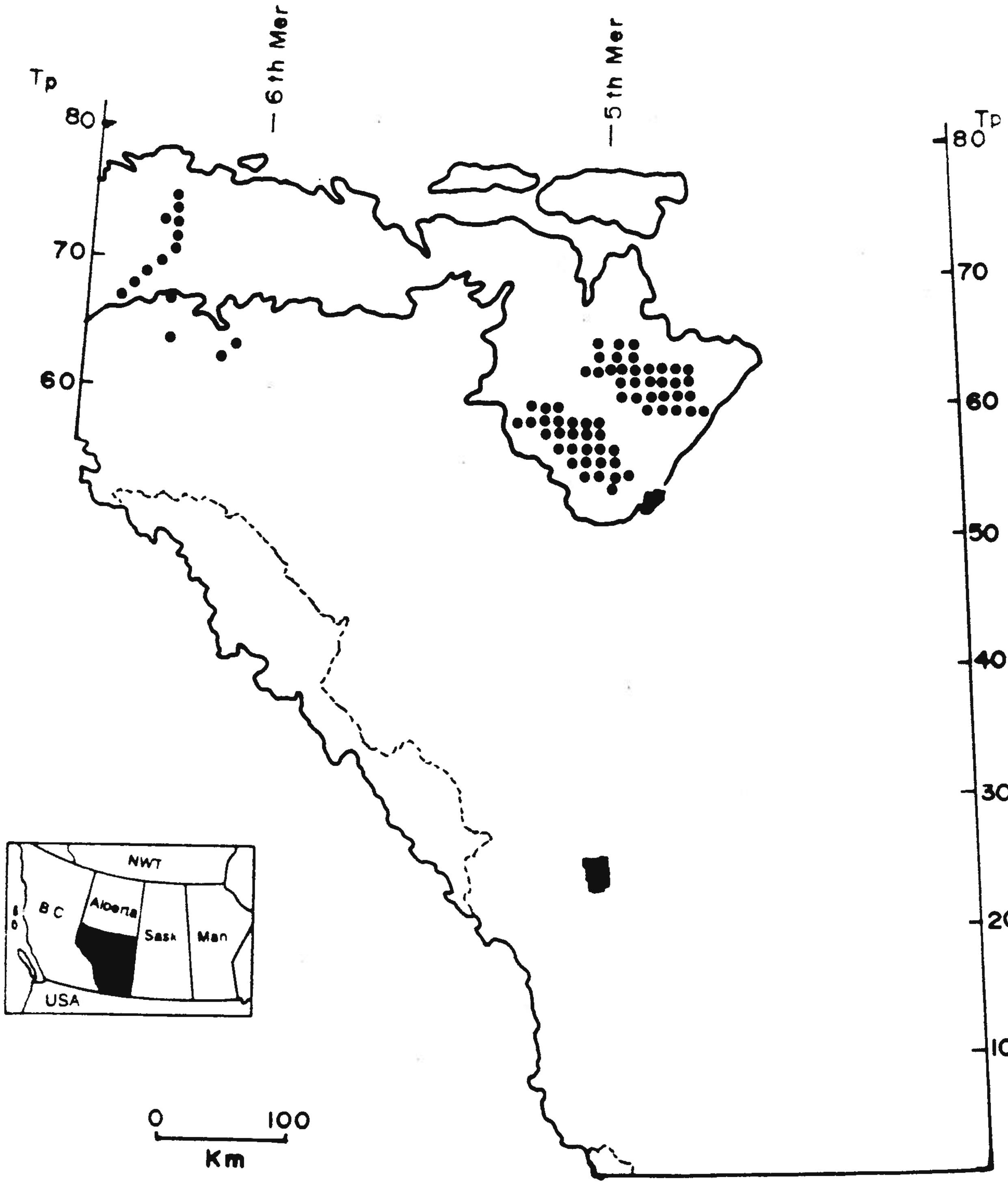
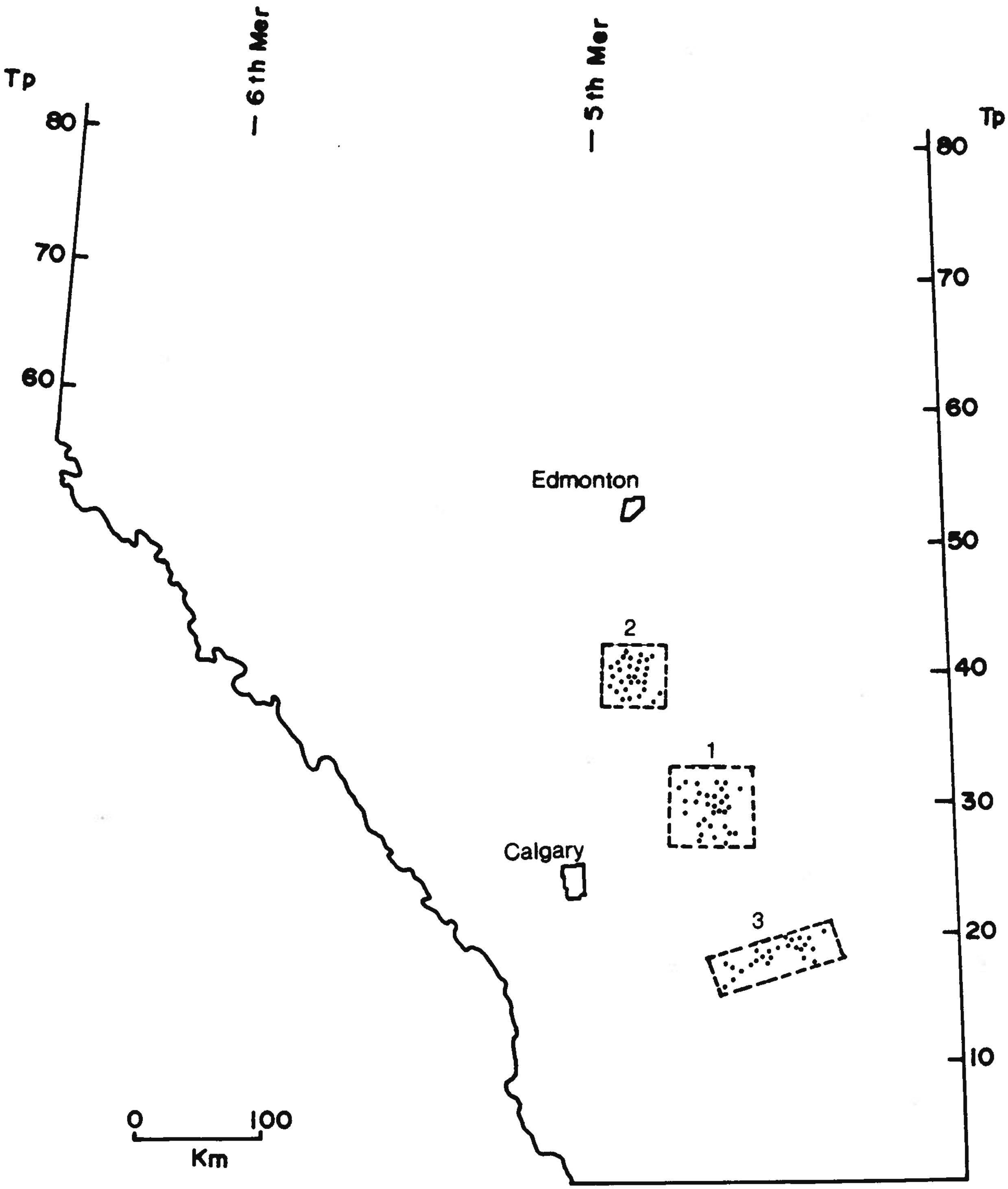



Figure 10. Location of holes drilled in the 1977 Alberta Research Council drilling program in the Wapiti Formation. Drilling was done on a one hole per township basis. The outcrop of the Wapiti Formation is shown for reference.




1 Drumheller detailed study (lower Horseshoe Canyon Formation)
2 Alix detailed study (Ardley coal zone, Paskapoo Formation)
3 Brooks detailed study (Belly River Group)

Figure 11. Location of holes drilled in the 1979-1980, 1981-1982 and 1983 Alberta Research Council drilling program of the Drumheller, Alix and Brooks areas respectively. Holes are closely spaced (up to 5 holes per township) for each study area.

# COAL QUALITY

All Alberta coals were not created equally. Their composition and physical properties vary greatly, not only from coal field to coal field, but even within individual seams. Some of the variation is reflected in rank, where rank is a classification system expressing the degree of metamorphism (which is chemical and physical changes under increasing temperature and pressure) of coal.

## COMPOSITION AND PHYSICAL PROPERTIES

Because coal is a heterogeneous mixture of organic compounds, moisture and mineral impurities, its composition determines its behaviour when used. The general nature of the organic compounds of coal can be adequately evaluated by a combination of three sets of analytical data, which are proximate analysis, ultimate analysis and petrographic analysis. Proximate analysis gives the relative amounts of moisture, ash, volatile matter and fixed carbon. Ultimate analysis determines the total amounts of carbon, hydrogen, oxygen, nitrogen, ash and sulphur. Petrographic analysis provides data on the proportions and optical characteristics of macerals in coal.

For thermal coal, the heating value is generally determined. The ease with which a thermal coal can be ground to a fine powder (grindability) is often also determined. Metallurgical coal is generally tested for its abilities to form coke. These tests involve establishing the free swelling index (FSI), dilatation and apparent fluidity.

Information on coal quality of Alberta coals has been released in government reports (Stansfield & Lang, 1944; Parkash, 1985; and Faurschou et al. 1982). The areas covered are shown in figure 12. Faurschou et al. (1982) only reported on commercial coals and for metallurgical coal they generally only present analyses for clean coal and not the raw run-of-mine coal. Additional compositional data for plains coal is reported by Nurkowski (1985). In that report the data is

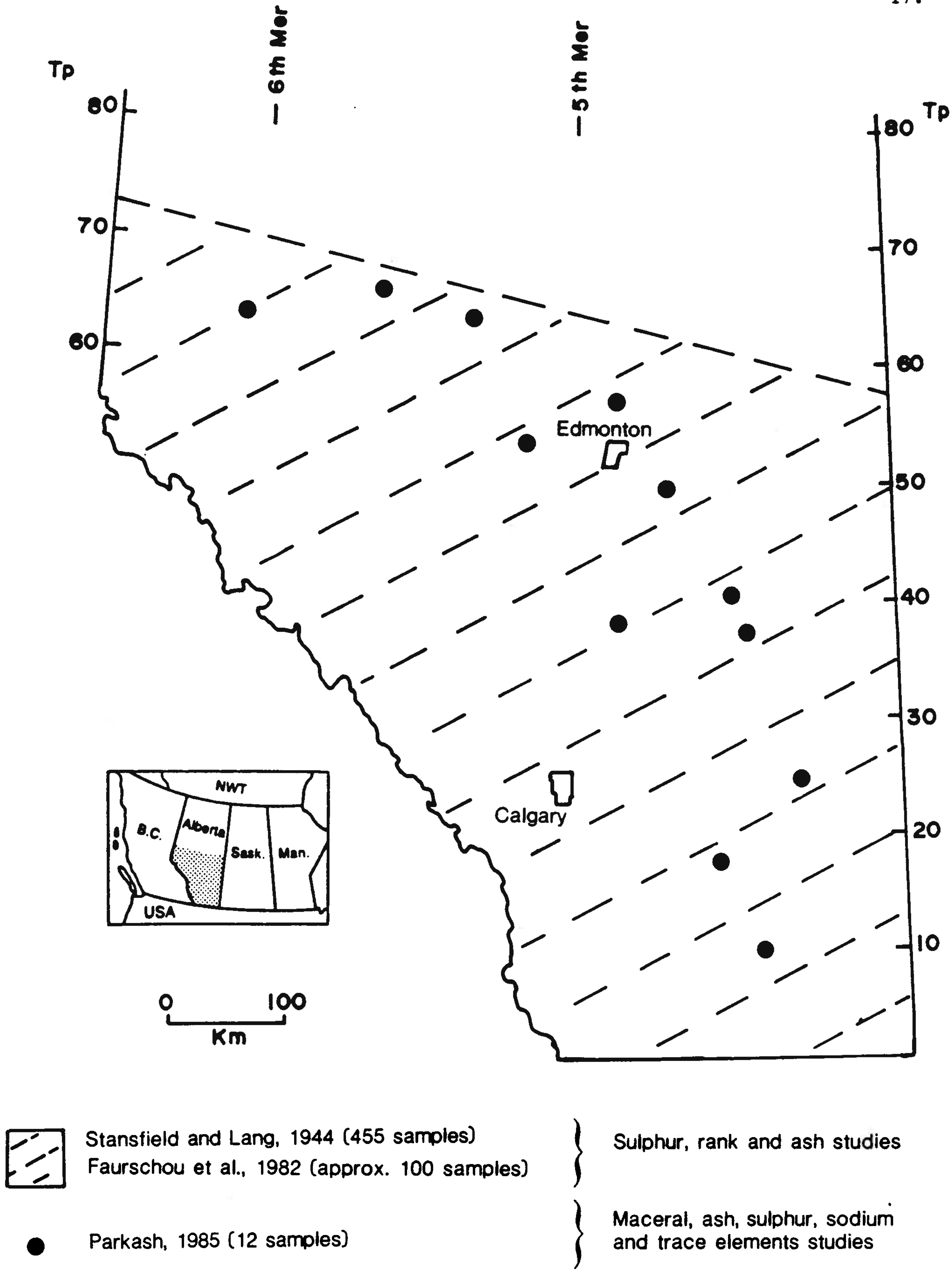



Figure 12. Map showing areas of preliminary coal quality studies in Alberta.

summarized by stratigraphic unit, rather than by coal field.

Coal companies are required by law to submit all coal quality data to the ERCB. This information may be released after two years. The ERCB is presently in the process of entering these data in its coal drillhole master file. The Geological Survey of Canada (GSC) is also in the process of building a coal quality data base. These data bases will probably contain partly overlapping data and both will be publicly available. Regional interpretations will have to be made based on these data, similar to preliminary work by Steiner et al. (1972) and Nurkowski (1985).

## UTILIZATION

Coal is presently used mainly as either a fuel for electric power generation or as a raw material for the manufacture of metallurgical coke. Significant amounts are also used for cement manufacture and a wide range of industrial processes. The future may see increased use of coal in liquifaction and gasification. The quality of the coal determines for which use it is best suited. Although all coal will burn, the lower rank coals are generally better suited as feed for power plants, while higher rank coals are better for the forming of coke. Anthracites do not cake and are therefore not capable of forming coke, but are an excellent source of heat with many applications. The liquefaction potential of Alberta coals has been extensively examined by the Alberta Research Council (Chakrabartty and du Plessis, 1985; Parkash, et al. 1984; Parkash et al. 1983).

Consequently, the study of coal quality forms an important part of the characterization of Alberta's coal resources. The quality of a coal determines its value. A geological understanding of coal quality allows prediction of vertical and lateral variability of coal measures. In general, this is still poorly understood. For this reason most geological surveys and many coal companies foresee a need for increased research in coal quality and its prediction (Appendix 3).

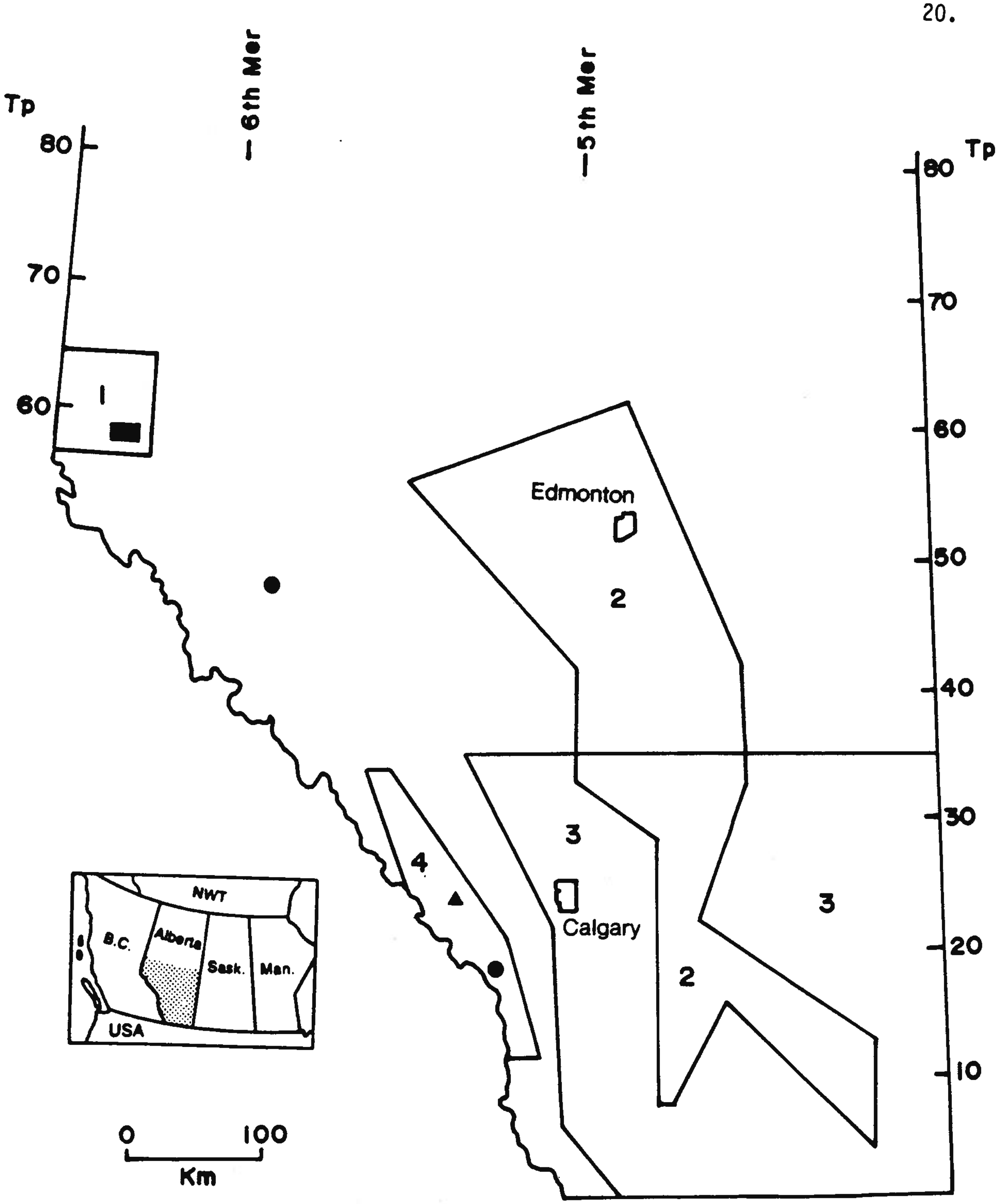
RANK STUDIES

Coals can be classified according to rank, that is, according to their degree of metamorphism, or progressive alteration, in the natural series from lignite to anthracite (ASTM standard D-388). Classification is according to fixed carbon for coals having fixed carbon of more than 69 percent on the dry, mineral-matter-free basis and according to calorific value for coals having calorific values less than 32564 kJ/kg (14,000 BTU/lb) on the moist, mineral-matter-free basis.

ASTM rank class can also be determined by measuring the maximum reflectances of vitrinite. A good correlation between ASTM rank determined according to the standard method and the rank determined from maximum vitrinite reflectance is generally reported (Bustin, et al. 1985). The vitrinite reflectance rank parameter has the advantage that it can be used over the whole range of coalification.

Completed rank studies in Alberta are shown in figure 13. Rank variation in near-surface coals of the plains is well known (Nurkowski, 1985). This is shown schematically in figures 14 and 15. Parkash (1985) reported on petrographic studies of the plains coals. ASTM rank classes can be compared with vitrinite reflectance from this publication. There are sometimes problems in comparing rank determinations in different publications. For example Faurschou et al. (1982) tends to report lower calorific values for plains coal than Nurkowski (1985) and Parkash (1985). These differences can be explained by the inclusion of rock partings in the samples used by Faurschou et al. (1982).

Samples used in the above mentioned reports came from the surface or from depths to a maximum of 300 m. Much less is known about the deeper coals. Preliminary work by England and Bustin (1986) shows a lot of variation in rank, probably as a result of varying geothermal gradients across the province. A thorough study of ranks of deeper coal will be necessary before good markets can be found for coal from potential underground mines.




1 Kalkreuth and McMechan, 1984 (surface-80 samples, subsurface to 3800m depth-24 samples)

2 Nurkowski, 1985 (subsurface to 300m depth-685 samples)

3 England and Bustin, 1986 (surface-23 samples, subsurface to 3200m depth-330 samples)

4 Gibson, 1985 (surface-43 samples)

● Hacquebard and Donaldson, 1984 (surface-12 samples)

▲ Hughes and Cameron, 1985 (surface-38 samples)

■ Kalkreuth and Langenberg, 1986 (surface-157 samples)

Figure 13. Map showing completed coal rank studies in Alberta. For each study the number of samples and maximum depth of wells sampled are given.

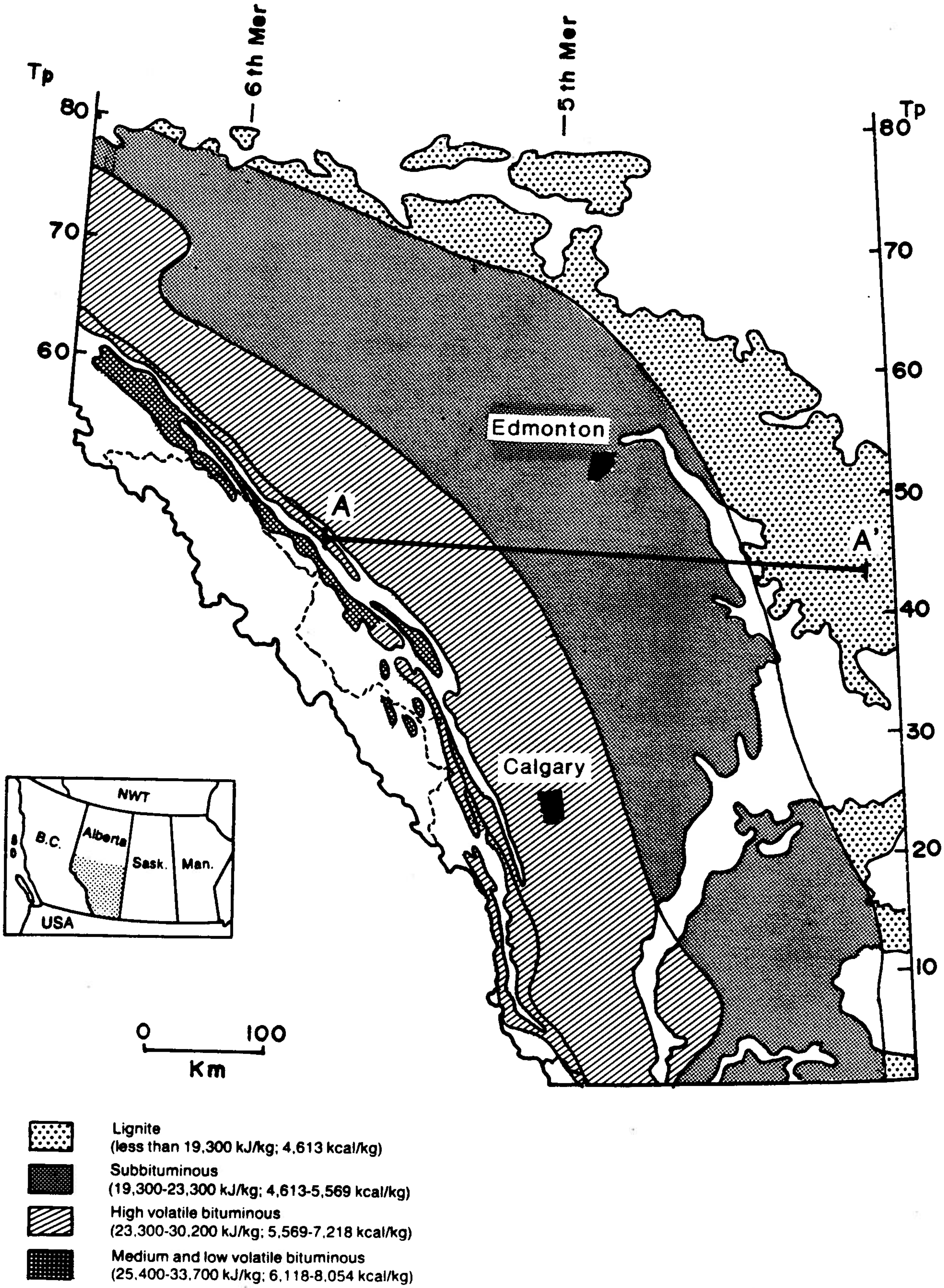



Figure 14. Map showing the rank of coal-bearing strata of Alberta (modified from maps by the Energy Resources Conservation Board and the Department of Energy and Natural Resources).

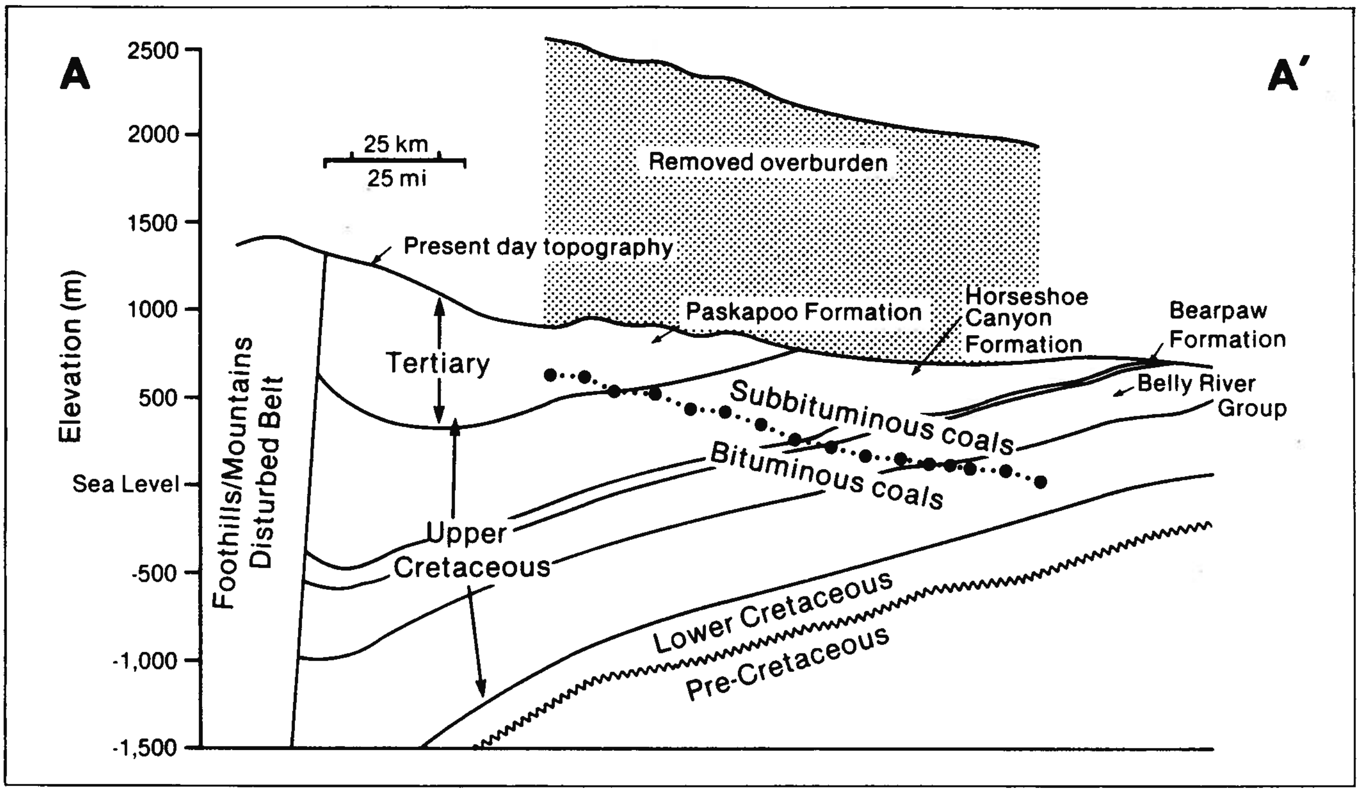



Figure 15. Generalized cross-section through the central plains area of Alberta, showing the southwesterly dipping coal-bearing formations and isorank lines.

In the foothills and mountains, coal rank is well known from mine sites, but not so well from other parts of the coal fields and outside the coal fields. The Geological Survey of Canada is performing rank studies based on petrography in the mountains and foothills (Hacquebard and Donaldson, 1974; Hughes & Cameron, 1985; Kalkreuth and McMechan, 1984). Some of this work is in cooperation with the Alberta Research Council (Kalkreuth and Langenberg, 1986). There is a lot of variation in rank and coal quality in these regions. The rank can change in an individual coal seam within a short distance. For example, on the Copton property in the Smoky River coal field, the rank is higher than the coal presently marketed from the Grande Cache area. This causes some concern about the marketability of the Copton coal. Rank variation needs to be investigated in detail within the foothills area.

## MACERALS

Megascopically coal may be classified as banded (humic) or non-banded (sapropelic) coals. In banded coals, layers can be classified in four lithotypes, i.e. vitrain, clarain, durain and fusain. Two major types of non-banded coals are 'cannel coal' (composed largely of spores) and 'boghead coal' (composed largely of algal material).

Under the microscope, coal is seen to consist of many different carbonaceous materials. They represent the coalified remains of various plant substances. They are distinguised based on optical properties and morphology, and are termed macerals (a term which was introduced as an analogy to minerals of inorganic rocks). Many different macerals exist and they are grouped in three groups, namely vitrinite (largely wood and bark), liptinite (spores and pollen) and inertinite (carbon-rich, hydrogen poor plant components). Vitrinite and liptinite are the reactive constituents in coking coal and are susceptible to liquefaction. Inertinite is inert during the manufacture of coke and is resistant to liquefaction.

Microlithotypes are associations of macerals with a minimum width of 50 microns. They can be mono-, bi-, or trimaceralic, according to whether they contain representative macerals of one, two or three of the maceral groups.

Study of the maceral content gives an indication of the texture of a coal and this has bearing on its utilization. For example, grindability increases with higher vitrinite content for low volatile bituminous coals (Cameron, 1974). These studies can give an indication of the size distribution of masses of inertinite and this may be important in coking behaviour (Ignasiuk, 1974). Maceral content can be critically important in coal seam correlations (Bustin et al. 1985) and in liquefaction potential (Parkash et al. 1984). In general, conversion yield increases with increase of the reactive vitrinite and liptinite macerals. However, coals of lower and higher ranks than high-volatile bituminous give lower yields while containing the same amount of reactive macerals (Bustin et al. 1985). The Horseshoe Canyon coals show generally the highest conversion yields of the plains coals, probably because they are enriched wih reactive macerals with respect to the other coals (Chakrabartty and du Plessis, 1985).

Maceral studies within the Alberta coal fields are in an infancy stage at present, compared to work that has been done in more mature coal fields around the world. Much more documentation of maceral variations in a regional and stratigraphic senses needs doing in Alberta.

## ASH

Ash is the noncombustible part of coal and is composed of mineral matter. During ashing of coal, decomposition and oxidation occurs as well as partial loss of volatile constituents. According to Stansfield and Lang (1944) ten parts of mineral matter in coal leave only nine parts ash. Mineral matter is either organically bound to the coal or it appears as shale or bentonitic partings within the coal seam. Ash content is often economically determined, because it depends on how many partings are included with the coal being mined. More selective mining could reduce the ash content, but is expensive. Sulphur, sodium and trace elements are very important components in ash and are dealt with separately within this section. In metallurgical coals, ash is one of the most serious problems in making coke. There are often penalty clauses in coal contracts for higher than agreed upon ash contents in coals delivered. In thermal coals, high ash content tends to reduce the calorific value of coal. Other problems related to high ash content in thermal coals are difficult ash handling, varying ignition stability and different heat transfer in boilers. High ash content may cause fusion of ash, which results in slagging and fouling in furnaces, and corrosion of high temperature surfaces. Insufficient ash data on a mine site development can be very detrimental and costly, as has recently been shown at the northeastern British Columbia Quintette Mine.

As with other coal quality parameters, the best data on ash content and composition are available within existing mine sites (e.g. Faurschou et al. 1982). Information becomes less abundant in the established coal fields and very sketchy in deeper regions of the Alberta coal basin. Steiner et al. (1972) show a provincial map describing ash contents for all coal zones, based on 300 sample points. Many of these samples came from existing mine sites and near surface outcrops. Large gaps appear in deeper regions of the Alberta basin. Nurkowski (1985) presents some summary histograms of typical ash contents, based on the Alberta Research Council drilling program, from near surface to about 400 m. Many of the data points in his report were gathered on a one sample per township basis (i.e. one sample representing approximately 100 sq km). No geographic distribution of ash contents or ash compositon is given in the Nurkowski report.

Two Western Canadian coal companies (Gregg River Resources and Denison Mines) expressed concern over ash contents, with high bentonite contents being specifically mentioned. The Illinois State Geological Survey mentioned future research into mineral matter in coal relative to combustion as being an important area. Much more work needs to be done in Alberta to determine the regional and stratigraphic distribution of ash content and composition in those areas outside the established coal mines. We are presently at a very introductory level of understanding in this area. Increased knowledge would likely assist in the international marketing of coal.

## Sulphur

Alberta coals are in general low in sulphur content compared to coals elsewhere. Knowledge about sulphur content of coals is very important, especially in thermal coals, because of potential environmental damage. Sulphur causes problems in power plant boilers by forming sulphuric acid, which causes corrosion. Sulphur also affects the electrical properties of fly ash, thereby decreasing the electrostatic precipitators efficiency. High sulphur content in coking coals, if retained in the coke, can lead to brittleness in steel being produced. Sulphur is contained in coals both in mineral and in organic form. Distinguishing between these two forms is important in deciding what technologies need to be applied to clean up the coal.

Sulphur content is usually monitored very closely at active mine sites in Alberta, as contracts often stipulate maximum sulphur contents that will be tolerated. The in-seam variation in sulphur content has been well documented at some Alberta minesites. Some selective mining does take place to remove high sulphur zones within mined seams. If the in-seam variations are well enough known at a given site, or can be predicted, much more can be done in the area of selective mining.

The distribution of sulphur contents in the various coal-bearing zones throughout the rest of the province is only scantily known. Steiner et al. (1972) presents a regional map of Alberta showing sulphur distribution in all coal zones. This study seems to be based on approximately 36 sample sites. The GSC and ERCB both administer coal databases that contain sulphur data for the established coal fields within the province. Little of this work has been compiled into a regional synthesis of sulphur distribution. Most recently Nurkowski (1985) showed by histograms the sulphur distribution in the main coal-bearing formations, based on Alberta Research Council shallow coal data. Very little work has been done to characterize the sulphur content in a regional sense, either by coal zone or individual seam.

Few Alberta coal companies cite sulphur content as a major problem in coal research. However, there has been new legislation passed recently regarding $SO_2$ emission by the Alberta Government. Specific studies undertaken at mine sites (e.g. geostatistical) would be very beneficial to producers in maintaining their contractual sulphur levels and in predicting mining blocks that may contain anomalously high sulphur contents. Sulphur problems were not mentioned specifically in responses received from U.S. geological surveys, though many felt that coal quality research was needed badly. Many of these same state surveys have, however, published extensive works on sulphur distribution already. For these organizations, the sulphur problem has already been addressed.

## Sodium

Sodium content in a coal is particularly troublesome to the thermal coal industry. Sodium contents that exceed 0.4% (expressed as $Na_2O$ by weight of the dry coal) will have fouling tendencies in boilers (Mitchell, 1974). In the past the total alkali content (potassium included with sodium) was taken as a measure of a coals fouling potential. It is now realized that sodium is by far the most troublesome of the alkalis, therefore, measurement of this element is most important. Sodium content in Alberta coals is believed to be in the 0 to 6% range (Faurschou et al. 1982). Sodium is found in both the organic and inorganic fractions of coal.

Average sodium contents at the various mine sites around the province are well known, however, in-seam variations are not clearly understood. Regional compilations of sodium content also seem to be lacking. The ERCB and GSC both maintain coal databases that contain some sodium data in the established coal field regions, however, no compilation of this data seems to have been undertaken. Virtually nothing is known of sodium content in the deeper coals of the Alberta basin. The Illinois State Geological Survey specifically mentions sodium as being an element they are currently investigating.

Trace elements

Many other elements are present in coals but only in trace amounts. They are called trace elements. They are associated with both the organic and inorganic (i.e. mineral matter) portions of coal. Early interest in trace elements in coal stemmed from the idea that they could be produced as possible byproducts of coal mining (germanium and uranium are two examples). Since the mid 1960's interest in trace elements was centered on the fear that toxic trace elements may be released into the environment, through coal combustion. Trace elements are also being examined with respect to hydrocarbon liquids, coke and other coal products. There is some evidence to suggest that trace elements may act as catalysts or inhibitors in coal conversion processes. Another new area of interest is, using trace elements to characterize individual coal seams to assist in seam correlations and in coal depositional environment research.

No Alberta coal companies specifically expressed an interest in trace element studies in coal. However, the Alberta Research Council has, over the past five years, received a few enquiries in this area. The Illinois State Geological Survey is presently looking at trace elements in coals and sees this as a future research activity. At present very little is known about trace element distribution at existing mine sites or throughout Alberta in general. Some data on trace element contents for fly and bottom ashed is provided by McCoy et al. (1981). Several mines have begun to collect trace element data, however, it has not been one of the standard components analyzed for in the past when collecting coal quality data. The Geological Survey of Canada has a five-year project dedicated to the composition of Canadian coals in which trace element composition of Western Canadian coals will be characterized and compared to depositional environments, coalification, tectonics and weathering.

## CALORIFIC VALUE

Calorific value or heating value is probably the single most important component in evaluating a thermal coal's potential. The rank of sub-bituminous and lignitic coals is determined by its calorific value (ASTM standard D-388). Many of the previously mentioned coal quality attributes (e.g. ash content and composition) affect the calorific value of a coal. The general distribution of calorific values of coals has been reasonably well established throughout the Alberta coal fields and to a limited extent in the deeper subsurface coals. Steiner et al. (1972), presents a map showing gross calorific values of Alberta coals based on 300 calorific determinations for all coal zones. Calorific value is one of the proximate analysis determinations that has been standardly performed in coal exploration for many decades. Information about calorific values for deeper, bituminous coal-bearing strata of the Plains region or for some regions in the foothills and mountains is not, however, available.

## MOISTURE

Moisture content determination forms part of a standard proximate analysis and can be reported in different ways. The moisture content of coal is directly related to the rank. Higher rank coals have, in general, a lower moisture content. Moisture causes three main problems to coal producers:

1) excess moisture uses up calories of useful heat to drive off the water.
2) moisture represents a useless weight to transport in the moving of coal.
3) moisture content will determine if spontaneous combustion problems will occur or not.
4) if moisture exceeds about 8 percent it can cause freezing in hopper cars and produce extra expense in chipping ice away.

The only regional assessment of moisture content in coals is the work of Steiner et al. (1972) who published an Alberta map showing average moisture contents of near-surface coal. This work was based on approximately 300 datapoints, many of which were in established mine sites or coal fields. Large data gaps occur in the deeper portions of the Alberta basin and in the northwest region of the province.

Excess moisture contents in Alberta coals were cited by three coal companies (Esso Resources, Denison Mines Ltd. and PanCanadian Petroleum Ltd.) as being a real problem which should be addressed. The problem is probably best addressed from a technological standpoint, i.e. attempting to discover effective and cheaper methods of onsite drying of coal. From a geological standpoint, better documentation of the moisture contents of all coal zones throughout the province could be undertaken.

## COKING PROPERTIES

Coking coal, which is used for steel production is exploited in the mountains of Alberta. They range from medium to low volatile bituminous in rank. Many tests can be used to evaluate the suitability of a coal for coke production (Ward, 1984). The simplest test is to determine the free swelling index (FSI). This test involves heating a small sample of crushed coal in a crucible to a temperature of around 800°C. After all volatiles are driven off, a small coke button remains in the crucible. The swelling of the coke button is compared with standards and expressed in numbers, where FSI=1 is no swelling and FSI=9 maximum swelling (ASTM standard D-720). The best coking coals have FSI's between 4 and 6, indicating the right combination of porosity and strength. Two other methods are often used in evaluating the mechanical properties of coke. The first one is by petrographic analysis, the second one by dilatometric determination (Ignasiuk, 1975).

Japanese steelmakers use a sixfold grouping of coking coal (Pearson, 1980), based on the various mechanical properties such as dilatation and strength. The rank of these groups are overlapping. Japanese coking blends are composed of all these groups in varying percentages. However, the technology of steel making is changing and the desired blends might in the future contain a larger percentage of lower rank coals. Nevertheless, it seems certain that bituminous coals will remain an important component of these blends.

## COAL FACIES STUDIES

Coal facies studies are a special type of sedimentological facies studies described earlier. This is a relatively new field and very little work in this area has been done on Alberta coals. The technique is usually applied over a relatively small outcrop region or at a mine site and involves preparing vertical maceral or coal quality profiles over an individual coal seam. This technique has been used in Nova Scotia to assist in seam correlations by characterizing the seams by their coal maceral lithotypes (Cameron, 1971). Maceral profiles can also be used to study the variations in environmental conditions during peat formation.

At least one coal company based in Alberta, Esso Resources, has used coal petrograpy in coal facies studies in order to develop a characteristic seam signature, similar to the work done in Nova Scotia. This technique is largely untried in Alberta and could hold great potential for in-seam coal correlations. The Geological Survey of Canada is planning on doing this kind of work in the near future (Kalkreuth, pers. comm.). Individual in-seam correlations have been mentioned by several Alberta coal companies as being very important. The possibility of increased use of selective mining in controlling the final coal quality would be increased through coal facies studies.

## FUTURE RESEARCH

A need is foreseen for increased research in coal quality and its prediction based on geological models (Appendix 3). This is in agreement with the Alberta Coal Research Strategic Plan (ENR, 1983) which supports research directed to improving the quality of Alberta coals. It is also in line with the research position of the coal industry (Coal Association of Canada, 1985) which supports research that develops increased coal utilization.

Rank gives an indication of possible utilization. Rank studies need to be extended to coals outside the established coal fields. These studies would also help in defining where low moisture coals are located. Petrographic studies (including maceral content studies) need to be undertaken because they define the texture of coal, which has a bearing on its utilization.

A better understanding of the factors controlling sulphur and ash distribution would be gained through documentation of their regional variation using geostatistics. Calorific values, though better understood in the province, would also benefit from such a study. Sodium and trace element concentrations in coals are only understood at specific mine sites in the province. A regional mapping program, combined with a geostatistical study, would help to fill in the gaps and provide a better understanding of why sodium and trace element concentrations are higher (or lower) in some coals. Variation in coking properties of Alberta coals could also be better documented in order to arrive at predictive models.

Coal facies studies need to be undertaken, in conjunction with sedimentological facies modelling to better predict coal quality, particularly at existing mine sites or coal fields. Very little work in this area has been attempted as yet in Alberta. This technique has been proven, in other parts of the world, to be a very useful aid in coal seam correlation, selective mining practices, and the prediction of coal quality.

## STRATIGRAPHY AND CORRELATION

One of the most fundamental problems in the early stages of assessing an area for its coal potential is to establish where the coals are within a succession of strata and how they are spatially connected. The progress of mapping of areas with coal deposits is shown in figures 16 and 17. Stratigraphy becomes a very important tool in establishing a framework whereby the geologist can make reasonable correlations of coal and rock units. The recognition of marker horizons, such as bentonites, tonsteins, coquina beds, or continuous sand beds is a necessary first step in establishing this stratigraphic framework in both surface and subsurface mapping. A stratigraphic framework is necessary at all levels of exploration, from reconnaissance to mine site planning. Once this stratigraphic framework is established, individual coal seams can be correlated and their lateral extent determined. Accurate stratigraphic correlations have far reaching economic implications. Incorrect coal seam correlations can lead to: production quotas not being met, reserve estimates being incorrect, and possibly having to alter mine planning and scheduling. Accurate stratigraphic correlations will also be very important if coal leases are eventually granted on a stratigraphic basis, as are oil and gas leases. Numerous legal disputes could arise as the result of incorrect correlations in this situation.

Stratigraphic correlations are undertaken using a number of different techniques. In regions where coal-bearing units outcrop, sections can be measured and correlated. Other techniques such as magnetostratigraphy and palynology can also be applied to surface exposures. In areas where no surface exposures are present, subsurface geophysical logs provide the basic correlation tool. Cores can also provide valuable subsurface stratigraphic information in these subsurface regions.

### PLAINS REGION

Stratigraphy and correlation problems within the Plains region

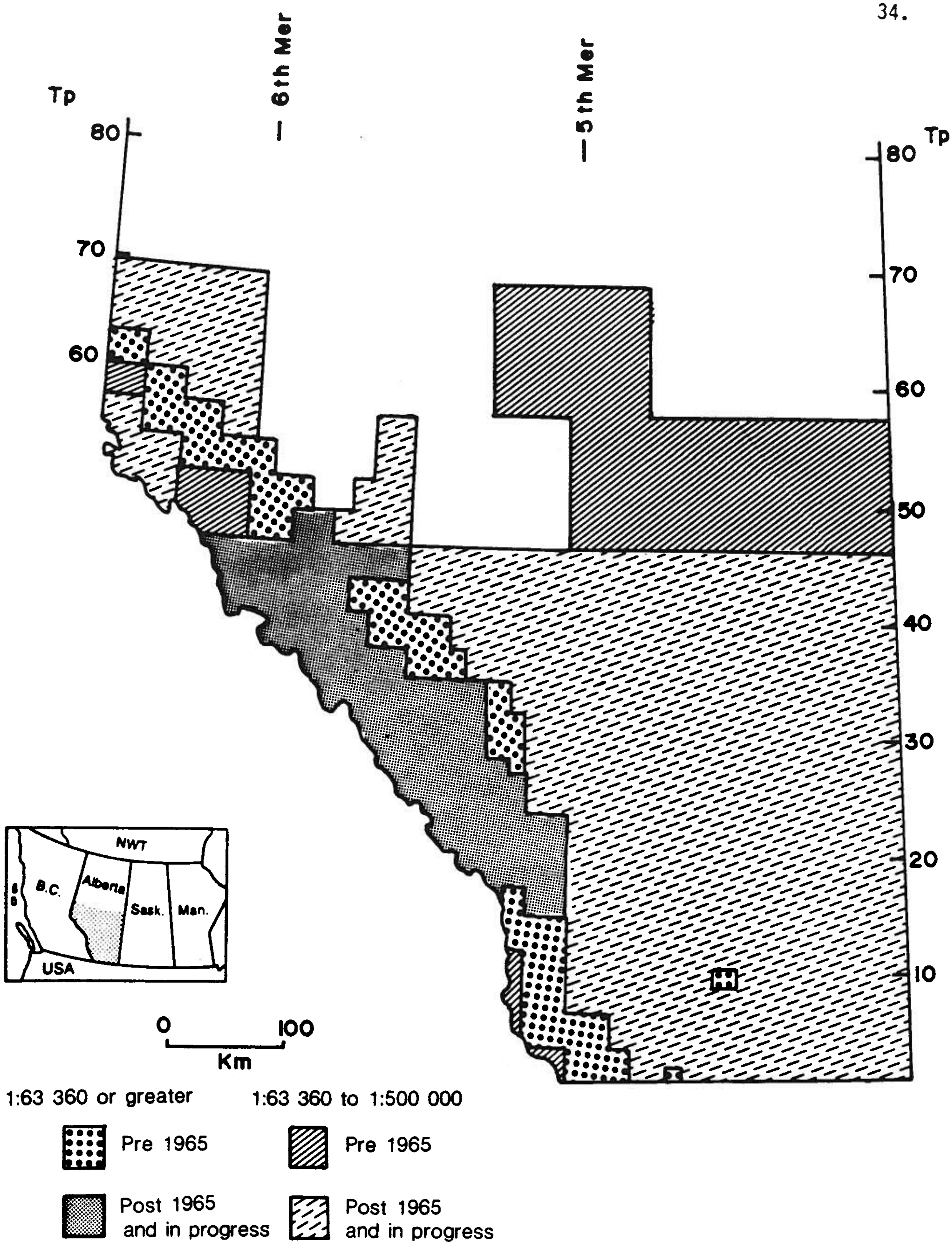
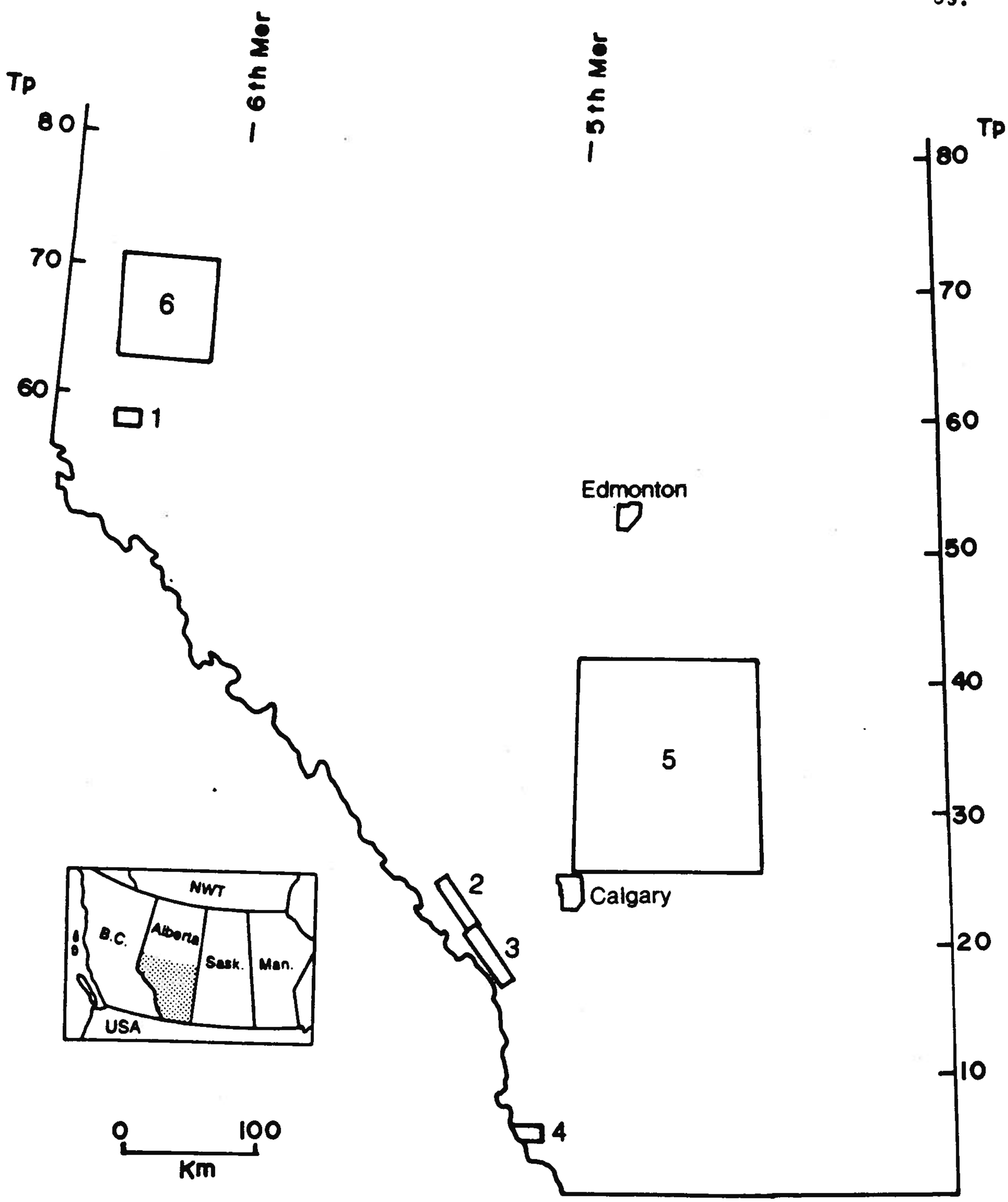



Figure 16. Map showing the areas of bedrock geological mapping performed by the Geological Survey of Canada.




1 Langenberg et al., in press — 1:15 000

2 Crockford, 1949
3 Allan and Carr, 1947
4 Clow and Crockford, 1951
} 1:63 360 or greater

5 Allan and Sanderson, 1947
6 Allan and Carr, 1946
} 1:63 360 to 1:500 000

Figure 17. Map showing the areas of bedrock geological mapping which includes information on coal performed by the Alberta Research Council.

will be discussed by geological unit (figure 1) in the following section.

Paskapoo Formation/Scollard Member

Regional stratigraphic studies of the Paskapoo Formation as a whole are not common. Most of the stratigraphic work undertaken is within the coal-bearing Scollard Member and lateral equivalents. The studies within the Scollard have been undertaken for two main reasons: 1) to better define the coal potential of the Ardley zone, and 2) to better define the Cretaceous/Tertiary time boundary, that lies near the base of the coal zone. Coal resource studies within the Ardley coal zone have mainly been undertaken by the Alberta Research Council (most recently Richardson, et al. 1986). Studies related to the Cretaceous/Tertiary boundary have largely been undertaken at the University of Alberta and the Geological Survey of Canada (Lerbekmo and Coulter, 1985; Jerzykiewicz, 1985). The techniques of magneto-stratigraphy, palynology, and geochronology are being used to define an absolute time line within the Scollard Member, hopefully providing better stratigraphic correlations.

The Battle Formation is a very distinct surface and subsurface marker horizon that is widespread throughout Alberta. Few other reliable, widespread markers exist within this part of the stratigraphic sequence, with the exception of a few bentonite horizons below the Battle Formation (Nurkowski, 1980).

Studies on individual seam correlations within the Ardley coal zone were included in most of the resource evaluation studies that were previously mentioned. Prior to the work by Richardson et al. (1986), it was widely believed that the Ardley coals were easily correlated throughout the basin and were divisible into an upper and lower unit. The work by Richardson et al. (1986) showed that this simple two-fold division was only applicable, if at all, in the eastern near subcrop region of the Ardley coal zone. Coal correlations in the deeper regions of the zone, i.e. to the west, are much more complicated. Two small regions had detailed coal seam thicknesses, geometry and partings mapped in the study by Richardson et al. (1986). Very little is known of the detailed coal correlations at the Obed coal zone, except for what has been done by the operators of the mine, Union Oil Ltd., and through a University of Alberta thesis currently in preparation (see Demchuk, 1986). Stratigraphic and correlation problems that remain to be solved within the Paskapoo Formation and the two coal zones are:

1) although stratigraphic markers are not common within the bulk of the Paskapoo Formation, this does not present a real problem in delineating the Ardley coal zone. This is because of the widespread occurrence of the Battle Formation in close stratigraphic proximity to the Ardley coal zone. The lack of markers is a problem in defining the Obed coal zone.
2) coal and rock unit correlations within the more western regions, are complicated by the fact that sedimentary rock units are wedge shaped, becoming thicker in the west where basin subsidence was greater.
3) the presence of extensive fluvial channel deposits that have cut out or were laterally equivalent to coals, cause difficulty in coal correlations.

## Bearpaw/Horseshoe Canyon Formations

Three major coal zones are found within the Bearpaw/Horseshoe Canyon Formations: a lower Basal zone (McCabe et al. 1986), the Drumheller/Clover Bar zone, and the Carbon-Thompson zone (Gibson, 1976). A large number of papers has been written on the Horseshoe Canyon and Bearpaw Formations. Among the earlier publications the work by Allan and Sanderson (1925) should be noted. Detailed studies have also been undertaken in recent years (Hughes, 1984). The Geological Survey of Canada has tended to undertake this latter type of study, while the Alberta Research Council has tended to undertake coal resource evaluation studies on a wider regional basis. Many of the general stratigraphic relationships of the Bearpaw/Horseshoe Canyon Formations have been revealed by these studies.

Marker horizons within the Horseshoe Canyon continental sediments tend to be scarce. Near the base of this sequence the tops of coarsening-up cycles, marine shale beds, and the top of the underlying Belly River Group are common markers. Near the top of the Horseshoe Canyon Formation, the Battle Formation and a few ash horizons form the only reliable markers. Stratigraphic correlation problems include:

1) lack of reliable markers within the clastic continental sediments.
2) difficulty in recognizing the unit in the western and northwestern regions, whenever the marine shale units are not present.
3) stratigraphic problems related to the interfingering continental, marine, and near-shore marine sediments.

Individual coal seams within the Horseshoe Canyon/Bearpaw series, have been correlated with some success within small study areas near the outcrop edge (e.g. Hughes, 1984). Very little is known of individual coal seam correlations at deeper stratigraphic levels. Many earlier workers on coal correlations in this sequence, had erroneously correlated seams from as far apart as Edmonton to Drumheller with only a few wells for control. It is now realized that coal correlations within this sequence are much more complex, requiring a much closer spacing of data points to be accurate. The detailed studies being undertaken by the Geological Survey of Canada within the established coal fields, will likely go a long way to providing detailed seam correlations in local areas. Recent regional studies undertaken by the Alberta Research Council (e.g. McCabe et al. 1986, Nurkowski, 1980) have provided general guidelines as to how coals within the Horseshoe Canyon/Bearpaw series, should be correlated.

## Belly River Group

Stratigraphic relationships within the Belly River Group were established from surface outcrops in southern Alberta during the early half of the century. More recently, McLean (1971) provided a regional synthesis of the subsurface stratigraphy of the Belly River in the southern Plains region. A number of coal resource evaluation studies undertaken by the Alberta Research Council (most recently Macdonald, et al. 1986) have helped to further refine the stratigraphic understanding. The latter study has had the largest scope in terms of geography and data point density.

Marker horizons related to the Belly River are generally found immediately above or below the unit, e.g. top and base of the Belly River Group or top of the Colorado Group. The three coal zones within the Belly River Group provide approximate stratigraphic placement within the sequence. Problems that remain in the stratigraphic understanding of the Belly River Group include:

1) few reliable markers, except the coal zones, are present within the Group.
2) the Belly River Group can be recognized into two mappable sub-units within southern Alberta, i.e. Oldman and Foremost Formations. This subdivision cannot be recognized in central and northern Alberta.
3) to the west and northwest of the central Plains area, the entire group cannot be distinguished from the overlying Edmonton Group, due to the absence of any recognizable marine strata. Again, the uppermost coal zone (Lethbridge) often provides approximate stratigraphic placement.
4) the presence of interbedded marine and brackish water sediments within the continental sequence causes correlation problems.

In the area of individual coal seam correlations within the Belly River, few of the aforementioned studies have been successful in showing laterally persistent, easily correlated coals within the unit. This may be due to the very nature of the seams and/or the data density of the studies done to date. The general geographic distribution of the three coal zones is also very poorly understood in the shallow (i.e. less than 200 m) surface mineable regions of central and northwestern Alberta.

In northwestern Alberta, the Belly River Group and Horseshoe Canyon Formation are difficult to separate because the marine Bearpaw Formation disappears. The stratigraphic interval, which is equivalent to the Horseshoe Canyon Formation and Belly River Group combined is known as the Wapiti Formation in this part of Alberta (Allan and Carr, 1946).

Mannville Group

The Mannville Group is not generally thought of as one of the main economic coal-bearing units in Alberta. The coals that do occur are generally found at very great depths throughout central and southern Alberta. Many papers have been published on the Mannville Group because of its importance in being the main reservoir rock for the oil sands deposits in northern Alberta and being an oil and gas reservoir in the Lloydminster and southern Alberta regions (Hayes, 1986). Marker horizons within the Mannville Group are usually based on marine shale units, locally continuous coal seams, or the tops of coarsening-upward cycles. Stratigraphic correlations are complicated in the Mannville Group because of a number of factors:

1) the formation overlies a major unconformity that separates Paleozoic from Mesozoic age strata and so there exists a great deal of paleo-topography that has influenced the continuity of sedimentary units.
2) there is thought to be a variety of sediment source areas that contributed to the Mannville sequence.
3) near-shore and restricted marine sediments are interbedded with the predominantly continental Mannville Group sediments.

Very little has been done on establishing individual coal correlations within the Mannville Group. The Alberta Research Council included an examination of Mannville Group coals (Yurko, 1976) in a regional synthesis of subsurface coals. It was concluded that the coals were mostly found within the upper part of the unit and were generally difficult to correlate due to lateral variability and lenticularity of seams. However, one major coal seam in central Alberta was shown to have good lateral continuity and was easily correlated.

## MOUNTAINS AND FOOTHILLS

Part of the coal-bearing strata in the Western Canadian Sedimentary Basin have been involved in movements that created the Rocky Mountains and its foothills. Although the rocks of the plains can often be correlated with rocks in the foothills, a different nomenclature for the plains has evolved (figure 1). The Paskapoo Formation is a notable exception, because it is continuously exposed from the plains into the foothills.

Economically viable coal seams occur in the foothills and mountains in three stratigraphic intervals; the Kootenay Group, the Luscar Group and the Coalspur Formation. They are designated as Kootenay, Luscar and Coalspur coal respectively.

### Kootenay Coal

Alberta's oldest coal-bearing strata belong to the Jurassic-Cretaceous Kootenay Group, found in the southern foothills and mountains. Some older mapping by the Alberta Research Council was performed in areas of Kootenay Group outcrop (Allan and Carr, 1947; Crockford, 1949; Clow and Crockford, 1951). The Kootenay Group has been recently described by Gibson (1985). From two to eight coal seams are present (excluding seams thinner than 1 m), with some up to 10 m thick. Correlation of individual seams is often very difficult, even between closely spaced sections (Gibson, 1985, p. 42). The thickness of individual seams is also very variable, which compounds the correlation problems. In general, there is a reduction in thickness of the Kootenay Group from west to east, accompanied by a proportional reduction in the number of coal seams. Gibson's work was regional in nature. More detailed work will have to be done, for example, in the Coleman-Blairmore coal field to establish better correlations. These correlations can be expected to be difficult because of the nearshore environment of the lower part of the Kootenay Group (Hamblin and Walker, 1979). In the southern Alberta plains, the Kootenay coals are buried deeply. The evaluation of their potential has not been attempted, except for preliminary work on coal rank by the Geological Survey of Canada.

## Luscar coal

Early Cretaceous, generally non-marine strata overlying the Nikanassin Formation (equivalent to Kootenay Group) in the central and northern foothills, are known as the Luscar Group. The group comprises of the Cadomin, Gladstone, Moosebar and Gates Formations (figure 1). The principal coal-bearing unit is the Gates Formation. The number of Luscar coal seams ranges from two to nine.

Correlations of the major coal seams within individual coal fields are reasonably well established. An example of these correlations is provided by the mapping of Langenberg et al. (in press) in the Smoky River coal field. In other coal fields of the mountains and foothills (such as the Cadomin-Luscar coal field) these correlations have been established by coal companies and university research teams. However, these correlations have not been made public except for unpublished university theses. Detailed correlations of coal seams in the coal fields of the mountains and foothills need to be published.

Much less is known about correlations between individual coal fields. The 1:50 000 scale mapping has been traditionally an area of concern for the Geological Survey of Canada. For this reason close cooperation with the GSC is required to establish areas of research. In this context it is important to notice that the GSC sees detailed mapping and correlations of coal seams in the foothills as an area of concern for the Alberta Research Council (Appendix 1).

## Coalspur coal

Coal occurs in the Coalspur and McLeod River coal fields in the

Coalspur Formation (Jerzykiewicz, 1985), which forms part of the Saunders Group (figure 1, p. 3).

Correlations between individual coal seams are well established in the Coalspur and McLeod River coal fields, where the lowest seam (the Mynheer seam) is situated just above the Cretaceous-Tertiary Boundary (Jerzykiewicz, 1985). Not so well established is the correlation with individual coal seams of the plains region, although it is known that the coals of the Coalspur Formation correspond to the Ardley coal zone of the plains (figure 1). Correlations with coals of the Jarvis Lake coal field have not been published either. Relatively little work has been done in the central foothills west and northwest of Rocky Mountain House. Before the potential of these areas can be assessed, accurate correlations of the seams have to be established.

## FUTURE RESEARCH

### Plains

The regional reconnaissance scale determination of the stratigraphic framework of the major coal zones in the plains region of Alberta is now complete. This has been done for coals down to a depth of 400 m in the deeper parts of the Alberta Basin. Individual seam correlations at this scale are generally not practicable and have not been attempted.

The next logical step is to undertake more detailed mapping of the major coal zones. In this analysis, individual seams would be correlated and mapped out. This step is being undertaken by many U.S. state geological surveys (Illinois, Pennsylvania, West Virginia, Alabama, Texas, and New Mexico, Appendix 3), usually on selected areas within the state to start with. The Geological Survey of Canada is undertaking such a detailed mapping program within the near surface coals of the established coal fields. The Alberta Research Council has a proposal to examine the feasibility of future coal development in the plains region. It could include an evaluation of deeper coal resources that might possibly be exploited by underground methods.

The Alberta coal industry holds varying opinions as to when underground mining will become feasible in the plains, with estimates varying from 10 to 30 years in the future. The whole problem hinges on economics. For example, there was very nearly an underground mine in the Lethbridge area in the early part of this decade, however, market conditions killed the venture. Lead time to develop an underground mine can be as long as 10 years, so that the urgency of undertaking these detailed stratigraphic studies should not be underestimated.

Some gaps in regional work exist, e.g. the Mannville coals have only been examined in a very cursory manner, with no stratigraphic relationships worked out as yet. Similarly, insufficient data is available on regional correlations of coals of the Wapiti map sheet.

Foothills and mountains

Large areas of the mountains and foothills are still insufficiently mapped (figures 16 and 17). Areas for regional mapping should be determined in consultation with the Geological Survey of Canada. Areas that need particular attention from the point of view of regional mapping and correlations are the Nordegg coal field and the general area in between Nordegg and Coalspur. The Jarvis Lake coal field and the area in between Hinton and Grande Cache also need attention. The Crowsnest Pass area may see renewed activity in the near future and consequently, some work in this area could be considered.

The Alberta Research Council needs to continue to establish detailed correlations of coal seams and determine controlling factors on seam geometry in selected areas of the mountains and foothills. Areas where this can be attempted are the Cadomin-Luscar area and parts of the Wapiti map sheet.

## STRUCTURAL GEOLOGY

In the mountains and foothills (and sometimes the plains) the structural position is an important factor in the mineability of coal. The structural complexity in these areas pose a challenge in mine design for the mining engineers. Fractures are often a major concern in the design of pit slopes. During exploration a thorough understanding of the structural geology is of utmost importance because a coal seam can easily be missed in drilling of a deformed terrain. The coal seam can either be too deep or the drillhole may have been started stratigraphically below the coal seam. On the other hand, the structural position may cause the coal seams to be structurally thickened. These coals form major exploration targets.

Over the last few years detailed mapping in individual coal fields (for example, Charlesworth and Gagnon, 1985 and Langenberg, 1985) has provided deformation models that may be tested elsewhere. These studies have been supported by computer software, developed at the University of Alberta, that enables the plotting of maps and cross sections. This software provides a powerful tool in establishing the three-dimensional geometry of the coal seams, which is the first step in a successful exploration program.

### MAPPING

In the past, the coal industry has benefitted immensely from maps produced by the Geological Survey of Canada. These maps indicated where the coal-bearing strata occur and often indicated coal outcrops. However, in a successful exploration program, more detailed mapping has to be done. Individual coal seams and other marker horizons have to be mapped and drillhole locations have to be selected.

Recognition and tracing of marker horizons is very important. Their distribution helps to correlate coal seams and delineates the geometry of the area. From this information, together with data from drillholes, the large-scale structure of each seam can be displayed on geological maps, cross-sections and structure contour maps. Although some of this mapping is performed by the coal industry, these maps are not made public. Detailed maps and cross-sections such as those at a 1:15 000 scale in Langenberg et al. (in press) from the Smoky River coal field form an important model for exploration elsewhere. The majority of responses of coal companies in the questionnaire indicate that they want the Alberta Research Council to carry out this detailed mapping. This position was also strongly endorsed by the Geological Survey of Canada (Appendix 1) and the Canadian Geoscience Council (Rutter et al. 1984).

## GEOMETRY AND PREDICTION OF COAL LOCATIONS

The geometry of individual coal seams can be used to predict the location of coal in areas of limited exposure or in areas where the stratigraphy is unknown. The model of cylindrical folding, for example, is well established in the mountains and foothills. This model can be used in the construction of cross sections (Langenberg, 1985) where information gathered from surface exposure is projected into the subsurface. The cylindrical fold model can also be used to obtain extra elevation points on the coal seam for the construction of structure contour maps in areas of limited drilling (Langenberg, 1985). This methodology has been successfully applied in the Smoky River coal field (D. Fawcett, Smoky River Coal Ltd., pers. comm.) significantly adding to existing reserves and in the Coalspur coal field (R. Engler, Luscar Coal Ltd., pers. comm.) where it resulted in future exploration models. The availability of microcomputer software enables the coal industry to use this methodology. Because it is a relatively new technique, it is not yet widely used. The Alberta Research Council could assist in promoting this technology in the coal industry.

## STRUCTURALLY THICKENED COAL

Coal which is structurally thickened, forms important exploration targets in the mountains and foothills. Structurally thickened coal has been known and mined many years ago in the Coleman-Blairmore coal field.

At Grassy Mountain, the coal is thickened to several times its normal stratigraphic thickness in the hinge of an anticline. This thickening is described in other areas of the Kootenay coals of southern Alberta (Bustin, 1985).

In the Coalspur coal field, coal has been thickened up to 20 times its stratigraphic thickness of 4 m by imbricate faulting and the resulting pods are mined at Coal Valley (Charlesworth and Gagnon, 1985). The thickening is related to the geological boundary of foothills and plains. Consequently, this boundary could become an exploration target south of the Coalspur coal field.

In the Cadomin-Luscar coal field, the coal is often thickened in the hinges of folds. The open pits of Gregg River Resources and Cardinal River Mines are generally situated along synclines with thickened coal.

In the Smoky River coal field, coal is thickened up to two times in the hinges of folds. Another exploration target is formed by thickened coal resulting from imbricate faulting (Langenberg et al. in prep.). The thickening can be up to three times its normal thickness, which results in very favourable stripping ratios. This type of thickening is generally present in the limbs of folds. It is not yet understood why it forms in some locations and not in others. The industry would be helped if it could be predicted where the thickening by imbricate faulting will occur, because this may become the major exploration target of the Smoky River coal field (and probably elsewhere) in the near future.

## FAULTING

The recognition of faults is very important because they cause major displacements of coal seams. They may explain why coal is present in some areas and not in others. Insufficient recognition of faulting during mine development may result in lower recovery and higher ash content than predicted. This can be very dramatic and costly as recently shown at the northeastern B.C. Quintette Mine. Shearing of coal that is related to faulting, had a profound effect on the coal quality in the Crowsnest Pass area (Bustin, 1982). These effects have not yet been studied in other areas, although Kalkreuth and Langenberg (1986) documented an increase in rank in the immediate footwall of a thrust fault in the Smoky River coal field.

Movement displacement transfer between folds and thrust faults occurs and the recognition may assist in finding locations of coal seams (Langenberg, 1985). The recognition of thrust faults is also important in developing burial curves and establishing regional coal rank patterns (Kalkreuth and McMechan, 1984).

GLACIAL DEFORMATION

Glacial deformation is present throughout the glaciated plains of Alberta (Moran et al. 1980). It has affected pre-glacial sediments to a depth of about 30 m. The glaciers have faulted and folded these sediments, and in places 100 m high thrust ridges were formed. These deformed sediments often form the overburden of coal in strip mining operations in the Alberta plains. Sometimes the coal itself is deformed. Glacially deformed sediments are fractured and as a result the natural strength of the rock is decreased. For this reason, glacially deformed sediments contribute to highwall failure in strip mines of the plains (Moell et al. 1985). Thrusts, folds and fractures are related to glacial advances to the south.

Deformation models obtained from deformed strata of the foothills can be applied to the glacially deformed sediments. The Alberta Research Council has expertise in both the deformed sediments of the foothills and the glacially deformed sediments of the plains. This combination of expertise makes the Alberta Research Council a natural choice for the development of slope failure models for plains strip mines. TransAlta Utilities has requested the Coal Geology Group of the Alberta Research Council to perform geotechnical studies of highwall failure for 1987-1988.

## FUTURE RESEARCH

Detailed mapping in established coal fields of the mountains and foothills should continue. The areas most often mentioned in the questionnaire are in decreasing order, the Cadomin-Luscar coal field, the Coalspur coal field and the Copton Creek part of the Smoky River coal field. A lot of information is available in the Cadomin-Luscar area, that has not yet been summarized. Models developed in this area will have predictive capabilities elsewhere. A structural study of the Copton Creek property could be combined with a coal quality study because coal quality variations in this area are insufficiently documented. Research needs to continue in the areas of prediction of coal locations and structurally thickened coal.

The development of a model of structural thickening of coal is of great importance to the industry because it will define exploration targets. Shearing of coal from faulting effect the coal quality and needs to be further investigated. Structural fabrics of glacially deformed coal and overburden of the plains could be further studied.

# SEDIMENTOLOGY

Sedimentology is the study of sedimentary rocks and the processes that formed them. In the past 15 or so years there has been a proliferation of studies in geology dealing with sedimentology and facies models. This came about because of the realization that rock units within a stratigraphic sequence are not laterally continuous in a layer cake fashions, as was previously believed. The same held true for coal seams, i.e., although they were often perceived to be laterally continuous over large areas, more detailed studies showed that this was not always the case. By studying modern day sedimentary depositional environments it was realized that the ancient rock record must have more complexities to it than was previously believed. This had a profound effect on stratigraphy and the way in which rock (and coal) units were correlated. Facies models can be defined as a general summary of a specific sedimentary environment. Facies models must also fulfill four other functions (Walker, 1984):

1) it must act as a norm for comparison purposes.
2) it must act as a framework and guide for future observations.
3) it must act as a predictor in new geological situations.
4) it must act as an integrated basis for interpretation of the environment it represents.

With respect to coal exploration and development, facies models are most useful in:

1) helping to provide a correct stratigraphic framework within which coal seams can be correlated.
2) predict variations in floor and roof rock.
3) predict variations in seam thickness.

The geometry and thickness of coal seams in the plains region can, to some extent, be predicted based on facies models. It may also be possible to predict the roof and floor rock conditions in underground mines by developing models. Predictions of geological parameters, such as those outlined, have produced significant economic savings in exploration or mine site development work in the U.S. (Ferm, 1974, Horn, 1978).

The following section will outline the three major depositional environments that are thought to be the most important in Alberta's coal-bearing sequences.

DELTAS

Rahmani and Hills (1982) describe a tide dominated delta model for parts of the Horseshoe Canyon, Drumheller/Clover Bar coal zone in the Drumheller area. Hughes (1984) describes a fluvial dominated delta setting for the same coal zone in a detailed study of the Dodds-Roundhill coal field. Differences between these models can be attributed to either real geological differences between the areas, or a difference in amount of available information. The coals in the Belly River Group were thought to have formed in a delta setting by McLean (1971).

The delta type model suggests that coals will be thickest away from distributary channels, and will also thin in a seaward direction. Ash content will also be highest in locations proximal to paleochannels, and seam splitting generally, becomes more common toward channels and in a seaward direction. The overall geometry of individual seams is also likely to be pod-like, being bound by individual channels, and perhaps slightly elongated in the paleoslope direction. Sulphur content is often predicted to be highest in those seams that underlie strata deposited in marine type subenvironments of the delta model.

FLUVIAL PLAINS

A fluvial environment is suggested by Richardson et al. (1986) and Dawson et al. (1985) to explain the Paskapoo Formation, Ardley coal zone. Similarly, in the foothills, Jerzykiewicz (1985) has also suggested a fluvial model for the equivalent Coalspur beds. Nurkowski

(1980) suggests a fluvio-lacustrine model for the upper Horseshoe Canyon Formation, Carbon-Thompson coal zone.

A unique set of coal thicknesses, coal quality and geometric patterns can be predicted from a fluvial model. Geometry of individual seams tends to be elongate, parallel to paleochannels. Lateral continuity of seams, tends to be over very short distances, within the fluvial model framework. Seam splitting is predicted to increase in abundance and magnitude towards paleochannels. Sulphur contents tend to be low within fluvial coals.

COASTAL PLAINS

In Alberta, the coastal plain model has been used to explain part of the Drumheller/Clover Bar coal zone of the lower Horseshoe Canyon Formation (McCabe et al. 1986) and the Belly River Group coals (Macdonald et al. 1986). Langenberg et al. (in press) suggests a low energy coastal plain or delta plain as possible facies model for the coal-bearing Grande Cache Member of the Gates Formation.

The coastal plain model suggests that the thickest and cleanest coals will be found landward of any paleo shoreline. The geometry of individual seams or whole zones will likely be controlled by the paleo shoreline, i.e. the major coal trends will likely be parallel to shorelines. McCabe et al. (1986), suggests that the optimal location for coastal peat swamps (and later coals) to form would be some 40 km or so inland from the coastal shoreline. Because of the close associaton with marine environments, many of the coals might be expected to be relatively high in sulphur content. The number of splits and ash content are predicted to increase in a seaward direction from the region of maximum seam development.

FUTURE RESEARCH

A problem faced in the widespread adoption of facies models to coal exploration in Alberta is the small number of facies studies. In the eastern United States, extensive coal facies studies have been undertaken in most of the mature coal basins and their value is recognized by the coal industry. In Alberta, the value of facies models used in coal exploration is generally not recognized. The oil and gas industry in the province uses facies models very successfully. More facies studies need to be undertaken in the future and the economic importance to the coal industry must be demonstrated. When underground mining of plains coals becomes economic in Alberta, it will be absolutely essential that facies models be developed in order to predict seam and enclosing rock thickness variations.

Several U.S. state geological surveys contacted (New Mexico, Illinois, and Texas) and the Geological Survey of Canada undertake facies and depositional environment studies in support of their coal programs (Appendix 3). Difficult economic times in the coal industry, worldwide, have perhaps discouraged facies studies in favour of more immediate activities (e.g. regional mapping and seam correlation problems). This is unfortunate as facies studies can be a very powerful predictive tool in coal exploration. None of the coal companies contacted listed facies studies as an activity their company undertook, however, two companies (Unocal Canada Ltd. and Manalta Coal Ltd.) suggested that they would like to see the Alberta Research Council provide information on facies studies. Manalta Coal Ltd. suggested applying facies models to predicting coal quality variations. Understanding of the Ardley, Lethbridge, Taber and McKay coal zones would benefit from this type of study, as would regions of the foothills and mountains.

# COAL DATABASES

Electronic storage and manipulation of coal data has become common place. There are, however, a multitude of different standards, electronic storage and retrieval techniques, and manipulative methods. What is meant by database can vary widely from a straight analogue of paper files to relational or hierarchial data structures that allow complex inquiries. At present, much of the publicly available information on coal exists as data files. Data files by nature tend to have a limited lifetime and have been produced to meet the needs of a specific request or project. At the end of the project, the data can be cheaply stored on magnetic media. However, as is often the case, the lack of documentation limits any future potential use. The maintenance of an ongoing database is often very expensive, but the potential long-term savings for an organization can be substantial. Coal databases are a type of geographic database. They could evolve into a Geographic Information System (GIS).

## ENERGY RESOURCES CONSERVATION BOARD (ERCB)

The ERCB is required under the Coal Conservation Act to provide for the appraisal of Alberta's coal resources and for the recording and useful dissemination of data and information relating to the exploration for coal and the occurrence, reserves, quality, production, transportation, processing and use of coal in Alberta.

The ERCB has a publicly available Coal Hole Data File. The file contains the identification, location and descriptive information for drillholes in Alberta licenced since 1972. Only non-confidential data is publicly available, including coordinates, ground elevation, drill date, company, mechanical logs and analysis. This file also contains outcrop and excavation data. A file containing description of the coded data is also available. Other files, such as the Well Log File, although not specifically directed towards coal information, contain much information that can be used by the coal geologist. The coal hole data file has been constructed to allow the inclusion of many data elements, particularly those concerned with coal quality. At present, the database contains more than 118,000 records, mainly detailing the location and descriptive information (such as lithology and logs available) and some analysis (W. of the 4th meridian) for the 47,500 coal holes. The ERCB also holds considerable interpreted information related to coal geology that is not currently publicly available.

## ALBERTA ENERGY

Alberta Energy is involved in energy policy making within the province and has the responsibility for the administration of the acts previously assigned to the Department of Mines and Minerals. Hence the administration of the disposition of coal leases and the authorization to occupy fall under its jurisdiction. Although Alberta Energy does not have a database specifically dedicated to coal resources, two large databases include coal related information. The Mineral Agreements Information System (MAIS) commenced operation in 1978 and contains information such as location and ownership on over 40,000 agreements (not all coal related). The Land Status Automated System (LSAS) contains information on public lands surface records and is being expanded to encompass subsurface records. The two databases are essentially non-graphic and contain attribute information (eg. agreement details). Graphic or locational information directly related to these and other databases form part of a common map database which is itself part of a larger concept, the Natural Resources Information System (NRIS). NRIS is a pilot scale geographic information system which is in turn part of a concept of linked GIS for Alberta which will include all information on geology in Alberta and is termed the Land Related Information System (LRIS). The GIS concept and possible roles in coal geology research will be discussed later.

## ALBERTA RESEARCH COUNCIL

The Alberta Research Council has a series of data files containing locational information, geologic picks, and coal seam tops and bottoms for over 5,000 oil, gas and coal exploration holes. For the most part, the information held by the Alberta Research Council extends far past the present coal lease areas and to much greater depths than normally found within the lease areas. These data files were constructed as part of projects mapping the regional extent of Alberta's coal resources down to a depth of 400 m. Some information on resources at depths greater than 400 m is also available. Most of the information on the database is unique and not duplicated in any other database in Alberta. No update of the Alberta Research Council coal data files has been planned.

GEOLOGICAL SURVEY OF CANADA

The GSC's National Coal Inventory program is involved in the construction of computer databases containing all available geological data for coal fields. In Alberta, locational information from approximately 30,000 of 47,000 exploration bore holes has been compiled, interpreted and entered into the database. This information comprises lithologic, sedimentologic and coal quality data collected using a consistently defined set of procedures which have been applied across Canada (Hughes, pers. comm.). The coal information, however, constitutes only 30 percent of the total information available for the province. The GSC estimates that more than 40 person years of compilation and data entry of Alberta coal data remains. At the present level of effort this task will take more than 10 years to complete. The data sets can be grouped into three categories: identification (50 items), lithology (50 per hole) and analysis (up to 100 per hole). Each borehole or outcrop location is completely identified as to location and related logistic information. A series of lithologies derived from geophysical logs have been compiled. Any analysis available for the hole are then recorded (Hughes, 1984). Specialized retrieval routines and ad hoc inquiries are possible using the GSC database system. Information can be electronically uploaded or downloaded by computers over normal communication lines. Sequential files outputted from the database can be used by other computer programs for data manipulation and display. A joint agreement was initiated between Energy, Mines and Resources (of which the Geological Survey of Canada forms part) and Environment Canada for the evaluation of surface mineable coal resources in Canada through the use of a GIS system. This initial five-year interdepartmental agreement began in October 1982. The Geological Survey of Canada uses a combination of mainframe and microcomputers to support their databases.

LEVEL OF ACTIVITY OF OTHER PROVINCES AND STATES

The results of the survey sent out to other provincial and U.S. state geological surveys showed that most organizations do maintain a computerized coal database (Appendix 3). The Ohio Department of Natural Resources, Division of Geological Survey and the Arizona Geological Survey do not have coal databases. The geological surveys of Pennsylvania, Alabama, and Wyoming have less than 25 percent of their coal data on databases and in most cases these organizations are in the initial phase of a coal database. The remaining surveys (Geological Survey of Canada, B.C., Department of Mines, Saskatchewan, Illinois, West Virginia, Texas and New Mexico) all have a major portion of their coal data on a computer database.

The B.C. Department of Mines has some 17,000 outcrops and about 2500 boreholes on their database. The Saskatchewan Geological Survey's coal database has been inactive since 1978 and is currently held by the Geological Survey of Canada.

In the United States, among the previously mentioned major coal database holders, West Virginia and Illinois have over 20,000 datapoints (drillholes and outcrops) stored in their systems, with as many as 400 data items/datapoint. Texas and New Mexico have less than 5000 datapoints in their databases. Most of these state surveys collect outcrop data, borehole data and coal quality data. The two major database holders (West Virginia and Illinois) have continuous update programs for their databases, the other two update their data when needed. Most of these four U.S. database holders use main or mini-main frame computers, with some using additional support through microcomputers.

## GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) can give the coal geologist new ways to manipulate and display coal information. A geographic information system (GIS) is a specialized computer system consisting of hardware and software to which special consideration has been made for the treatment of geographic data (Levinson, 1985). The geographic data consists of two basic components; location and attributes which can be a value, name or classification. The main advantage of GIS for coal geology lies in its abililty to manipulate information about coal, other natural resources and non-resource oriented information such as leases and ownership. It offers another research tool for the geologist and is a needed tool for resource managers. The potential of GIS for coal geology information is directly related to the establishment of a comprehensive coal database or databases with easy exchange capability for Alberta coal information.

## FUTURE RESEARCH

An effort could be made to standardize and coordinate all Alberta coal geology databases to enable interchange of data with other organizations. As a custodian of current geological data pertaining to Alberta, the Alberta Geological Survey should take optimal advantage of the use of computers in storing and manipulating coal geoscience data (Rutter et al. 1984).

Coal information could become part of a GIS. The full capabilities of a GIS for coal geology need to be researched. New ways of looking at coal could be explored and products presented to researchers, the coal industry and resource managers in government.

The Alberta Geological Survey as part of the Alberta Research Council could advance into the area of applied technology. It could develop computer software, perhaps with industry, that will analyze geological data in unique ways and that could be sold on the open market. At present the Alberta Research Council puts considerable effort into the development of in-house programs often built around commercial programs. The resources of the Computing and Advanced Technologies Departments of the Alberta Research Council could be joined with the Geological Survey expertise, resulting in applied technology transfer related to coal geology. The market for geological software for microcomputers both within and outside Alberta is large and growing. The Alberta Research Council could assist in advancing Alberta's resource related applied technology.

# GEOPHYSICS

Geophysical methods are well established as an essential component in petroleum exploration. They have taken longer to get accepted by the coal industry, but are now playing a critical role in many coal field investigations.

## DOWNHOLE GEOPHYSICS

### Borehole logging

Geophysical logging techniques delineate the coal beds and provide useful data on thickness and depth. They also provide lithologic identification of neighbouring beds. These techniques are well established in the coal industry. A comprehensive overview is provided by the Coal Mining Research Centre (Hoffman et al. 1982).

### Downhole coal quality

Coal quality is usually determined by laboratory analysis of core or outcrop samples. However, geophysical logs are now starting to be used. These techniques have been developed by logging companies and some of the methods are explained in Appendix A of Hoffman et al (1982). It is reported that ash content and heating values can be determined within 1.5 percent and 1160 Kj/kg (500 Btu/lb) of laboratory values.

More research is needed to investigate the correlations between downhole and laboratory coal quality data and the control of geological parameters on the accuracy of downhole quality determinations.

### In-seam seismic

Seismic waves, guided by a seam, especially waves of Love type, have proved to be useful in the exploration of coal (Krey, 1976). These surveys are used to fill in areas between outcrops or drillholes. They are especially useful in detecting faults and channeling. The method has not been used very often in Alberta, but may see increased use in problem areas of possible faulting and washout in detailed coal field studies. However, it is also possible that the same information can be obtained from surface geophysical methods.

## SURFACE GEOPHYSICS

Data from regional surface geophysics surveys may be used, together with data from field mapping, to design a drilling program. An initial drilling program may be followed by surface geophysics surveys with higher resolution potential. The latter type of surveys are the areas presently being investigated and used in Alberta. Consequently only high resolution surface techniques will be discussed in this section on surface geophysics. A joint venture between industry and government is presently investigating these techniques applicable to surface coal mines in Alberta (Green, 1985).

### Electromagnetic methods

Several electromagnetic methods exist. Some examples are the EM (fixed frequency), the TEM (transient induction) and the DC (direct current) methods. In the EM and TEM methods a transmitter coil is used, while in the direct current resistivity method current is driven into the earth.

The versatility of these methods will be determined by the surface geophysics joint venture mentioned above.

### Seismic methods

Both reflection and refraction techniques are being tested by the joint venture in the plains of Alberta. Seismic data can establish fine structure and lateral continuity of seams. A facies analysis of coal-bearing strata can be performed from seismic data (Lawton, 1985).

In the near future surface geophysics will be investigated by the joint venture in the structurally complex mountains and foothills. At that stage it would be very beneficial if the expertise in coal geology of these regions of the Alberta Research Council would be used.

Very low frequency resistivity (VLF)

The VLF method uses radio waves. In general the exploration depth is less than 10 m. Its applications in the plains are investigated by the joint venture. Application in the mountains has been investigated by Smoky River Coal Limited (1985), partially funded by the Alberta/Canada Energy Resources Research Fund. It was shown that VLF can provide a great deal of stratigraphic and structural information during exploration of complex mountain coal properties.

Magnetic methods

Magnetic surveys can be used for general structural mapping and for mapping burned coal seams. These methods are not used extensively in Alberta.

Gravity methods

Gravity methods can be used to map the extent of sedimentary basins. In Alberta there is generally not enough density contrast to apply these techniques.

FUTURE RESEARCH

In downhole geophysics, research is needed on the influence of geological parameters on the accuracy of downhole quality determinations from geophysical logs. This work could be performed by the Alberta Research Council as part of the proposed project on the feasibility of future coal development in the plains. Some work on in-seam seismic might also be included in this project.

Surface geophysical methods in the plains will be adequately covered by the present joint venture. However, when the joint venture starts working in the mountains and foothills it is strongly recommended that the Alberta Research Council expertise in these regions of Alberta will be utilized.

# RESOURCE AND RESERVE CALCULATIONS

Most coal geology studies ultimately contribute to better evaluations of the resource. Along with coal quality an estimation of the amount of coal available is of primary concern to both industry and government. Reliable estimates of resource are necessary for economic evaluations and planning. There are, however, many ways to estimate in-ground coal resources. In Alberta there are several classification schemes currently in use. The two major schemes are the Canadian Coal Resource Classifications Scheme (Williams and Murphy, 1981; Irvine, 1981) employed by federal government departments and the ERCB classification scheme (ERCB, 1984). Unfortunately the terminology differs between the two schemes and a direct correlation between the two systems is not possible (Romaniuk and Rushton, 1985). These schemes, no matter how well defined, are open to different interpretations resulting in widely varying estimates of coal tonnages. For example, an estimate of the recoverable coal reserves for the Alberta plains varied from more than two gigatonnes reported by Bielenstein et al. (1979), to less than one gigatonne by Romaniuk and Naidu (1983) because of a more stringent definition of reserves. Terms within the individual schemes can be combined in different ways resulting in a wide range of resource estimates. Ideally the methods and schemes used in estimating coal resources should be standardized so that comparable estimates by different workers could be calculated from compatible data sets.

The Coal Association of Canada has produced a draft of standards (pers. comm.) for reporting coal resources and reserves. This classification scheme is closest in character to the Canadian Coal Resource Classification Scheme. The future of this scheme is as yet uncertain.

The United Nations Economic and Social Council is encouraging member nations to follow the United Nations International Classification of Mineral Resources Scheme (United Nations, 1984). This scheme is in response to a proposal originally submitted by Canada concerning the need for a common set of definitions of terms. The scheme again differs from any scheme currently in use in Alberta.

The Alberta Research Council is not specifically involved in reserve calculations although it cooperates with and provides geoscience information to other provincial organizations. However, in the past estimates of inferred resources based on a modified United States Geological Survey Classification Scheme (Strobl et al. 1986) have been used.

## RESOURCE ESTIMATE CONCEPTS

In North America it is generally agreed that the term resources includes all coal that may conceivably be of value to mankind, either now or sometime in the future and that the term reserves refers to material that is actually known to be usable under the technical and economic conditions prevailing at the time the assessment is made (Ward, 1984). Internationally, in areas where Alberta markets coal, the terms resources and reserves may give rise to confusion. The term reserves has been eliminated from the United Nations International Classification of Mineral Resources Scheme, because in some languages only one term was available or both terms had virtually the same meaning. The term resource in the United Nations Scheme includes what is commonly accepted as reserves in Alberta.

All classifications schemes take into account economic factors and geological assurance, determined by borehole spacing, seam geometry and geologic complexity. Location, mining method, quality, thickness, depth and rank are the main physical economic factors. Current market price influences reserves more than any other single factor (Romaniuk and Rushton, 1985).

The criteria used for establishing the level of geologic assurance vary between the classification schemes. Even within individual schemes location, depth or rank can influence geologic assurance. For example, coals in the plains region of Alberta are evaluated differently than those in the mountains. Although precise definitions are available and evaluation methodology and reporting terminology is well documented, interpretation of the various schemes is still somewhat subjective.

## CURRENT RESOURCE AND RESERVE CALCULATIONS

In general there is a good appreciation of coal resources and reserves in the present Alberta coal development areas.

Recently reported resource and reserve estimates are:

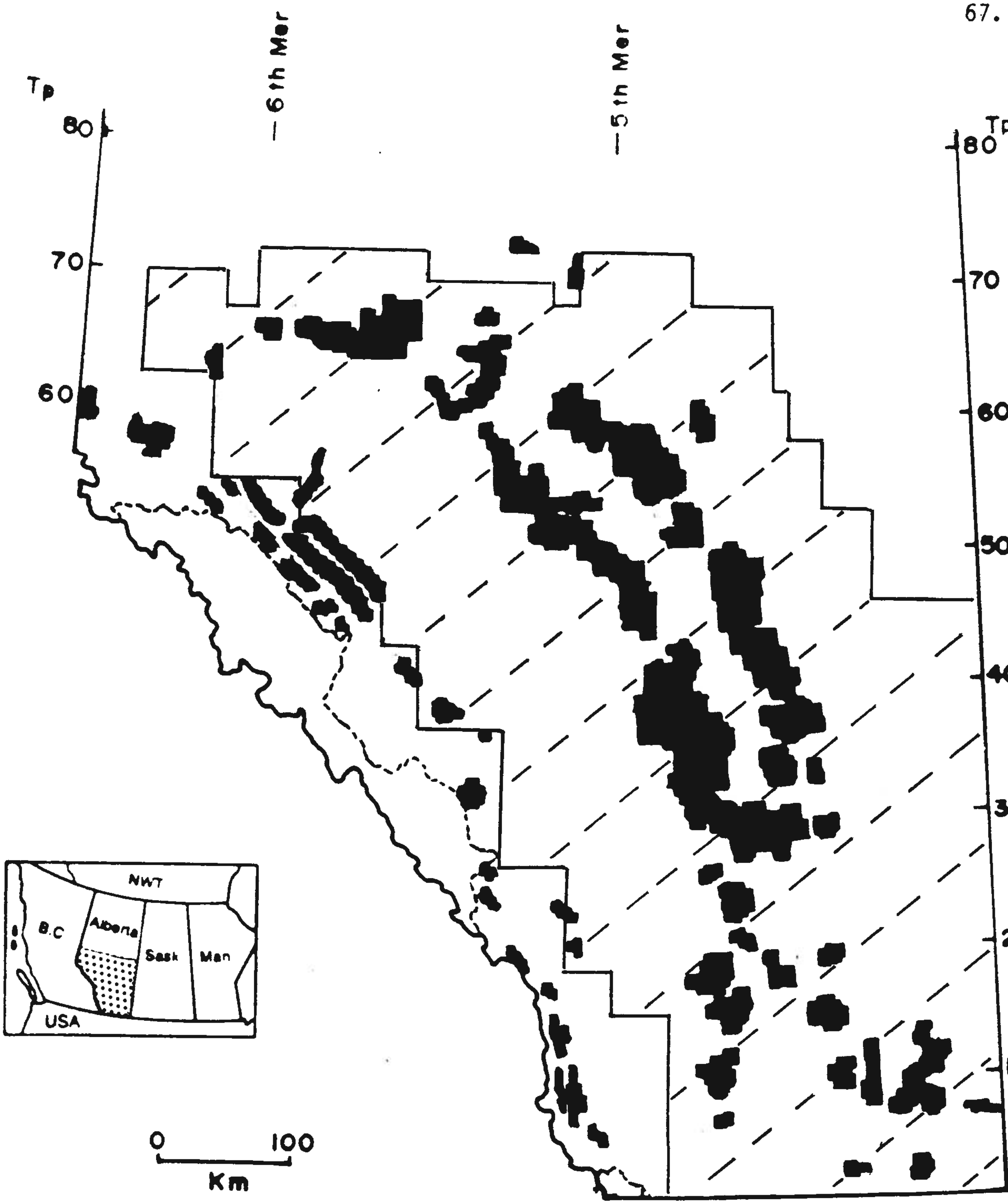
| | GIGATONNES | REPORTING AGENCY |
|---|---|---|
| Total resources in place | 2600 | ERCB |
| Ultimate potential | 800 | ERCB |
| In place established resources | 59 | ERCB |
| In place established reserves | 22 | ERCB |
| In place established mine reserves | 1.9 | ERCB |
| Coal in mineable seams | 2.26 | CANMET/GSC |
| Recoverable coal | 1.44 | CANMET/GSC |
| Inferred resources (Ardley coal zone) | 105 | ARC |
| Inferred resources (Horseshoe Canyon Fm) | 125 | ARC |
| Inferred resources (Belly River Group) | 93 | ARC |

The areas where these calculations are performed are shown in figures 18 and 19. All these estimates indicate a large amount of coal available in the province but demonstrate the need for uniformity in terminology and assessment methodology.

## FUTURE RESEARCH

To increase confidence in resource estimates both within the province and in overseas markets, efforts should be made towards establishing a common coal classification scheme and inter-related master databases that are available to all interested parties.

Research into geostatistical methods that give more reproducible and




Reserve estimates (E.R.C.B.)

Inferred resource estimates to 400m depth (Alberta Research Council)

Figure 18. Map showing the areas of reserve (ERCB) and resource calculations (Alberta Research Council) in Alberta.

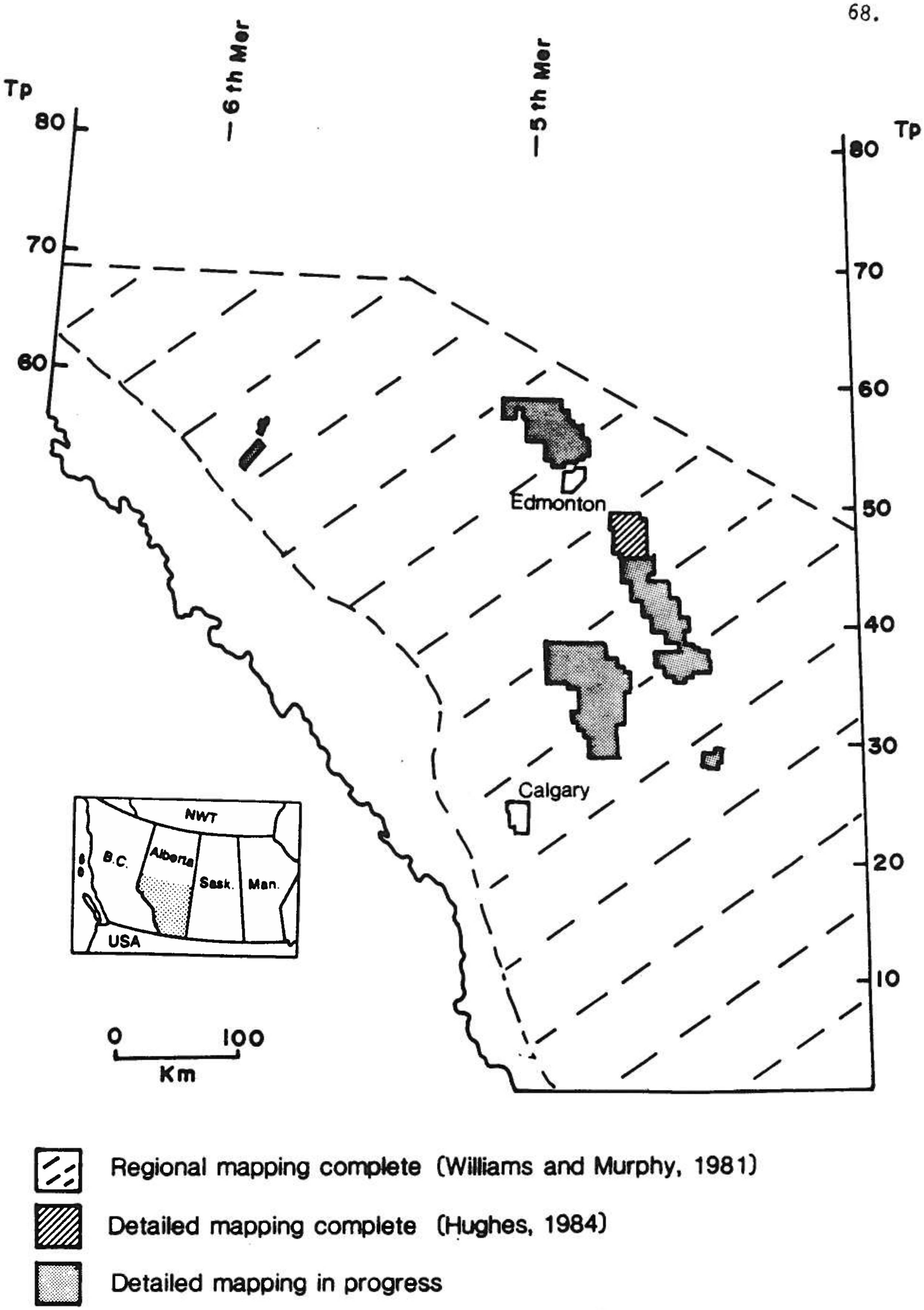



Figure 19. Map showing areas of recent coal resource studies performed by the Geological Survey of Canada.

meaningful estimates of coal resources could be initiated. At present the radius around drillhole (or sample) locations, which is somewhat arbitrarily chosen, is the only criteria used to determine accuracy of measurement. Where drillhole or sample spacings are irregular and seam thickness is highly variable, alternate geostatistical methods could be employed such as kriging variance or percentage error (Romaniuk and Naidu, 1983).

Research could also be done into Geographic Information Systems (GIS) for applications in resource and reserve estimation. GIS employ software routines that are based on different assumptions than those currently used in resource estimation. A powerful advantage of this technology for resource estimates lies in its ability to overlay, collate and analyze dissimilar attributes such as seam thickness, depth to seam, percent sulphur and water content. The establishment of a uniform classification scheme and data transportability between various agencies involved in coal resource estimation would enable rapid and reproducible coal resource and reserve calculations.

# RECOMMENDATIONS

## RECOMMENDATIONS: RESEARCH FIELDS

From the discussion of the various research fields in coal geology a set of recommendations for future research by the Alberta Research Council can be established.

First, the seven research fields were ranked according to five criteria, i.e. benefit to regional exploration, benefit to lease site development, benefit to resource planners, high research pay-off potential (short term) and high research pay-off potential (long term). No future research by the Coal Geology Group of the Alberta Research Council is recommended if extensive and sufficient work is being done in the particular area of research in other institutions or in other departments of the Alberta Research Council.

The following ranking was obtained. Coal quality is the most important field of research, according to all criteria. Structural geology and coal databases ranked as second most important. Stratigraphy and sedimentology ranked third. Geophysics and resource calculations came in fourth, largely because these areas are adequately researched elsewhere.

### Coal quality

A strong need is foreseen for increased research in coal quality and its prediction based on geological models. A better understanding of the factors controlling rank, sulphur, sodium, trace elements, moisture, calorific value, coking properties and ash contents would be gained through documentation of their regional variations. In addition research should be done on detailed in-seam coal quality variation in selected smaller areas.

Coal facies studies could be undertaken, in conjunction with sedimentological facies modelling to better predict coal quality, particularly at existing mine sites or coal fields.

Structural geology

Detailed mapping in established coal fields of the mountains and foothills should continue because of mining problems in structurally complex areas. This position is strongly supported by opinions from the coal mining industry (see Appendices). These studies could be integrated with regional correlation and mapping of coal seams of foothills and mountain areas.

Coal databases

Research into ways to standardize and exchange information through databases and electronic means from a geological perspective is needed. Duplication of effort could be reduced through the development of information systems based on geological expertise.

The full capabilities of a Geographic Information System (GIS) for coal geology could be researched. New ways of looking at coal need to be explored and products presented to researchers, the coal industry and resource managers in government. Co-operative projects between the Alberta Research Council, Energy Resources Conservation Board, Geological Survey of Canada, Alberta Energy and Alberta Forestry could be promoted.

Stratigraphy and correlations

Detailed correlations of all major coal zones in the plains and mountains, on a priority basis, should take place. This position is supported by opinions from the coal mining industry (see Appendices). At the present time, only the regional correlations of major coal zones in the plains are known. Many blank map areas still exist in the mountains and foothills. Detailed studies would allow individual coal seams to be identified and the controlling factors on seam geometry to be determined.

Sedimentology

Sedimentological facies models have predictive applications in the areas of coal occurrence and coal quality. Any facies study undertaken needs to be done with an emphasis on user application (i.e coal industry). Facies modelling needs to concentrate on the coal zones with more emphasis on understanding the general geometry of coal seams. For possible future underground mining of plains coal it will be essential that facies models be developed in order to predict coal seam and enclosing rock thickness variations.

Geophysics

Although geophysical research is adequately covered elsewhere, some research might be done by the Alberta Research Council on the accuracy of downhole coal quality determination from geophysical logs. Surface geophysical methods in the plains will be adequately covered by an existing joint venture between industry and government. However, when the joint venture moves to the mountains and foothills, it is strongly recommended that the Alberta Research Council's expertise in these regions of Alberta will be utilized.

Resource and reserve calculations

The calculation of resources and reserves of coal in Alberta is primarily the area of concern of the ERCB. No extensive work by the Alberta Research Council in this research field is proposed at the present time. However, the ERCB foresees a need for additional work on establishing potential resources.

RECOMMENDATIONS: RESEARCH PROJECTS

Although useful research could be carried out in most aspects of coal geology, it is particularly important for the Alberta Research Council to be involved in three areas: (a) coal quality, (b) regional coal evaluation and (c) database management. These are discussed in more detail below and the rationale for suggested projects is presented.

(a) Coal Quality

Maps of coal quality, on varying scales, may be used in aspects of coal work from regional planning and exploration to mine site development. In contrast to other coal-bearing areas of North America there is a paucity of information on coal quality in Alberta. It is understood, however, that the ERCB will be producing maps of coal quality over the next 1 to 1 1/2 years.

An understanding of the geologic factors which control coal quality is essential for effective use of coal quality maps. Questions that need to be addressed are: (a) To what degree has data been measured in a uniform way? (b) With what degree of confidence can one extrapolate between data points? (c) To what extent can knowledge of other geologic parameters (e.g. depositional environments) be used to predict coal quality or degree of variation in coal quality in areas with little data? (d) What scale of mapping is needed to adequately show variations in coal quality for specific purposes? (e) How can sampling procedures be optimized in future exploration and mine site development?

An understanding of in-seam variation in coal quality is important in optimizing coal use. Such knowledge is essential for less conventional uses of coal, such as liquefaction.

A project is proposed to develop a better understanding of geologic factors controlling the quality of coal in the plains area. Aspects of coal quality to be emphasized will be seam thickness, ash percentage, elemental composition (especially sulphur), maceral content, moisture content and calorific value. The plains area has been chosen because (a) there is a much more extensive database than in the foothills and (b) because coals of this area have not suffered regional tectonic deformation. Results of this study would form a basis for any subsequent study of the more complex foothills/mountains area. Emphasis in the proposed study would be on coals of the Horseshoe Canyon Formation and Ardley coal zone.

(b) Regional Assessment of Coal Resources

The size of the coal resources in most parts of the plains has been well documented on a regional scale by the Alberta Research Council. Detailed assessments of coal in designated coalfields of the plains area have been carried out by the ERCB and GSC and both will continue to do this in the foreseeable future. In contrast, there is a paucity of maps and cross-sections delineating the size and extent of coal resources in large parts of the inner foothills and in the transitional area of the outer foothills and plains (especially the Coalspur and Wapiti map sheet areas).

Most of the foothills area has been mapped on a scale of 1:50 000 (or 1:63 360) although some maps show blank areas that have not been surveyed in detail. The GSC is gradually updating these maps (e.g. the Copton Creek and Grande Cache maps are currently being revised).

At the scale of 1:50 000 (or less detailed) maps can only show the outcrops of coal-bearing strata. Maps showing individual seams and accompanying cross-sections showing areas of potential seam thickening (e.g. the recent ARC maps + cross-sections of the Grande Cache area) are necessary to make a fair assessment of an area's coal resources. This requires mapping on a scale of between 1:15 000 and 1:25 000 depending on the complexity of deformation. Mapping on this scale requires excellent exposures and/or large amounts of borehole data.

The Research Council's mapping efforts over the next few years would be optimal if mapping was done on a scale of 1:25 000 or more detailed in areas with abundant data. Knowledge gained from these studies could be applied in assessing coal resources in areas with less data but where the overall stratigraphic and structural setting could be compared to well studied areas.

In replies to the questionnaire, the area suggested most frequently as requiring detailed mapping was the Cadomin-Luscar coalfield. This area has abundant drill hole data and good exposures that would allow a detailed assessment of the coal resources. The GSC has recently contracted

Dr. Eric Mountjoy of McGill University to revise the 1:50,000 map of this area. This map would put into a broader geologic context any work that the Research Council may do in the area.

Mapping of the coal resources of the Cadomin-Luscar coalfield is a major undertaking. It requires extensive fieldwork and examination of data from several thousand boreholes. A two year project is proposed to do this. A bulletin should also be published on the geology of the Grande Cache area to complement the recently printed maps and cross-sections.

(c) Database Management

It is important that information on coal geology collected by the Alberta Research Council be kept in a form that allows continued use of the data in the future. An efficient database needs to be established that is compatible with other Alberta government database systems (particularly the ERCB's). There is also a need for geologically interpreted products that are in a form suitable for inclusion in the NRIS.

Existing data files on coal resources of the plains region should be used to create a database. The design and testing of a comprehensive database is an extensive undertaking. There should be an ongoing management of the database once it is implemented as it will form an essential support function for other projects.

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# APPENDIX 1

Examples of the two different questionnaires sent out to geological surveys (response of GSC) and to the coal industry (response of TransAlta). Note that responses to questionnaires reflect the personal opinion of the respondent and not official company or organizational policy.

# ALBERTA RESEARCH COUNCIL COAL GEOLOGY

# QUESTIONNAIRE

**Name:** G. Grant Smith
Head, Coal Geology Subdivision

**Institution:** Institute of Sedimentary and Petroleum Geology
(Geological Survey of Canada)

1. **Are you familiar with the coal geology program of the Alberta Research Council?**

   Yes

2. **Have you ever used any information on coal geology produced by the Alberta Research Council?**

   Yes

3. **If yes, what sort of information did you use and comment on its usefulness.**

   Geology, coal occurrences, coal resources, coal quality, coal mines and coal leases, etc.

   Most published reports which have resulted from ARC coal geology studies have proven to be valuable references, to varying degrees, for various GSC coal geoscience studies.

4. **Can you specify projects on Alberta coal geology that you would like to see carried out by the Alberta Research Council?**

   **Detailed geologic mapping (1:50 000 or better) and structural studies pertaining to coal measures in the Alberta Foothills (Inner and Outer).** Research both mesoscopic and megascopic structures as they impact origin, distribution, quality, mineability and utilization of coal resources within the deformed belt.

   Compilation of primary coal geoscience data in a computer-processable form like that of the GSC - providing the fundamental basis for geoscience studies in support of effective coal resource management.

5. **What type of mapping of coal resources is your institution presently doing (surface or subsurface)? On what scale, to what depth and with what data point density?**

   A Foothills Mapping Project in the Crowsnest Coal District (Blairmore, Carbondale River, Livingston River and Beehive Mountain) is nearing completion and will result in publications by D K Norris (now retired). Although no other mapping projects are currently planned or underway, geologic models of Alberta's coal deposits are being established at various scales, using exploration data obtained mainly from coal companies (refer to attached).

**6. Are you calculating coal resource estimates and in what category do they fall?**

Coal resource quantities are being estimated on the basis of geologic models established for various coal deposits. The GSC is developing a national inventory of coal resources on a consistently-defined basis, and in a manner whereby estimates can be readily updated and categorized according to a number of user-specified criteria (refer to attached).

**7. What is the maximum depth of your calculation of coal resources?**

In establishing a national inventory of coal resources, the GSC considers all coal which might be exploited now or in future. The depth of coal (along with other parameters) affects its classification in the resource scheme. Coal which cannot be considered mineable either now, or within the foreseeable future, might be exploitable through in situ processing methods and, therefore, should be considered in any comprehensive coal inventory.

**8. What kind of drilling, coring or geophysical work are you doing?**

The GSC is not directly engaged in acquiring coal-related subsurface primary geologic data.

**9. How much coal petrography are you doing and for what reasons?**

The Coal Geology Subdivision includes an Organic Petrology Section comprising 3 scientists and 1 technician. The nature of their coal research is described in the attached documents.

**10. Have you done any work on evaluating coal-bed methane resources?**

No.

**11. What percentage of your data on coal is computerized?**

$>$ 95% of borehole and outcrop data.
$<$ 10% coal analytical data - (currently being computerized).

**12. If possible, quantify your computer database.**

**(a) How many datapoints (e.g. drillhole and/or outcrop)?**

Current exploration databases contain information from about 13 000 boreholes in Alberta, having an aggregate depth of nearly 600 000 m.

**(b) How many data items per datapoint?**

About 50 lithologies per hole
100 analytical items per hole
50 identification items per hole

**13. How frequently is your database updated?**

Databases will not generally be updated until initial databases are first established for all coalfields/deposits in Canada.

**14. What type of database hardware and software do you use?**

HP 3000 series 68 computer
Database systems are generally developed inhouse.

**15. What types of application software do you use?**

A variety of software packages are used to produce maps, cross sections, perspective block diagrams and graphic lithologic sections, and to perform statistical analyses. Variables can be modelled (projected 3-dimensionally) and arithmetically manipulated whereby resource quantities can be estimated according to a number of user-specified criteria.

**16. What kinds of output from computer data do you use (e.g. tables, maps, cross sections, etc.)?**

Maps, tables, cross sections, perspective block diagrams, graphic lithologic strip logs, cross plots, dendograms, cluster analyses, variogram models, etc.

**17. What other types of research are you doing (e.g. in the areas of sedimentological facies studies, stratigraphic/paleontological studies, structural geological studies, geostatistics, mining geology)?**

The Coal Geology Subdivision includes a Geology of Coal Section comprising 3 scientists who conduct stratigraphic, sedimentologic and structural studies which focus on the fundamental geological context of Canadian coal measures. These studies result in an understanding of paleoenvironments which favoured coal formation, and tectonic elements which affected coalification histories in various sedimentary basins. The specific nature of their research is described in the attached documents.

**18. What level of effort is your organization putting into coal geology in terms of manpower and budget?**

Coal Geology Subdivision:

10 geoscientists
1 EDP Analyst/Programmer
2 Technicians
1 Secretary

**Annual operating funds: $600 000.**

| | | |
|---|---|---|
| (includes | $155k | -database development Plains |
| | 55k | -database development B.C. |
| | 60k | -database development N.S. |
| | 65k | -computer costs |
| | 15k | -digitizing & reproductions |
| | 15k | -contract software development |
| | 125k | -trace element analyses |
| | 25k | -lab materials & supplies |
| | 65k | -field work |
| | 20k | -admin. word processing, photos, communication, etc.) |

**19. What type of reports on coal geology has your organization produced? Attach a list of reports if available. Printed brochures or annual reports are also welcome.**

Refer to attached documents which include bibliographic information.

**20. What type of future research directions in coal geology does your organization foresee?**

Refer to attached documents.

GGS/ds
July 7, 1986

ALBERTA RESEARCH COUNCIL COAL GEOLOGY

QUESTIONNAIRE

Name: D. Nikols/T. Godfrey

Institution (or company): TransAlta Utilities

| | | Yes | No |
|---|---|---|---|
| 1. | Are you familiar with the coal geology program of the Alberta Research Council? | X | |
| 2. | Have you ever used any information on coal geology produced by the Alberta Research Council? | X | |

3. If yes, what sort of information did you use and comment on its usefulness.

   We have used numerous Maps and Reports; for example "Coal Resources of the Carbon Thompson Coal Zone" (Nurkowski) used to evaluate Horseshoe Canyon potential on some TransAlta leases in central Alberta. Another example is "Coal Resources of the Ardley Coal Zone" (Holter, Yurko, Chu).

   The Nurkowski report was useful in aiding the determination of coal volumes on our leases.

   The Holter report was useful in aiding us in the development of a useful and practical Ardley Coal Zone model.

4. Can you specify projects on Alberta coal geology that you would like to see carried out by the Alberta Research Council?

   a) Sulphur mineralogy and distribution
   b) Standard methods of coal characterization
   c) Detailed assessment of resource potential for specific areas not necessarily known for mining or mining potential.
   d) Correlation of seams and partings in coal zones of fields - both along strike and down dip.

5. What do you consider the major problems in coal geology in Alberta to be addressed in the next 3 to 4 years?

    1) In the Plains our coal tends to be of low rank and therefore not a highly desirable sale product. One major subject area required research relates to the upgrading of this product to form a true salable product, both for domestic and export purposes.
    2) Geologic factors are important part of mining costs. Mining costs must be controlled and lowered if we are to be competitive on the International markets for our export quality thermal and metallurgical coals (Foothills Mountains).
    3) The sterilization of resources by government or quasi government before a complete assessment of them has been made.
    4) Characterization of smaller units as depositional models and establishing a criteria so that the most favourable areas can be identified, that is sub areas or sub fields and mine sized units.
    5) Gross regional correlations.

6. Which coals in Alberta do you predict to be exploited in the next 10 years and by what mining methods (i.e. surface or underground)?

For the next ten years surface methods will predominate. Underground and in-situ will not be feasible. Ardley and Horseshoe Canyon will be widely used for electrical power generation with very minor "domestic" needs. Some small less than 500,000 ton mines may open to feed cement or other potential users, depending on the price of gas. The Horseshoe Canyon may feel some expansion of heavy oil development if oil prices rise (depending on the ERCB view of gas prices and supply). Foothills/Mountains export coal will remain about were it is unless some transportation break through or major mining cost reductions can be found. We see the potential use of Plains coal in the next ten years to be something along following lines:

- 1990 Horseshoe Canyon thermal mine and expansion
- 1992 Ardley thermal mine expansion
- 1993 one new thermal mine plus or minus 3 x $10^6$ t/yr year likely to be Ardley
- 1996 Ardley or Horseshoe Canyon new thermal mine

In the next 20 years?

Surface mostly, if not all. Ardley and Horseshoe Canyon coals will continue as prime thermal electric fuel sources. 1998 should see an Ardley coal deposit being developed into a thermal mine. 2000 should see Horseshoe Canyon's deposit for enhanced oil recovery (heavy oil). In the year 2005 Ardley/Horseshoe Canyon? new thermal mine.

Foothill/Mountains - The market looks bleak with only a slight increase in metallurgical coal can be expected. Most metallurgical coal market will be taken up by mines in BC. Canadian thermal coal exports should double and could mean a 20 to 25% increase for Alberta, primarily from Bow Valley area.

In the next 30 years?

A move to underground mining should begin during this time, likely a 50/50 split by approximately the 50th year, unless some major break through occurs to up grade plains coals, such as pipeline agglomeration. The export potential is limited. We should see and increase in the potential or "direct liquefaction" that is heavy oil recovery and some syn fuels through the use of coal as a driving fuel. We could see all of the major Ardley and most of the available Horseshoe Canyon sites exploited by the 30 year mark. Underground development in the Ardley, Wabamun and Red Deer are likely. Coal valley and the Smokey area will be 50 - 75% underground mine. Minor development in southern Alberta of underground deposits and a re-awakening of the Crowsnest Pass area should occur plus 20 years time with three new mines, one underground working by 30 years.

NOTE: Question 6 is speculative at best and the 20-30 year projections could be 100% wrong.

7. What type of exploration and research have you been doing in coal geology over the last 5 years?

A) Research
   1) sulphur distribution and mineralogy Ardley coal to Wabamun
   2) geophyical characterization of coals and overburder - research and implementation
   3) definition of paloe environments of deposition of coal and associated overburden
   4) ice thrusting - mapping and definition as related to coal and overburden.

B) Exploration
   1) some surface geophysical methods
   2) drilling and drillhole geophysics in both coal mines and prospects
   3) deep Ardley holes southeast of Ardley

8. What surface geophysics techniques do you use?

Reflection and Refraction Seismic - Indirect current resistivity

9. What areas of particular concern do you have regarding:

   A) Plains coal?
   Predicting quality variations across a mine or field ie. ash, heat, moisture, sulphur etc. The identification and distribution of sodium, potassium. chorine and fluorine plus trace elements.

   B) Foothills and mountain coal?

   C) Coal quality in general?
   The tests know used were developed for metallurgical and or Eastern thermal coals and may not properly represent younger Western coals. Sampling and testing procedures must be standardized for each different coal type.

10. What types of database hardware and software do you use?

    Hardware - Currently we are using a VAX 8600 - IBM PC, Tetronics, Calcomp plotters.
    Software - We are using inhouse Database system which uses Datatrieve software. On the PC's were are primarily using Symphony and D Base 3 plus.

11. What types of application software do you use?

    Geostatisticals, mapping, mine planning and general statistical.

12. What kind of information on coal geology would you like to see from the Alberta Research Council and in what format would you like to receive it (i.e. reports, maps, computer files)?

    I think it should be available in all 3 forms. Reports and maps are essential, computer files are useful for large groups or amounts of data. In some cases the data could be made available in conjunction with the ERCB's current data files.

13. In which areas of coal geology do you see a role for the Alberta Research Council?

    1. Regional setting definition
    2. Correlation along strike and down dip
    3. Structural setting of coal deposits
    4. Setting standards and developing procedures for exploration and definition of coals and coal quality
    5. Gross resource identification
    6. Resource identification on intermediate scales ie. fields, zones or area
    7. Model development and refinement of existing models

# APPENDIX 2

Responses to questionnaire, with reference to the Alberta Research Council's Coal Geology Program. Note that responses to questionnaires reflect the personal opinion of the respondent and not official company or organizational policy.

1. Summary of responses to questions 1 and 2.

Table A1 shows that all of the coal companies and private consultants that responded to the questionnaire were familiar with the Alberta Research Council's Coal Geology program and all had used information from the program. Similarly most of the university professionals that replied were also familiar and used information from the program. Of the geological surveys that responded, 40 percent (6 of 15) were familiar with the program and 33 percent (5 of 15) had actually used information from the program.

TABLE A1. Summary of responses to questions 1 and 2.

| | Are you familiar with the Coal Geology Program of the Alberta Research Council? | Have you ever used any information on coal geology produced by the Alberta Research Council? |
|---|---|---|
| Coal Companies | | |
| Denison | Yes | Yes |
| Esso | Yes | Yes |
| Gregg River | Yes | Yes |
| Luscar | Yes | Yes |
| Manalta | Yes | Yes |
| PanCanadian | Yes | Yes |
| Smoky River | Yes | Yes |
| Transalta | Yes | Yes |
| Unocal Canada | Yes | Yes |
| Geological Surveys | | |
| Alabama | No | No |
| Arizona | No | No |
| B.C. Geol. | Yes | Yes |
| Colorado | No | No |
| GSC Calgary | Yes | Yes |
| Illinois | Yes | Yes |
| Louisiana | No | No |
| New Mexico | Yes | No |
| Nova Scotia | Yes | Yes |
| Ohio | Yes | No |
| Pennsylvania | No | No |
| Sask. Geol. | No | No |
| Texas Bureau | No | Yes |
| West Virginia | No | No |
| Wyoming | No | No |
| Universities | | |
| U of A (Charlesworth) | Yes | Yes |
| U of A (Lerbekmo) | Yes | Yes |
| U of C (Lawton) | Yes | No |
| Consultants | | |
| MacFarlane Consult. | Yes | Yes |
| Northwest Resources | Yes | Yes |
| Wrightson | Yes | Yes |

2. Listing of responses to question 4.

Question: Can you specify projects on Alberta coal geology that you would like to see carried out by the Alberta Research Council?

- You have asked for our opinion regarding future projects. I would suggest that priority be directed to evaluating the Foothills coal resources of the Province between Calgary and the Smoky River. The present "state of the art" is embarrassing. The only available regional geologic map for the Coal Valley area was published by John Allen in 1924 and the subsequent GSC map by B.R. MacKay in 1947 is essentially blank in the Coal Valley area and inaccurate at Mountain Park. This particular region produces over 70 percent of Alberta's metallurgical coal and all of its high grade bituminous thermal coal. With the exception of those companies working in the area, very little is known about the region geology. If the mandate of the Research Council Geology Program is to aid the government in the management and development of coal resources, then surely this important coal producing region must be properly evaluated. At present, the government is establishing Integrated Resource Plans for the entire Foothills without the benefit of such a resource evaluation.

- Compilation of available geological and coal exploration data supported by some field mapping to determine the possible surface traces of the Ardley (Coalspur) and Horseshoe Canyon equivalent coal zones south of Grande Prairie in the Wapiti, Smoky, Little Smoky River areas. Data from petroleum wells might be used to assist with the subsurface correlation of the zones and possibly the individual seams in this area. A geological compilation supported by some field studies should also be conducted on the Luscar Formation west and southwest of Hinton.

- Research into in-situ gasification.

- Detailed geologic mapping (1:50 000 or better) and structural studies pertaining to coal measures in the Alberta Foothills (Inner and Outer). Research both mesoscopic and megascopic structures as they impact origin, distribution, quality, mineability and utilization of coal resouces within the deformed belt.

- Compilation of primary coal geoscience data in a computer-processable form like that of the GSC - providing the fundamental basis for geoscience studies in support of effective coal resource management.

- Continued research into developing and refining specific models for coal exploration through increased study of techniques for paleogeographic analysis of coal basins.

- Coal geochemistry specifically related to incorporation of sulphur in coal.

- Utilization studies of specific coals based on chemistry, petrography, etc.

- Sampling techniques for evaluation of coals.

- Additional work on coal bed methane resources.

- Detailed lilthologic studies would be useful, including various facies analyses.

- The Plains Coal Study sounds interesting, but it must be done with considerable attention to detail to be very meaningful. There are numerous plains deposits which have been quite well defined. A few well placed coreholes could be very useful in interpreting the geological environments of these deposits.

- In situ Coal Density studies.

- Regional correlation of seams - plains & foothills.

- Continuation of the work done in the Grande Cache area in regions to the south - especially the Hinton-Cadomin area.

- Effective Alberta Coal marketing

- Copton Creek study

- More systematic mapping (detailed) of deformed coal-bearing strata in the Foothills.

- Magnetostratigraphic correlation of coal zones.

- Updating database to include well log information, much like ERCB petroleum files.

- Involvement in geophysical techniques, both surface (seismic, electrical) and down-hole.

- Expansion of the foothills studies to include the Crowsnest Pass area.

- Additional petrographic and reflectance work on the foothills coals.

- Sulphur mineralogy and distribution.

- Standard methods of coal characterization.

- Detailed assessment of resource potential for specific areas not necessarily known for mining or mining potential.

- Correlation of seams and partings in coal zones of fields - both along strike and down dip.

- Surface geology maps in the west central Alberta (east slopes are old and dated). Stratigraphic nomenclature has changed. These maps should be updated. The usefulness of these maps are not limited to the coal industry alone but would have a much wider application.

- Fence diagrams (or columnar section) that correlate major units and thicknesses and local seam names of Lower Cretaceous coal measures from the northwest BC/Alta border down to southern Alberta would be useful.

# APPENDIX 3

Results of questionnaires, with reference to individual coal geology research fields as discussed in report. Note that responses to questionnaires reflect the personal opinion of the respondent and not official company or organizational policy.

## COAL QUALITY

### Geological Surveys

The results of the questionnaire show that 40 percent (6 of 15) of the geological surveys that responded are presently undertaking some coal quality research. A total of 67 percent of the respondents (10 of 15) see coal quality as an important area of future research for their organization.

### Coal Industry/Consultants

The results of the survey of the coal industry when asked what concerns they had in the area of coal quality and what they are doing in this area show that all of the companies are interested in coal quality to some extent. However, there seems to be a broad range of specific interests within the general field of coal quality. Rank variations and moisture contents, in particular, seem to be of interest.

## STRATIGRAPHY AND MAPPING

### Geological Surveys

In the area of stratigraphy, coal correlations and mapping, the results indicate that most geological surveys contacted are involved in coal mapping and stratigraphic analysis (12 out of 15, 80 percent).

The results also indicate that most agencies are mappping at a much more detailed scale than the Alberta Research Council has in the past, except for the Alberta Research Council's detailed work in the Foothills region. Most agencies are involved in surface and subsurface mapping and depth cutoffs in subsurface studies are highly variable (ranging from 76 m to no depth limit). Interestingly, many surveys make a distinction between mapping depths and resource calculation depths.

### Coal Industry

The coal industry was not specifically questioned as to their mapping involvements, however most companies seemed to be mapping at a detailed scale within their own lease boundaries. Approximately 85 percent (11 out of 13) of the coal companies and private consultants responding, expressed a need for detailed mapping and stratigraphic correlation studies to better define coal resources.

## STRUCTURAL GEOLOGY

### Geological Surveys

Five out of fifteen geological surveys (33 percent) indicated that they are doing structural studies of coal measures. This response is biased by responses from states, which do not have any deformed coal measures.

### Coal Industry

The coal industry was not specifically asked about their involvement in structural geology. However, eight out of twelve companies (66 percent) indicated that they would like to see the Alberta Research Council involved in the mapping of the coal resources of the Foothills and mountains. This work will by necessity involve structural geology.

## SEDIMENTOLOGY AND FACIES STUDIES

### Geological Surveys

Of the geological surveys that replied to a general question on types of research being undertaken, 33 percent (5 of 15) replied that they are or were recently undertaking facies related studies.

### Coal Industry

The coal industry and consultants were asked what type of information they would like to receive from the Alberta Research Council and which areas of coal geology they thought the Alberta Research Council should be involved in. Of those responding, 25 percent (3 of 12) suggested facies/depositional environmental studies be undertaken.

## COAL DATABASES

### Computer Databases/Electronic Processing

Most provincial surveys and the Geological Survey of Canada (100 percent-4 of 4) and state surveys (73 percent-8 of 11) have computerized a large part of their data and efforts are being made to computerize the rest. The databases are most often maintained on a daily bases (55 percent-6 of 11), particularly since the datasets are as yet incomplete. Databases typically contain thousands of datapoints and tens of thousands to hundreds of thousands of data items. Prime and VAX mini computers are most commonly used while many organizations have IBM-PC class machines. In Canada provincial surveys (100 percent- 3 of 3) work cooperatively with the Geological Survey of Canada (GSC), while in the United States most state surveys (73 percent-8 of 11) use the facilities or software of the USGS.

A wide variety of software is used for both databases and applications. Those groups that have access to either GSC or US Geological Survey software produce a wide variety of products.

Industry applications focused on mine planning and mine economics.

## GEOPHYSICS

### Drilling and Geophysics

Seven out of fifteen geological surveys (47 percent) were involved in a drilling program, which included geophysical logging.

### Coal Industry

The coal industry was asked what surface geophysics techniques they use. The response was that seven out of twelve (58 percent) use this methodology. Of these seven companies, four use high resolution seismic, two use VLF, two use EM resistivity and one uses gravity.

## RESOURCE ESTIMATES

The federal (GSC) and provincial surveys other than Alberta's (3 of 3) calculate coal resources according to a uniform national classification scheme. All coal which might be exploited now or in the future are considered and therefore there is not a maximum depth limit in that system. Most state surveys (73 percent-8 of 11) calculate coal resource estimates in the U.S. Geological Survey format. Resources calculated range from depths as little as 76 m to 3048 m in coal bed methane studies.

# APPENDIX 4

Listing of miscellaneous comments from the returned questionnaires. Note that responses to questionnaires reflect the personal opinion of the respondent and not official company or organizational policy.

- Next three to four years a major problem is to develop a database that will allow for a reasonable estimate of the quantities and qualities of possible coal resources in any area of the Province. This database can be used to assist the government in resource and landuse planning and coal companies with their longer range exploration and production plans.

- Concern about sterilization of resources by government or quasi government before a complete assessment of them has been made.

- See role for the Alberta Research Council in resource estimates.

- See role for the Alberta Resource Council in computer databases of plains and Foothills coal geological information.

- Would like to see Alberta Research Council updating database to include well log information much like ERCB petroleum files.

- One aspect of coal research in Alberta is confusing to me. There are several organizations involved in research programs (Office of Coal Research and Technology; Alberta Research Council, Coal Geology Group; Institute of Sedimentary and Petroleum Geology, GSC; Devon Research Labs). Is there overlap between these groups and how much communication between the groups is there? It seems to me that at least some coal projects would benefit by interaction with all of the above groups, not just the funding agency.

- Technology will eventually limit the economic value of coal much in the same way it did in the 1950's. Coal resources that are not developed in the next 20 years will likely never be developed (I'm referring mainly to surface mines). Met coal properties on the East Slope will have little value when any source of carbon can be utilized for metallurgical purposes.

- Concern about restrictive landuse policies in the foothills and mountain coal areas.

- Geologic factors are important to mining costs.

- The biggest problem to the industry today that will have adverse effect on the province in years to come, is the incomplete recognition of coal resource potential in the completed (to date) Integrated Resource Plans.

- Would like to see Alberta Research Council take responsibility for regionally defining the coal geology and hence resource base of Alberta.

- It is important for a program to succeed to provide long-term support at a level above the "critical mass". Data accumulation over long periods of time is required; a stable, easily accessible common filing system for data to which all staff members contribute regularly must be maintained. Regular data collection, not just as part of a specific project must be supported, e.g. drillhole logs, outcrop descriptions, mine notes taken during mine visits, samples collected and analyzed, etc.

- We have on hand and have utilized all of the Alberta Research Council geology publications. Traditionally, these reports have been the first information available for certain regions and therefore very useful in planning a coal exploration program.

- I consider that the information database is of vital importance to coal researchers and should be a primary role of the Alberta Research Council. In particular, raw data from the regional drilling program would be of great interest to me. Are core samples available and were the holes logged (density, sonic, etc.)?