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Mineral potential mapping using a knowledge-based fuzzy logic approach for Melville Island, Northwest Territories

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CANADA-NORTHWEST TERRITORIES MINERAL INITIATIVES (1991-1996), AN INITIATIVE UNDER THE CANADA-NORTHWEST TERRITORIES ECONOMIC DEVELOPMENT COOPERATION AGREEMENT.

MESURES CANADA-TERRITOIRES DU NORD-OUEST RELATIVES AUX MINÉRAUX (1991-1996),MESURES NÉGOCIÉES EN VERTU DE L'ENTENTE DE COOPÉRATION CANADA/TERRITOIRES DU NORD-OUEST DE DÉVELOPPEMENT ÉCONOMIQUE.

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SUMMARY

This report presents the results of a GIS study to model base metal resource potential for Melville Island, NWT. The geology of Melville Island owes most of its base metal potential to three primary deposit types as described in Eckstrand (1984); 1 - Mississippi Valley Type Lead - Zinc, 2 - Sediment Copper, and 3 - Sediment Hosted Sulphides. From the many methods available in GIS for mineral potential modelling, a knowledge based fuzzy logic approach was used. While the results of this study are preliminary, and require further investigation in several spatial and non-spatial problems, the results are interesting and favourable. The knowledge based fuzzy logic approach is shown to be a useful method for application in geographic areas where there are few known deposits, or where adequate time and cost resources are too limited for data driven modelling.

ACKNOWLEDGMENTS

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INTRODUCTION

Regional mapping of the Parry Islands by Okulitch (in prep.) based on more detailed mapping by Harrison (1991) at a scale of 1:250,000 provides a new understanding of the geology of the island, and the possibilities for base metal resource potential. The exclusive sedimentary geology of the island serves as a target for sedimentary hosted type base metal deposits, particularly Cu, Pb, and Zn.

This study reviews one approach for modelling base metal potential of Melville Island using GIS technology. GIS is being used more successfully in recent years as the technology and high quality data become more accessible to the geological community. There are a great variety of GIS methods available to the explorationist, or the resource analyst for mineral potential modelling. Most methods fall into either "data driven" models or "knowledge driven" models. The objective of this study is to explore the use of the knowledge driven "fuzzy logic" method in mineral potential mapping of sedimentary type deposits on Melville Island.

GENERAL GEOLOGY

Melville Island is located approximately 1500 km north of Yellowknife in the northwestern most part of the Northwest Territories among the Queen Elizabeth Islands (Fig. 1). It is bounded by latitudes 74° to 77°, and longitudes 110° to 117°, and covers an area of 42,077 km^2 with a rugged 2713 km long shoreline. The southern portion of the island lies in the Parry Islands Fold belt, while the Canrobert Hills Fold Belt occupies the north portion of the island. Rocks that outcrop here are composed primarily of two major successions of sedimentary rocks that were deposited during mid-Cambrian to Quaternary time (Fig. 2).

The first is the Franklinian Succession which represents shelf-marginal clastic and chemical sediments deposited during mid-Cambrian to Devonian time which includes the Cass Fiord and Cape Clay Fms through to the Griper Bay Subgroup. The second is the Sverdrup Basin Succession which includes the Otto Fiord Fm to the Beaufort Fm. Age ranges, dominant rock types, mineral showings and other key information are provided in **APPENDIX A** as Table A - Bedrock Lithology Classification Table and Fuzzy Memberships.

These rocks have experienced multiple phases of deformation associated with the Ellesmerian Orogeny. This deformation produced the characteristic east-west trending, southerly verging, fold-thrust pattern of the south-eastern portion of the island during mid-upper Devonian time, and continued as thrust and strike-slip style faulting associated with uplift and rifting during the upper Devonian to Permian time. This faulting pattern is present everywhere except for the south-eastern portion of the island where the open folding patterns are well preserved. A final, but more subtle phase of rifting occurred during Tertiary time associated with the Eurekan Orogeny.

APPROACH FOR MINERAL POTENTIAL MODELLING

Knowledge Driven vs. Data Driven

Spatial analysis methods in GIS offer a flexible two-pronged approach to mineral potential modelling. The first is data driven which is a quantitative approach based on probability measures such as weights of evidence modelling (Bonham-Carter, et. al. 1988). The second is knowledge driven which is more qualitative or expert driven.

The data driven approach requires a sufficient number of known mineral occurrences to examine their relationships with geologic map patterns. There are nine known base metal or related mineral occurrences that provide a limited knowledge for the mineral deposit types which may occur on the island, however this number is too few for the development of a statistically adequate data driven approach. Therefore, the approach taken for this study is primarily knowledge driven based on an early evaluation of the possible mineral deposit types which would be characteristic of the geology on Melville Island.

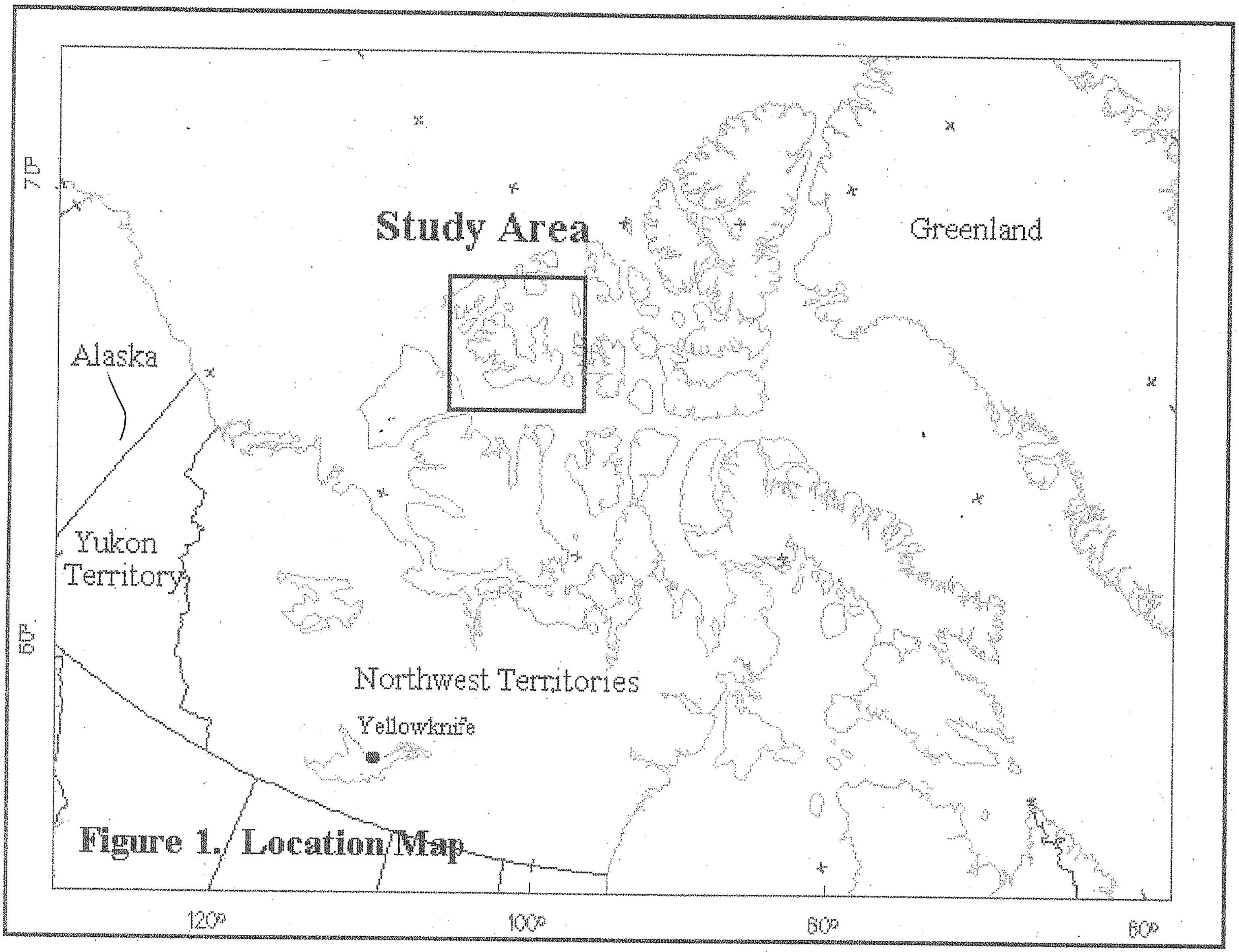

Figure 1. Location Map

Deposit Models

The nine occurrences mentioned above have been described by Harrison (1990) and are presented in Figure 3 and as Table G in **APPENDIX B.** Most notable are the three copper and one lead-zinc occurrences, although the remainder provide an indirect source of evidence of possibly richer base metal mineralization. Harrison (1990) attributes these occurrences to three possible ore deposit types:

1. Carbonate-hosted Mississippi Valley Type lead-zinc in the Cape Phillips (Ordovician-Silurian) and Ibbet Bay (Ordovician-Devonian) Formations.
2. Sedimentary exhalative lead-zinc in the Ibbet Bay Formation (Ordovician-Devonian).
3. Sedimentary redbed copper in the Canyon Fiord Formation (Carb-Permian).

These descriptions correspond well with the following three models described in Eckstrand (1984) (See **APPENDIX A** for detailed descriptions):

1. 6.1 - Mississippi Valley Lead-Zinc
2. 9.2 - Sediment Hosted Sulphide
3. 6.3 - Sedimentary Copper

Whereas a great variety of sediment-hosted mineral deposit types are described in Eckstrand (1984), the geology of Melville Island owes its greatest base metal potential to these three types.

Map Modelling

The knowledge-driven approach to mineral potential mapping for this study is based on mineral deposit models described in Eckstrand (1984). Three knowledge driven approaches which may be applied to these models are summarized as follows:

- **Boolean Modelling** - determine mineral potential areas simply on the basis of the presence or absence of a given geologic pattern.

- **Index Overlay** - determine mineral potential areas on the basis of applied weights to various geologic map patterns which are applied according to their importance to a given deposit model.

- **Fuzzy Logic** - determine potential areas on the basis of Fuzzy Membership values which are assigned to geologic patterns.

In Boolean modelling, the presence or absence of a given pattern is represented as either a 0 (absent) or 1 (present). With fuzzy logic modelling (An et. al. (1991), the geologic patterns are assigned fuzzy membership values which range between 0 and 1. In a sense, the knowledge-driven fuzzy logic approach is a combination of Boolean modelling and

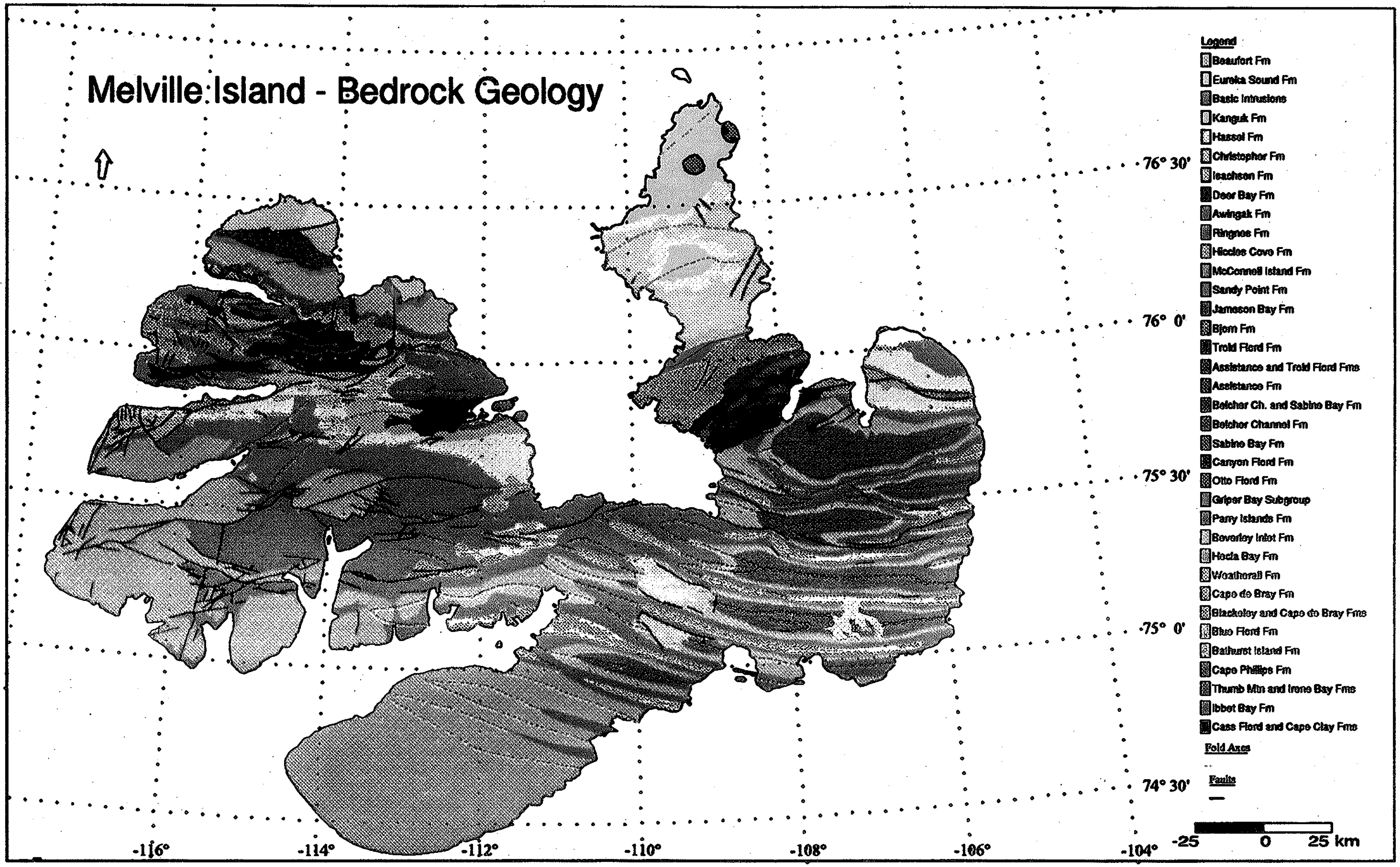
Melville Island - Bedrock Geology
Legend
Beaufort Fm
Eureka Sound Fm
Basic Intrusions
Kanguk Fm
Hassel Fm
Christopher Fm
Isachsen Fm
Deer Bay Fm
Awingak Fm
Ringnes Fm
Hiccles Cove Fm
McConnell Island Fm
Sandy Point Fm
Jameson Bay Fm
Bjorn Fm
Troid Fiord Fm
Assistance and Troid Fiord Fms
Assistance Fm
Belcher Ch. and Sabine Bay Fm
Belcher Channel Fm
Sabine Bay Fm
Canyon Fiord Fm
Otto Fiord Fm
Griper Bay Subgroup
Parry Islands Fm
Beverley Inlet Fm
Hecla Bay Fm
Weatherall Fm
Cape de Bray Fm
Blackeley and Cape de Bray Fms
Blue Fiord Fm
Bathurst Island Fm
Cape Phillips Fm
Thumb Mtn and Irene Bay Fms
Ibbet Bay Fm
Cass Fiord and Cape Clay Fms
Fold Axes
Faults
-25
0
25 km
76° 30'
76° 0'
75° 30'
75° 0'
74° 30'
-116°
-114°
-112°
-110°
-108°
-106°
-104°

FIGURE 2

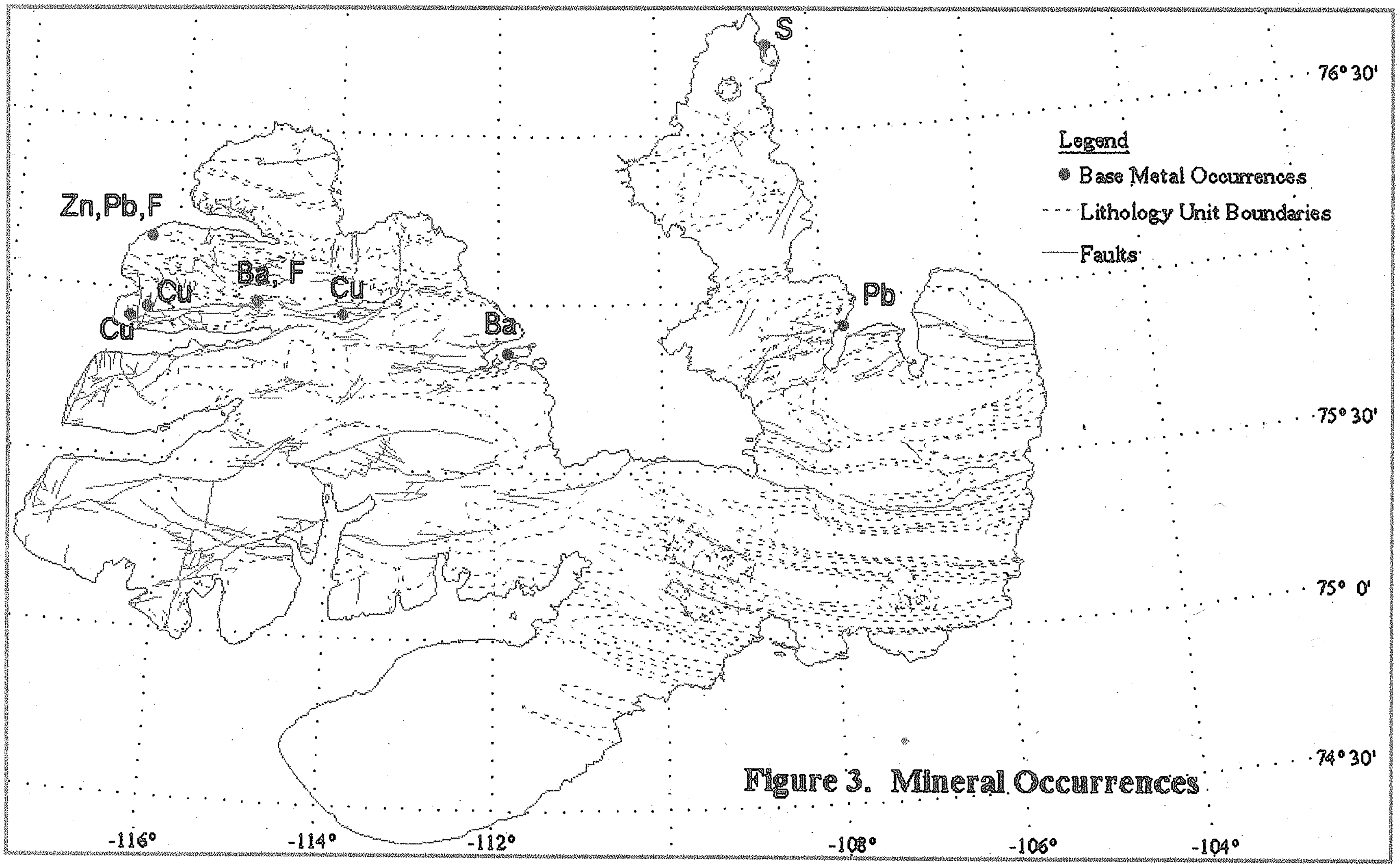

Figure 3. Mineral Occurrences

index overlay modelling where the fuzzy membership values represent a weight of importance assigned to the presence of a geologic pattern in a given area. The knowledge-driven fuzzy logic approach is employed for this study primarily because of its flexibility in applying map combination rules on fuzzy membership values assigned to patterns from different input maps.

MODEL DESIGN

The methods employed for knowledge-driven fuzzy logic modelling are generally straight-forward and technically the same for each of the three deposit types. The design involved completing the following tasks:

1. Determine which **geologic patterns** are applicable to the **deposit model** in question.
2. Prepare the appropriate **maps** and **look-up tables** which describe these patterns.
3. **Write** and **process** the **fuzzy logic model** for each deposit type.

Deposit Models and Associated Geologic Patterns

For this exercise, the following key criteria for the mentioned deposit models are summarized from Eckstrand (1984) (**APPENDIX A**):[1]

Mississippi Valley Type Lead-Zinc

- Secondary brecciation in dolomite.
- Reef facies lithologies - limestone, dolomite
- Carbonate-shale-limestone facies change
- Close proximity to unconformities

Sedimentary Copper

- Shallow marine sedimentary sequences (shale, siltstone)
- Sources of copper (basement or syngenetic deposits)
- Paralic marine - base of major transgressive unit overlying redbeds.
- Continental - permeable parts of fining upwards cycle
- Close proximity to (above) unconformities

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[1] We are aware of many other attributes, but for simplicity and clarity, only those provided in Eckstrand (1984) are used for this exercise.

Sediment Hosted Sulphide

- Thick successions of clastic sedimentary rocks
- Starved basin deposits (carbonaceous shales) at base of coarsening upward sequence.
- Second order basin changes (rapid lateral facies change)
- Syndepositional tectonic activity (faults)
- Presence of chemical sediments of hydrothermal origin (chert,anhydrite,gypsum)

These criteria show some common elements pertaining to lithostratigraphic and structural patterns. First, each model is strongly dependent on lithostratigraphic features, therefore, the fuzzy membership values assigned for each model to each lithology map class must reflect this. This requires the preparation of a bedrock lithology map with an associated table which describes the lithology, and fuzzy membership values for each deposit model.

Secondly, each model focuses on rapid changes in lithology (facies changes) and/or closeness to unconformities. The stratigraphic position of each lithology map class to unconformities determined by Harrison (1991) (Figure 4) and units with significant facies changes must also be considered. Also, proximity to unconformities must be regarded not only from the chronostratigraphic standpoint, but also spatially at surfaces where they are likely to occur. This requires the preparation of a map showing the proximity at surface to possible unconformable contacts, and an associated table describing the relative fuzzy memberships of each buffer class for each deposit model.

The third factor, although only directly applicable to the sediment-hosted sulphide deposit model, is proximity to faults. The presence of faults is not a strong determinant in the Mississippi Valley Type lead-zinc or the Sediment Copper models, although it may be considered to be a mechanism for secondary mineralization related to these models. This is noted by Harrison (1991) for Pb-Zn occurrences. The preparation of a map is required for showing the proximity to faults at surface with an associated table describing the fuzzy membership value of each buffer class for each deposit model.

Preparation of Maps and Tables

Bedrock Lithology Map

The bedrock lithology was hand digitized from a 1:1,000,000 hard copy map provided by A. Okulitch (pers. comm. 1993), which is a re-compilation of 1:250,000 maps of Harrison (1991). This map contains 36 lithological units (Figure 2), each of which has been described fully in **APPENDIX B** (Table A). The map exists as a quadtree file, and also as a unique vector areas file. Once the map was digitized and entered, no further transformations were necessary for modelling. (For more details on the digitization of this and other maps, refer to **Appendix D - Data Input Procedures**).

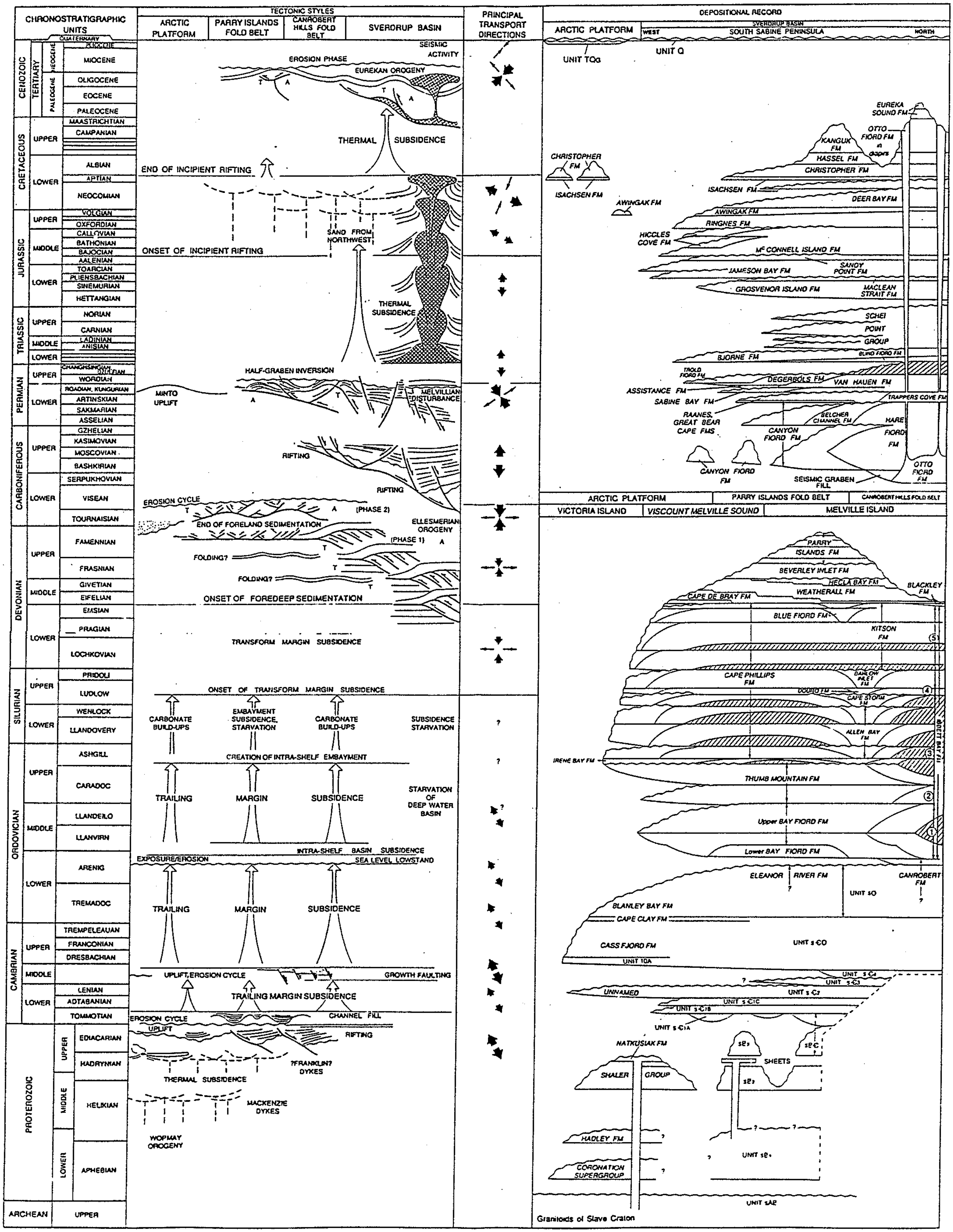


Figure 4. Correlation chart for Melville Island (after Harrison, 1990).

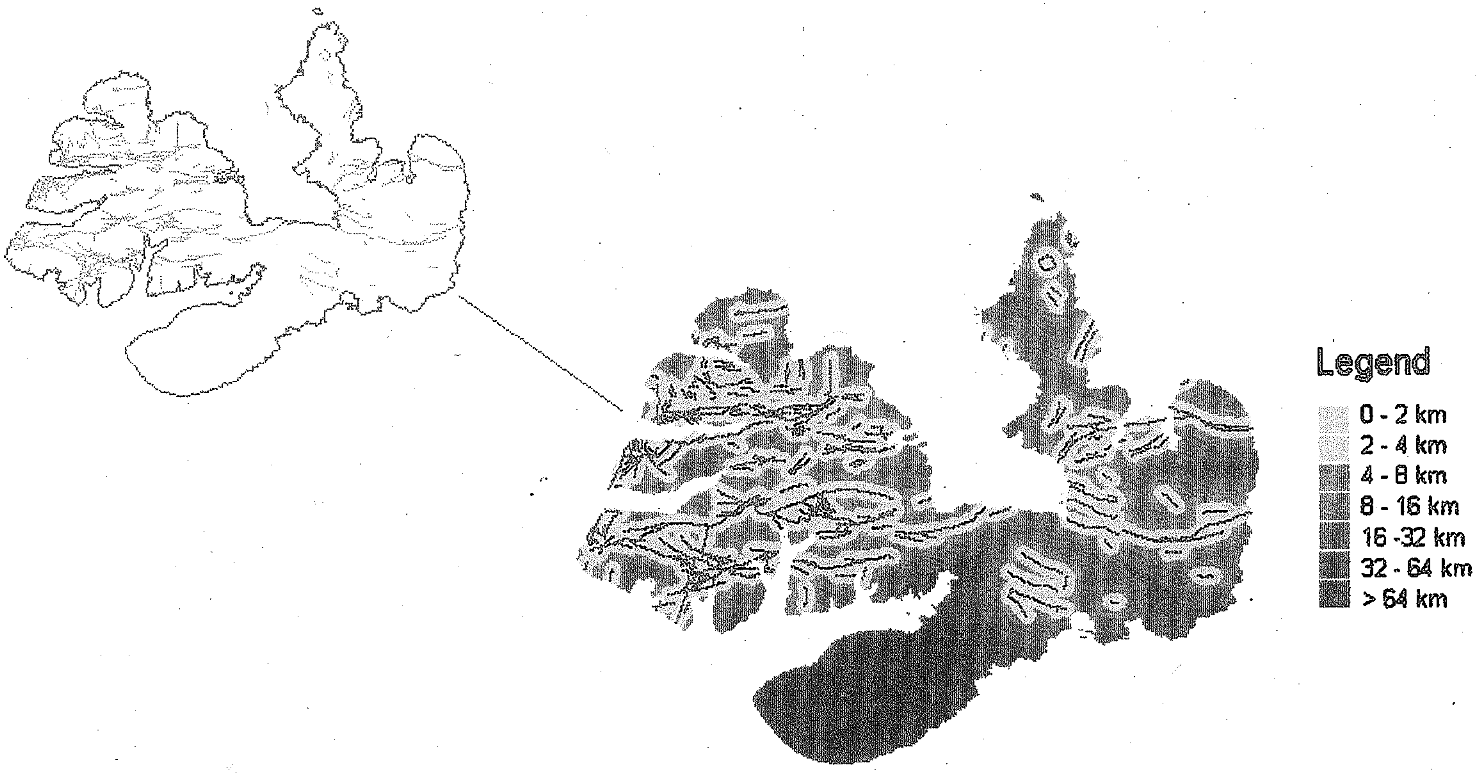


Figure 5. Proximity to Faults Map Preparation

Proximity to Unconformities Map

The preparation of a map showing the proximity to unconformities was more involved than the preparation of the previous two maps. Ideally, one would prefer to have the unit boundaries on the source map distinguish between conformable and unconformable contacts, but this information was not available.

However, the time periods for the significant unconformities in the stratigraphic record are well noted by Harrison (1991) (Figure 4). Using this information, the bedrock lithology map was reclassified according to the various depositional sequences which are bounded by the unconformities (Figure 6). **Table 1** below shows the depositional sequence classes which were assigned to the bedrock lithology table.

CLASS	ROCK UNIT	SEQUENCE CLASS	GEOLOGIC AGE
1	Beaufort Fm	1	Pleistocene
2	Eureka Sound Gp	2	Cretaceous
3	Gabbro dykes and sills	2	.
4	Kanguk Fm	2	.
5	Hassel Fm	2	.
6	Christopher Fm	2	.
7	Isachsen Fm	2	.
8	Deer Bay Fm	3	U. Jurassic - L. Cretaceous
9	Awingak Fm	3	.
10	Ringnes Fm	3	.
11	Hiccles Cove Fm	4	L. - M. Jurassic
12	McConnell Island Fm	4	.
13	Sandy Point Fm	4	.
14	Jameson Bay Fm	4	.
15	Bjorn Fm	5	L. Permian - U. Triassic
16	Trold Fiord Fm	5	.
17	Assistance and Trold Fiord Fms	5	.
18	Assistance Fm	5	.
19	Belcher Ch. and Sabine Bay Fm	5	.
20	Belcher Channel Fm	6	M. Carboniferous - L. Permian
21	Sabine Bay Fm	6	.
22	Canyon Fiord Fm	6	.
23	Otto Fiord Fm	7	L. - M. Carboniferous
24	Griper Bay Subgroup	8	L. - U. Devonian
25	Parry Islands Fm	8	.
26	Beverly Inlet Fm	8	.
27	Hecla Bay Fm	8	.
28	Weatherall Fm	8	.
29	Cape De Bray Fm	8	.
30	Blackeley & Cape De Bray Fms	8	.
31	Blue Fiord Fm	9	U. Ordovician - M. Devonian
32	Bathurst Island Fm	9	.
33	Cape Phillips Fm	9	.
34	Thumb Mtn & Irene Bay Fms	10	L. Ordovician - U. Ordovician
35	Ibbet Bay Fm	10	.
36	Cass Fiord & Cape Clay Fms	11	M. Cambrian - L. Ordovician

Table 1. Depositional sequence classification.

The bedrock lithology map was reclassified according to the depositional sequence class. The boundaries of the resulting map represent the contacts where unconformities may occur at surface. However, it was noticed in the compilation maps, and by overplotting the faults vector file that some of these boundaries corresponded with faults. That is, the boundary of a given unit on the bedrock lithology map is sometimes a fault boundary and not an unconformity. Therefore, the new map was modified to remove boundaries which overlie faults.

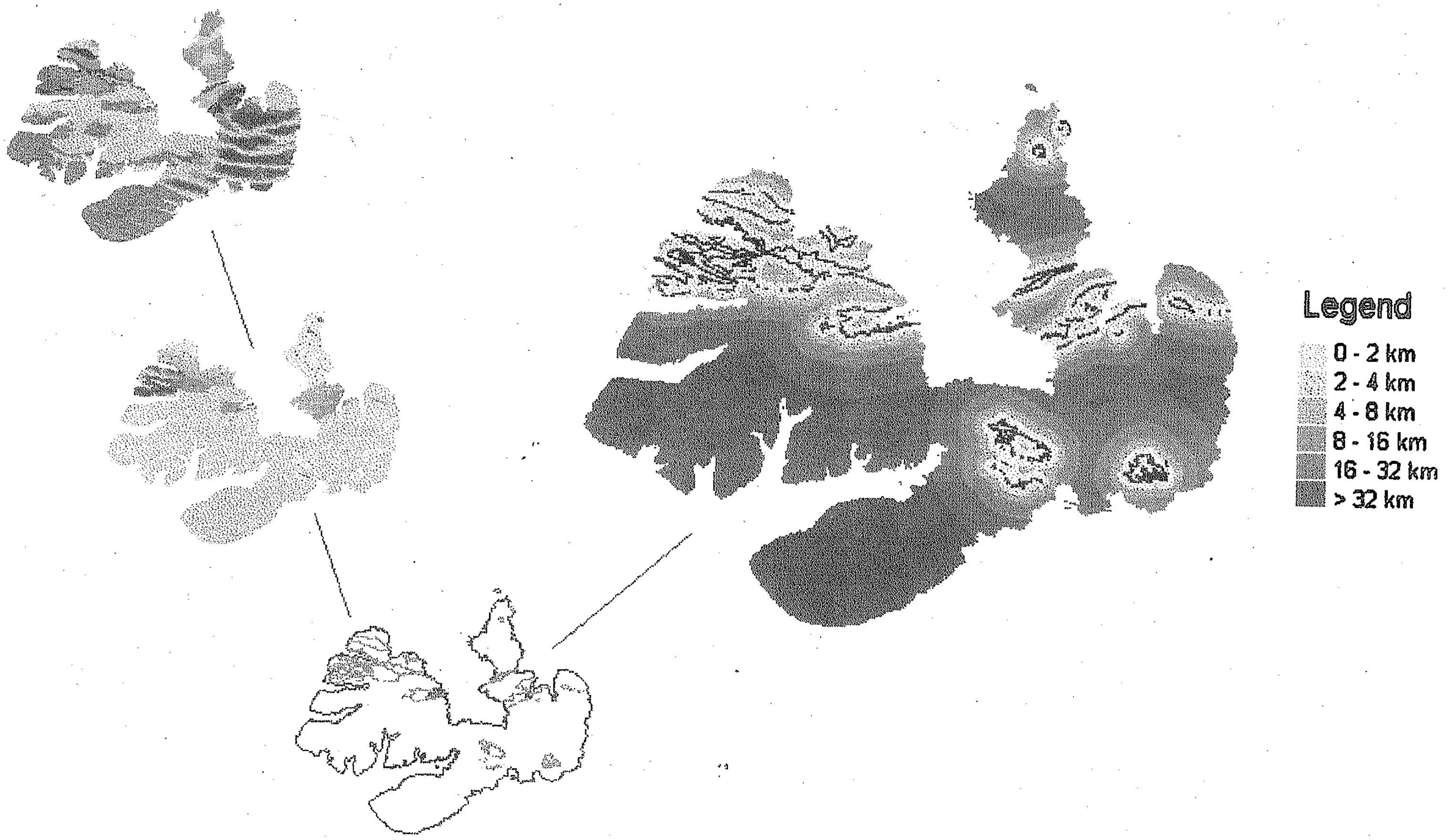


Figure 6. Proximity to Unconformities Map Preparation

This was done by first converting the depositional sequence map to a vector arc file, then transforming the boundaries vector file to a quadtree file where each boundary was buffered to a 1 km thickness interval. The same was done for the faults map. A short routine was written to overlay the two maps which would remove any sequence boundary which coincided with a fault. The new map file showing the unconformities was then transformed again to a vector arc file. The proximity map was created by transforming the unconformities vector file to a map file following the same approach as before with the proximity to faults map.

Preparation of Tables

Once the three input maps were created, the next task was to create an associated table for each map which contains the fuzzy membership values for each map class with respect to each deposit type (Figure 7). Tables 2-6 below list the fuzzy memberships which were assigned to each map class.

Assignment of Fuzzy Membership Values

The integrity of the results of this approach generally reflects the depth of knowledge on the geology of the area and the deposit models being reviewed. The first author (BGE) of this report has only recently become familiar with both in this respect, and therefore, may have assigned some values which may differ from values which would be assigned by an expert who has more geological experience in the area. However, while the focus of this report is on the methodology of applying fuzzy logic to mineral potential mapping, considerable care was taken while assigning these values to ensure that they adequately reflected their potential contribution to each deposit model as best understood by the author.

As noted above, each of the three deposit models places a relatively higher value on favourable lithologies and stratigraphic characteristics of lithological units than on spatial proximity to faulting or unconformities mappable at surface. This is reflected in the fuzzy membership values assigned to each map class as shown in Tables 2-6.

For the bedrock lithology class assignments, higher fuzzy membership values were assigned on the basis of combinations of 'potential' features a given unit may have based simply on the information provided in the geological map and stratigraphic model. It is important to understand that thorough stratigraphic research for each unit was not undertaken at this stage, and in most cases, the rationale for fuzzy membership values in terms of its conformity to one of the three deposit models are based on inferences from map and table information. A significantly higher fuzzy membership value was assigned to a unit if it contained a known mineral occurrence(s).

The fuzzy membership values assigned to the proximity to faults and proximity to unconformities map classes are based generally on a relative closeness factor combined with the relative level of importance each map has in each deposit model.

Bedrock Lithology

Map Class	Fuzzy Membership Values		
	MVT	Sed. Cu	Sed. Suphide
1	----	------	-------
2	----	------	-------
│	│	│	│
36	----	------	-------

Proximity to Faults

Map Class	Fuzzy Membership Values		
	MVT	Sed. Cu	Sed. Suphide
1	----	------	-------
2	----	------	-------
│	│	│	│
7	----	------	-------

Proximity to Unconformities

Map Class	Fuzzy Membership Values		
	MVT	Sed. Cu	Sed. Suphide
1	----	------	-------
2	----	------	-------
│	│	│	│
6	----	------	-------

Figure 7. Fuzzy Membership Table Design.

MAP CLASS	ROCK UNIT	MVT Pb-Zn	Rationale for Values
1	Beaufort Fm	0.01	
2	Eureka Sound Gp	0.01	
3	Gabbro dykes and sills	0.01	
4	Kanguk Fm	0.01	
5	Hassel Fm	0.01	
6	Christopher Fm	0.01	
7	Isachsen Fm	0.01	
8	Deer Bay Fm	0.01	
9	Awingak Fm	0.01	
10	Ringnes Fm	0.01	
11	Hiccles Cove Fm	0.01	
12	McConnell Island Fm	0.01	
13	Sandy Point Fm	0.01	
14	Jameson Bay Fm	0.01	
15	Bjorn Fm	0.01	
16	Trold Fiord Fm	0.01	
17	Assistance and Trold Fiord Fm	0.01	
18	Assistance Fm	0.01	
19	Belcher Ch. and Sabine Bay Fm	0.01	
20	Belcher Channel Fm	0.01	
21	Sabine Bay Fm	0.01	
22	Canyon Fiord Fm	0.01	
23	Otto Fiord Fm	0.40	- sulphur mineralization, limestone/dolomite,possible brecciation in dolomite.
24	Griper Bay Subgroup	0.20	- close proximity to unconformity in stratigraphic model.
25	Parry Islands Fm	0.20	- same as Griper Bay.
26	Beverly Inlet Fm	0.20	- same as Griper Bay.
27	Hecla Bay Fm	0.01	
28	Weatherall Fm	0.01	
29	Cape De Bray Fm	0.01	
30	Blackeley & Cape De Bray Fms	0.01	
31	Blue Fiord Fm	0.30	- reefal facies.
32	Bathurst Island Fm	0.40	- reefal facies,shale-carbonate facies change.
33	Cape Phillips Fm	0.80	- Pb mineralization, reefal facies, shale-limestone facies change.
34	Thumb Mtn & Irene Bay Fms	0.70	- Ba mineralization, reefal facies, shale-limestone facies changes.
35	Ibbet Bay Fm	0.99	- Cu,Pb,Zn,Ba,P,F mineralization, reefal facies, carbonate-shale-limestone facies changes.
36	Cass Fiord & Cape Clay Fms	0.80	- reefal facies, facies changes, close proximity to unconformities.

Table 2. Fuzzy membership values assigned to bedrock lithology classes for MVT Deposit Model.

MAP CLASS	ROCK UNIT	Sed Cu	Rationale for Values
1	Beaufort Fm	0.01	
2	Eureka Sound Gp	0.50	- close proximity to (above) unconformity, shallow marine sedimentary sequence, poss. source of copper (Otto Fiord).
3	Gabbro dykes and sills	0.01	
4	Kanguk Fm	0.30	- close proximity to (above) unconformity, shallow marine sedimentary sequence.
5	Hassel Fm	0.50	- close proximity to (above) unconformity (closer than Kanguk), shallow marine sedimentary sequence.
6	Christopher Fm	0.30	- shallow marine sedimentary sequence, close proximity to unconformity.
7	Isachsen Fm	0.10	- shallow marine sediments
8	Deer Bay Fm	0.30	- close proximity to unconformity, shallow marine sedimentary sequence.
9	Awingak Fm	0.20	- some shallow marine sediments, close proximity to unconformity.
10	Ringnes Fm	0.30	- shallow marine lithofacies, close proximity to unconformities.
11	Hiccles Cove Fm	0.10	- some marine lithofacies
12	McConnell Island Fm	0.20	- shallow marine lithofacies
13	Sandy Point Fm	0.20	- shallow marine lithofacies
14	Jameson Bay Fm	0.40	- close proximity to unconformities, shallow marine sedimentary sequence, redbeds.
15	Bjorn Fm	0.10	- some marine lithofacies.
16	Trold Fiord Fm	0.20	- "
17	Assistance and Trold Fiord Fm	0.20	- "
18	Assistance Fm	0.20	- "
19	Belcher Ch. and Sabine Bay Fm	0.30	- shallow marine lithofacies, transgressive cycle,
20	Belcher Channel Fm	0.20	- "
21	Sabine Bay Fm	0.10	- "
22	Canyon Fiord Fm	0.95	- Cu, F mineralization, marine sequence, base of major transgressive cycle, close proximity to unconformity.
23	Otto Fiord Fm	0.85	- Sulphur mineralization, close proximity to unconf.
24	Griper Bay Subgroup	0.20	- some marine lithofacies.
25	Parry Islands Fm	0.20	- "
26	Beverly Inlet Fm	0.20	- "
27	Hecla Bay Fm	0.10	- "
28	Weatherall Fm	0.01	
29	Cape De Bray Fm	0.20	- some marine lithofacies.
30	Blackeley & Cape De Bray Fms	0.20	- "
31	Blue Fiord Fm	0.01	
32	Bathurst Island Fm	0.20	- some marine lithofacies.
33	Cape Phillips Fm	0.70	- Pb mineralization, shale lithology, contains base of major transgressive unit.
34	Thumb Mtn & Irene Bay Fms	0.30	- Ba mineralization.
35	Ibbet Bay Fm	0.99	- Cu,Pb,Zn,Ba,P,F,S mineralization, marine lithofacies, base of major transgressive sequence.
36	Cass Fiord & Cape Clay Fms	0.50	- shale lithology, base of major transgressive sequence.

Table 3. Fuzzy membership values for bedrock lithology classes for Sediment Cu Deposit Model.

MAP CLASS	ROCK UNIT	Sed Sulphide	Rationale for Values
1	Beaufort Fm	0.01	
2	Eureka Sound Gp	0.01	
3	Gabbro dykes and sills	0.01	
4	Kanguk Fm	0.01	
5	Hassel Fm	0.01	
6	Christopher Fm	0.01	
7	Isachsen Fm	0.01	
8	Deer Bay Fm	0.01	
9	Awingak Fm	0.01	
10	Ringnes Fm	0.01	
11	Hiccles Cove Fm	0.01	
12	McConnell Island Fm	0.01	
13	Sandy Point Fm	0.01	
14	Jameson Bay Fm	0.01	
15	Bjorn Fm	0.01	
16	Trold Fiord Fm	0.80	- thick clastics, syndepositional faults, presence of chert.
17	Assistance and Trold Fiord Fm	0.80	- same as Trold Fiord Fm.
18	Assistance Fm	0.30	- clastic strata, syndepositional faults.
19	Belcher Ch. and Sabine Bay Fm	0.60	- thick clastics, syndepositional faults, presence of chert.
20	Belcher Channel Fm	0.70	- thick clastics, syndepositional faults, presence of chert.
21	Sabine Bay Fm	0.50	- thick clastics, syndepositional faults.
22	Canyon Fiord Fm	0.95	- Cu, F mineralization, thick clastic strata, syndepositional faults.
23	Otto Fiord Fm	0.85	- Native Sulphur, presence of chert and anhydrite.
24	Griper Bay Subgroup	0.50	- thick clastic strata
25	Parry Islands Fm	0.50	- "
26	Beverly Inlet Fm	0.50	- "
27	Hecla Bay Fm	0.60	- thick clastic strata, syndepositional faults.
28	Weatherall Fm	0.20	- some clastics, some faults
29	Cape De Bray Fm	0.40	- thick clastic stata, lateral facies changes.
30	Blackeley & Cape De Bray Fms	0.40	- same as Cape De Bray Fm.
31	Blue Fiord Fm	0.60	- rapid lateral facies changes, syndepositional faults.
32	Bathurst Island Fm	0.70	- thick clastics, lateral facies changes, syndepositional faults.
33	Cape Phillips Fm	0.60	- Pb mineralization, some clastic strata, lateral facies changes.
34	Thumb Mtn & Irene Bay Fms	0.60	- Ba mineralization, presence of anhydrite, thick sequence with some clastics.
35	Ibbet Bay Fm	0.99	- Cu,Pb,Zn,Ba,P,F,S mineralization, lateral facies changes, presence of chert.
36	Cass Fiord & Cape Clay Fms	0.60	- presence of chert, shale.

Table 4. Fuzzy membership values assigned to bedrock lithology classes for Sediment Sulphide Deposit Model.

MAP CLASS	DESCRIPTION	MVT Pb-Zn	Sed Cu	Sed Sulphide
1	0 - 2 km	0.40	0.20	0.60
2	2 - 4 km	0.15	0.05	0.25
3	4 -8 km	0.05	0.01	0.10
4	8 - 16 km	0.01	0.01	0.01
5	16 - 32 km	0.01	0.01	0.01
6	32 - 64 km	0.01	0.01	0.01
7	> 64 km	0.01	0.01	0.01

Table 5. Fuzzy membership values for proximity to faults classes.

MAP CLASS	DESCRIPTION	MVT Pb-Zn	Sed Cu	Sed Sulphide
1	0 - 2 km	0.60	0.30	0.20
2	2 - 4 km	0.05	0.10	0.10
3	4 - 8 km	0.01	0.01	0.01
4	8 - 16 km	0.01	0.01	0.01
5	16 - 32 km	0.01	0.01	0.01
6	> 32 km	0.01	0.01	0.01

Table 6. Fuzzy membership values for proximity to unconformities classes.

Fuzzy Logic Model

The next stage involved model processing which would create new maps by performing some mathematical operations on the fuzzy membership values of the three input maps. A variety of fuzzy logic operators are available which could have been applied (An et. al. 1993). The following operators were chosen for each deposit model in order to create four mineral potential maps for each deposit type. The chosen equations aim to demonstrate the variety of operations that may be performed with fuzzy theory for mineral potential mapping.

The equations for each operator reference the fuzzy membership values of the individual classes of the three input maps:

A - Bedrock Lithology, B - Proximity to Faults, and C - Proximity to unconformities, respectively.

Fuzzy 'AND' Operator = min (A, B, C)

The fuzzy 'AND' operator assigns the minimum value from the values of the three maps to each pixel on the map . This is especially useful for models where it is known, or desired that all conditions of the three maps must be met to conform to a given model.

Fuzzy 'OR' Operator = max (A, B, C)

The fuzzy 'OR' operator assigns the maximum value from the values of the three maps to each pixel on the map. This operator is useful in applications where not all conditions need to be met at the same location. This operator highlights the maximum values available of all conditions.

$$\text{Fuzzy 'SUM'} = A + B + C - (A*B*C)$$

The fuzzy 'SUM' operator is an algebraic sum equation which assigns values to pixels that are at least the value of the fuzzy 'OR' operator. This usually results in pixels having values higher than the minimum of values of conditions from the map set.

$$\text{Fuzzy 'GAMMA'} = ((A * B * C)^{1 - G})*((1 - ((1- A) * (1- B) * (1- C))^{G})$$

In this operator, G is some value $\{0 < G < 1\}$. This operator is used to down weigh the effect of the input maps by decreasing the value of G. The aim of this operator is to compensate for conflicting evidence from the input maps.

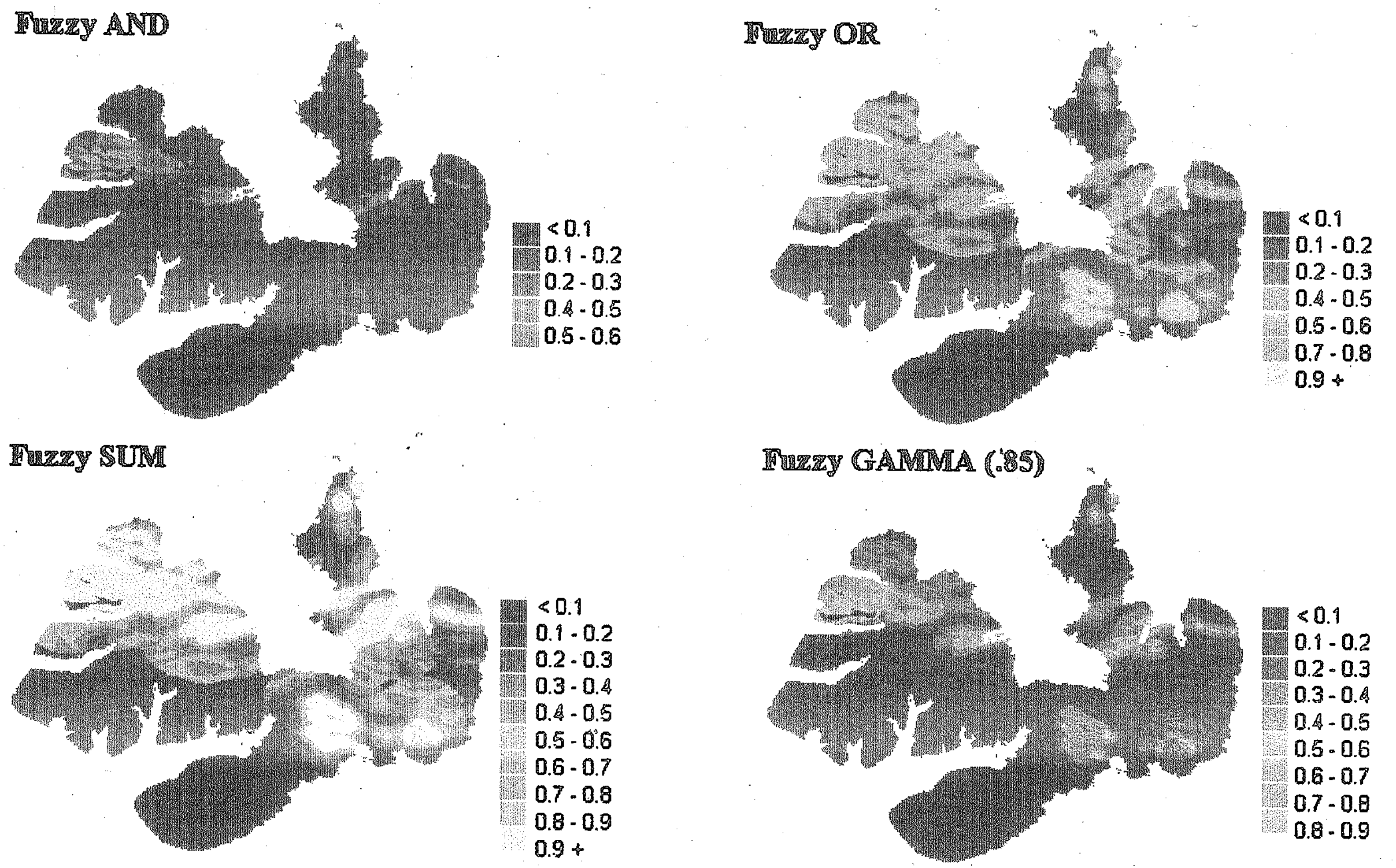
Each of these operators was written into a set of equations used in map modelling. (Refer to **APPENDIX C** for a list of the actual equations used).

ANALYSIS and RESULTS

Each of the fuzzy operators was performed on the map set to produce twelve output maps; four for each deposit model. Figures 8, 9, and 10 reveal a recurring pattern among the operators described in the previous section. The fuzzy 'AND' results show the relative importance of the lithology values compared to the two proximity maps. The buffer patterns from the two proximity maps shine through more significantly in the fuzzy 'OR' and 'SUM' operators.

The criteria established earlier for each deposit type stressed a higher importance of the values assigned to lithology than for proximity to faults and unconformities. While the fuzzy 'AND' operator shows this contrast, it is important to not entirely overlook the weight of the proximity maps. The fuzzy 'GAMMA' operator appears to have succeeded at doing this with a value of G = .85. Initially, G values of .90, .95, and .975 were used but the influence of the proximity maps on the results was considered too high. For this reason, the fuzzy 'GAMMA' operator can be regarded as yeilding the most desirable results from an expert's standpoint.

One way of comparing the result of each operator is to append the map classes from each fuzzy output map to the mineral occurrence point file. Table 5 below shows the GAMMA values appended to each occurrence according to deposit model type.


Fuzzy AND

Fuzzy OR

Fuzzy SUM

Fuzzy GAMMA (.85)

Figure 8. Fuzzy Logic Models for Mississippi Valley Type Pb-Zn.

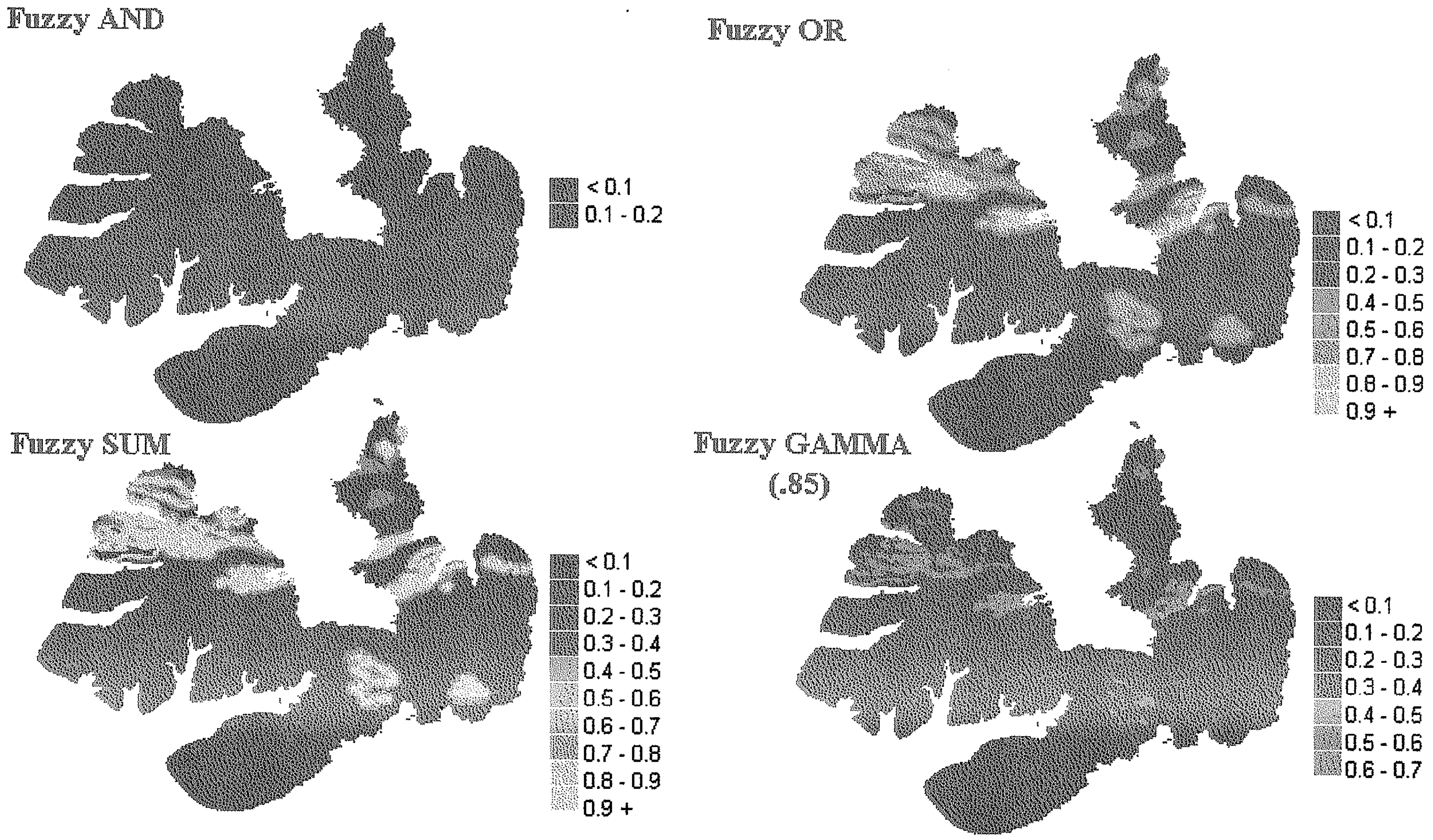


Figure 9. Fuzzy Logic Models for Sediment Copper Type Deposits.

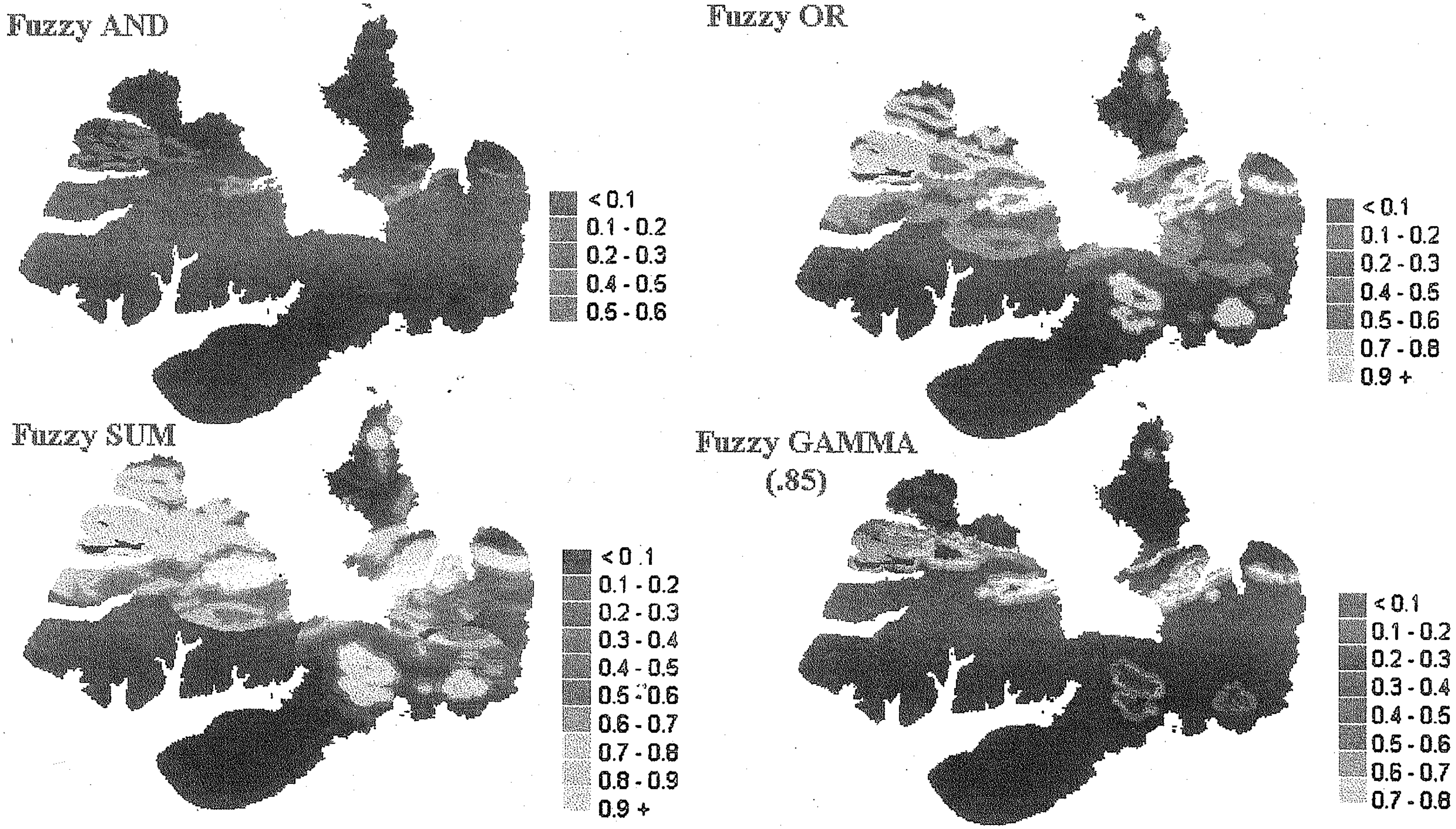


Figure 10. Fuzzy Logic Models for Sediment Hosted Sulphide Type Deposits.

Mississippi Valley Type Pb-Zn

No.	Rock Unit	Mineral	AND	OR	SUM	GAMMA
1 '	CPC' '	Cu'	5	8	10	8
2 '	OTM' '	Ba'	3	10	10	9
3 '	OSD' '	Cu'	6	8	10	9
4 '	OSD' '	Cu'	6	8	10	9
5 '	OSD' '	Zn,Pb,F'	2	8	10	6
6 '	CPC' '	F'	6	8	10	9
7 '	OSD' '	Ba'	6	8	10	9
8 '	OSC' '	Pb'	5	6	10	6
9 '	COF' '	S'	3	8	10	7

Sediment Copper

No.	Rock Unit	Mineral	AND	OR	SUM	GAMMA
1 '	CPC' '	Cu'	2	9	10	7
2 '	OTM' '	Ba'	1	10	10	1
3 '	OSD' '	Cu'	2	8	10	6
4 '	OSD' '	Cu'	2	8	10	6
5 '	OSD' '	Zn,Pb,F'	1	8	8	1
6 '	CPC' '	F'	2	8	10	6
7 '	OSD' '	Ba'	2	8	10	6
8 '	OSC' '	Pb'	1	9	10	6
9 '	COF' '	S'	2	8	10	5

Sediment Hosted Sulphide

No.	Rock Unit	Mineral	AND	OR	SUM	GAMMA
1 '	CPC' '	Cu'	5	8	10	8
2 '	OTM' '	Ba'	3	10	10	8
3 '	OSD' '	Cu'	6	8	10	7
4 '	OSD' '	Cu'	6	8	10	7
5 '	OSD' '	Zn,Pb,F'	2	8	10	6
6 '	CPC' '	F'	6	8	10	7
7 '	OSD' '	Ba'	6	8	10	7
8 '	OSC' '	Pb'	5	6	10	7
9 '	COF' '	S'	3	8	10	7

Table 5. Mineral occurrences with appended fuzzy map output classes.

This method is partially circular because the fuzzy memberships assigned to lithology classes were weighted higher if the unit had a known occurrence, although the assignment of fuzzy membership values also considered strongly the importance of lithological and stratigraphic characteristics. On this basis the results are favourable, as most occurrences are correlated with the higher class values of each fuzzy operator output map.

DISCUSSION

For the most part, the knowledge driven fuzzy logic approach applied in this study provides a simple means of producing mineral potential maps using a geology map and a selection of applicable mineral deposit models. This approach to mineral potential modelling was taken primarily because of lack of sufficient known occurrences to satisfy a data driven approach, but also serves as an alternative to mineral potential mapping using expert knowledge.

The fuzzy logic methodology has great potential for government agencies responsible for mineral resource mapping, especially for large geographic areas where available data is usually sparse or fragmented. A potential area for further investigation would be to develop a fuzzy logic approach which could allow a panel of experts to assign their respective values, and compare the results.

Another benefit of this method is that in many situations, especially in the mineral exploration industry, there is either a lack of sufficient occurrences, or financial resources are insufficient to allow a more intensive data driven approach to be carried through. Whereas research geologists can use this method to infer 'mineral potential' for regional economic and mineral development planning, this method also allows the explorationist to filter through available datasets in much the same way to identify 'exploration targets' based on their own approach to mineral exploration.

Several spatial related problems encountered during this study provide an interesting base for further investigation. The first is related to mapping unconformities from a bedrock geology map which does not provide such information. What was not considered in the approach used in this study are the complex relations that result from the intercalation of units in a succession, and their relationships to bounding unconformities. For example, areas of Ibbet Bay Fm may or may not potentially be unconformable to adjacent units. Therefore, a comparison would need to be made with adjacent units on the basis of actual age relationships such as upper age lower age limits, with positions of observed unconformities in the stratigraphic model. More intensive topological modelling will be required to resolve this problem.

The second problem deals with the display of units which are considered to have low mineral potential, but are overlie units of higher potential at an accessible depth. Stratigraphic modelling may be useful here, however, the variability of unit thickness in space combined with structural orientation remains a problem.

A third problem would be to determine relationships between fault patterns, and stratigraphy. Harrison (1991) noted several phases of faulting which are the result of different orientations of principal stress on the region at different times during the orogeny. Much of the upper part of the Franklinian Succession, and the lower part of the Sverdrup Succession were deposited syntectonically to the deformation. As this is an important feature for sediment hosted sulphides, it would be interesting to examine the relationships between the fault geometries and the lithology.

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APPENDIX A - MINERAL DEPOSIT MODELS (taken from Eckstrand (1984).

6. STRATABOUND SEDIMENT—HOSTED LEAD, ZINC, COPPER, URANIUM

6.1 MISSISSIPPI VALLEY LEAD-ZINC

COMMODITIES	Pb, Zn (Ag, Cd)
EXAMPLES: **Canadian – *Foreign***	Pine Point and Polaris, N.W.T.; Newfoundland Zinc, Nfld.; – *Viburnum Trend and Old Lead Belt Districts, Missouri; East Tennessee District, Tennessee; Silesian District, Poland*
IMPORTANCE	Canada: about 30% of lead-zinc production. World: major source of lead and zinc in U.S.A., Poland and Austria.
TYPICAL GRADE, TONNAGE	Data for individual deposits are difficult to obtain because of lack of production records and the fact that, in many districts, deposits tend to be interconnected. Best estimate for most individual deposits: 5 to 10% combined Pb-Zn, 1 to 10 million tonnes.
GEOLOGICAL SETTING	In platform carbonate successions. Commonly, but not always, located between a zone of tectonic instability characterized by vertical movement (commonly called a "hinge line" and marked by rapid lithological facies changes such as at a reef front, or edge of a sedimentary basin), and the tectonically stable platform.
HOST ROCKS OR MINERALIZED ROCKS	Carbonate rocks, generally highly brecciated dolomite.
ASSOCIATED ROCKS	Most commonly limestone; less commonly shale, sandstone and evaporites.
FORM OF DEPOSIT, DISTRIBUTION OF ORE MINERALS	Form: highly irregular in shape, usually discordant on deposit-scale but stratabound on a district scale. Distribution of ore minerals: mostly as open-space filling in highly brecciated dolomite in which sphalerite, especially, shows colloform texture. Also commonly disseminated with secondary carbonate gangue; occasionally massive, coarsely crystalline aggregates.
MINERALS: Principal ore minerals ***– Associated minerals***	Sphalerite, galena. *– Pyrite, marcasite, dolomite, calcite, lesser amounts of quartz, barite, fluorite, chalcopyrite*
AGE, HOST ROCKS	Canada: Helikian to Carboniferous; most abundant in early to mid-Paleozoic. Foreign: mainly Cambrian to Triassic.
AGE, ORE	Not known with any certainty.
GENETIC MODEL	Although "...no general consensus has been reached...geologists do not know the physiochemical reasons why Mississippi Valley deposits are where they are..." (Ohle, 1980, p. 163), fluid inclusion studies suggest ores were precipitated from low temperature (commonly 80°C - 150°C) brines. A commonly cited model is based on the Beales and Jackson (1966) interpretation whereby the brines originated from shale basins adjacent to the platform carbonates, and the ore minerals precipitated in some cases during early diagenesis, and in other cases long after lithification of host rocks.
ORE CONTROLS, GUIDES TO EXPLORATION	No consensus on genetic models hence no consensus on ore controls, or guides. However, one or more of the following features are commonly associated with these deposits: 1. Secondary breccia in dolomite, cemented by white sparry dolomite. 2. Unconformities within carbonate sequence (ore horizon will be below unconformities). 3. Reefs. 4. Carbonate-shale and limestone-dolomite facies changes. 5. Basement high(s). 6. Open spaces of any type within carbonate sequences, especially those formed by karstification as evidenced by brecciation, thinning of carbonate strata, local increase in concentration of insoluble residue material.
AUTHOR	D.F. Sangster (see Plate 2, page 5)

6.3 SEDIMENTARY COPPER

6.3.a Paralic marine (Kupferschiefer-type)
6.3.b Continental (Red bed-type)

COMMODITIES	Cu (Ag, Co)
EXAMPLES: Canadian – *Foreign*	**(6.3.a)** Redstone, N.W.T. – *Kupferschiefer, Poland-Germany; Zambian and Zairean Copperbelts; Udokan, U.S.S.R.; White Pine, Michigan; Spar Lake, Montana; Creta, Oklahoma.* **(6.3.b)** Dorchester, N.B. – *Dzhezkazgan, U.S.S.R.: Nacimiento, New Mexico.*
IMPORTANCE	Canada: No economic deposits in Canada but large deposits in United States near Canadian border. World: 15% to 20% of world copper production and reserves; primarily from a few large districts such as Zambian and Zairean Copperbelts; Lubin, Poland; and Dzhezkazgan, U.S.S.R.
TYPICAL GRADE, TONNAGE	**(6.3.a)** Highly variable. 1.0 to 5.0% Cu and 1 to 30 g Ag/tonne; 5 to 500 million tonnes. Cobalt is an important byproduct in Zambian and Zairean Copperbelts. **(6.3.b)** 1 to 2% Cu and 1 to 30 g Ag/tonne, 1 to 10 million tonnes.
GEOLOGICAL SETTING	Continental or shallow marine sedimentary rocks deposited in low latitude, arid and semi-arid environments. Evaporites occur in the section. **(6.3.a)** Anoxic marine rocks overlie or are interlayered with redbeds. **(6.3.b)** Anoxic fluvial and lacustrine rocks overlie or are interlayered with redbeds.
HOST ROCKS OR MINERALIZED ROCKS	**(6.3.a)** Carbonaceous claystone, siltstone, sandstone, marl, limestone and dolomite. **(6.3.b)** Carbonaceous sandstone, conglomerate, claystone and siltstone.
ASSOCIATED ROCKS	Redbeds, evaporites.
FORM OF DEPOSIT, DISTRIBUTION OF ORE MINERALS	Concordant or peneconcordant zones of disseminated sulphides, mainly tabular or blanket-shaped, but also channel-like or linear. Typical lateral extent of mineralized beds is of the order of kilometres; typical thickness, 0.5 to 30 m. Sulphides are commonly zoned both vertically and laterally, showing part or all of the following sequence (upward and outward from the base of the orebody): native copper, chalcocite, bornite, chalcopyrite, galena, sphalerite, pyrite.
MINERALS: Principal ore minerals – *Associated minerals*	Chalcopyrite, bornite, chalcocite, native copper, carrollite. – *Pyrite, other sulphides, ordinary rock forming minerals of sedimentary rocks such as quartz, feldspar, carbonates, clays*
AGE, HOST ROCKS	Early Proterozoic (about 2.25 Ga) to Tertiary. Only after the formation of undisputed redbeds.
AGE, ORE	The same as, or slightly younger than, host rocks.
GENETIC MODEL	Diagenetic subsurface brines (probably derived from evaporites) extracted copper from available basement rocks or sediments, transported it through oxidized beds, and precipitated it by reduction in anoxic sediments. Early diagenetic pyrite was a common reductant.
ORE CONTROLS, GUIDES TO EXPLORATION	1. Low latitude, arid, continental and shallow marine sedimentary sequences. 2. Sources of copper such as copper-bearing basement and/or sediments. 3. Extensive redbed or other oxidized aquifer system and adjacent pyritic, carbonaceous host rocks. The typical sites of ore deposition differ in the two subtypes: **(6.3.a)** the base of a major marine transgressive unit overlying redbeds; **(6.3.b)** the permeable lower parts of fining-upwards fluvial cycles. 4. Large-scale zoning of sulphides (indicating that the mineralizing systems were large-scale phenomena).
AUTHOR	R.V. Kirkham

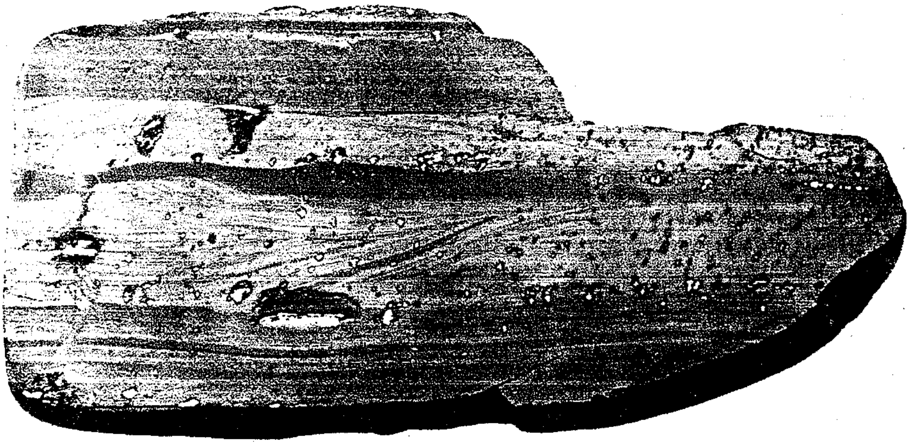


Figure 9. *6.3.a Sedimentary Copper (Kupferschiefer type). Redstone deposit, Northwest Territories. Typical pale, fine grained silty carbonate grainstone with delicate climbing ripples and erractically disseminated chalcopyrite. The 12 mm-long lens (lower centre) is a calcite nodule with chalcopyrite along the top. Sample is 12 cm long. Sample: R.V. Kirkham (GSC 203641-W).*

9.2 SEDIMENT-HOSTED SULPHIDE

COMMODITIES	Zn, Pb, Ag, barite (Cd, Cu, Sn)
EXAMPLES: **Canadian – *Foreign***	Sullivan, Cirque, B.C.; Faro, Howards Pass, Tom and Jason, Yukon; Walton, N.S. is probably a deposit of this type, comparable to Silvermines, Ireland. – *Balmat, New York; Broken Hill, Mt. Isa and McArthur River, Australia; Broken Hill and Gamsberg, South Africa; Rammelsberg and Meggen, West Germany; Silvermines and Tynagh, Ireland*
IMPORTANCE	Canada: in 1977-78, 16% of the zinc, 45% of the lead and 10% of the silver produced in Canada was from this type of deposit. These proportions will probably increase in the future. World: currently, the bulk of the world's known reserves of zinc and lead in deposits of this type occur in Australia, Canada, and South Africa.
TYPICAL GRADE, TONNAGE	Range (and weighted average) of 38 worldwide examples: 4 to 550 (av. 60) million tonnes; 0.6% to 18% (av. 7.3%) Zn; 0.3% to 13% (av. 4.0%) Pb; nil to 1.0% (av. 0.1%) Cu; trace to 180 g/tonne (av. 48 g/tonne) Ag. Some deposits have large reserves of barite associated with the sulphide ores, e.g. Walton, N.S. (now closed) produced about 4 million tonnes BaSO$_4$. Meggen, Germany produced about 7 million tonnes BaSO$_4$. Anvil district deposits (e.g. Faro), Tom and Jason, Yukon and Cirque, B.C. have substantial barite contents.
GEOLOGICAL SETTING	Within second order, often tectonically (growth fault) controlled sedimentary basins situated in a continental rise, continental shelf or intracontinental marine basin.
HOST ROCKS OR MINERALIZED ROCKS	Deep marine clastic sedimentary rocks (shales, siltstones, fine to coarse grained turbidites), starved basin lithofacies (carbonaceous to siliceous shales, chert), shallow marine lithofacies (calcareous shales, carbonates).
ASSOCIATED ROCKS	Sedimentary breccias and conglomerates, especially in the stratigraphic footwall; talus from synsedimentary fault scarp. Sulphide zone may be overlain by, or pass laterally into, chemical sediments, particularly chert and baritite. Minor amounts of volcanic rocks, especially tuffs, recognized in host rocks of some deposits. Discordant feeder zone may be silicified, carbonatized, tourmalinized. Increase in biogenic activity near hydrothermal vents may be indicated by increase in carbon, silica and phosphorus content of associated rocks.
FORM OF DEPOSIT, DISTRIBUTION OF ORE MINERALS	Concordant interbedded layers of sulphide and host rocks form mineralized bodies whose lateral extents are tens to hundreds of times greater than their thicknesses. Ores are typically bedded on a scale varying from a few microns to several centimetres. Individual sulphide beds are often monomineralic. Relatively small "feeder zones" discordant to stratiform mineralization have been identified in many deposits. Pb/Zn, Cu/Zn, Zn/Ba ratios of the stratiform mineralization typically decrease away from the feeder zone.
MINERALS: Principal ore minerals **– *Associated minerals***	Sphalerite, galena, barite. – *Quartz, pyrrhotite, pyrite, chalcopyrite, marcasite, arsenopyrite, sulphosalts, cassiterite*
AGE, HOST ROCKS	Canada: Sullivan, 1.43 Ga; Northern B.C.-Yukon, 0.55-0.34 Ga; Australia, South Africa, 2.0-1.7 Ga; Europe, 0.38-0.36 Ga.
AGE, ORE	Same as host rocks.
GENETIC MODEL	Deposition in a brine pool in a second order basin. Discharge temperature of fluids is generally less than that of volcanic-associated deposits (9.1), i.e., probably in the range 150-250°C. Hydrothermal activity is associated with tectonic activity, manifested by growth faults, slump breccias, etc. Some deposits may be a product of low heat flux discharge or seepage of stratafugic water (e.g., derived by compaction of underlying sedimentary pile) into a euxinic, starved basin environment.
ORE CONTROLS, GUIDES TO EXPLORATION [illegible]	1. The majority of deposits are spatially associated with intracontinental or continental margin basins - usually thick successions of clastic sedimentary rocks. 2. Second order basins are prime exploration targets, and are recognized by local lithological facies that are additional or exotic to the regional lithological succession, and rapid lateral facies change. 3. Evidence of syndepositional tectonic activity: growth faults, fault scarp talus, slump and slide breccias. Tectonically active zone may represent reactivation of basement faults. 4. Evidence of syndepositional geothermal activity: presence of volcanic rocks in the succession, usually local flows or thin tuff horizons; presence of other chemical sediments of hydrothermal origin (e.g. chert, baritite, sediments enriched in iron and manganese), or of biogenic origin resulting from hydrothermal activity (e.g. sediments enriched in carbon, phosphorous, and silica).
AUTHORS	J.W. Lydon, D.F. Sangster (see Plate 9, page 9)

APPENDIX B - DATA TABLES

Table A - Bedrock Lithology Classification and Fuzzy Membership Table

```
ID newbed
TITLE Bedrock Geology Attributes Table
TABTYPE 4
FTYPE free
KEYFIELD 0
 1   3  2.000000 0    mibedroc Bedrock Geology Map Class Number
 2  52 32.000000 0        unit Unit Name
 3  24  4.000000 0       unann Unit Annotation
 4  24  4.000000 0     aokann Andy O'Kulitch Legend Annotation
 5  24  4.000000 0    1715Aann Map 1715A Legend Annotation
 6   3  3.000000 0      palcol Palet Color
 7   3  2.000000 0    upperage Upper Age
 8   3  2.000000 0    lowerage Lower Age
 9   3  2.000000 0       lith1 Primary Lithology
 10  3  2.000000 0       lith2 Secondary Lithology
 11  3  2.000000 0       lith3 Tertiary Lithology
 12  3  2.000000 0       lith4 Fourth Lithology
 13 25  5.000000 0     lithleg Legend Used for Lithology
 14  3  1.000000 0    mintyp1 Mineral Occurrence 1
 15  3  1.000000 0    mintyp2 Mineral Occurrence 2
 16  3  1.000000 0    mintyp3 Mineral Occurrence 3
 17  3  1.000000 0    mintyp4 Mineral Occurrence 4
 18  3  1.000000 0    mintyp5 Mineral Occurrence 5
 19  3  1.000000 0    mintyp6 Mineral Occurrence 6
 20  1  4.000000 0       fzmvt Mississippi Valley Type Fuzzy Membership
 21  1  4.000000 0     fzsedcu Sediment Redbed Copper Fuzzy Membership
 22  1  4.000000 0     fzsedsh Sediment Hosted Sulphide Fuzzy Membership
 23  3  2.000000 0      unconf Unconformable Successions Sequences
DATA
 1 "Beaufort Fm                    " "mTNB" "mTNB" "mTB "  11  1  2  37  39   0   0 "1715A"  0  0  0  0  0  0 0.01 0.01 0.01  1
 2 "Eureka Sound Gp                " "KTES" "KTES" "KTES"  14  6  8  44  46  39   0 "CHLEG"  0  0  0  0  0  0 0.01 0.50 0.01  2
 3 "Gabbro dykes and sills         " "Kb  " "Kb  " "Kb  "  49  8  8  14   0   0   0 "CHLEG"  0  0  0  0  0  0 0.01 0.01 0.01  2
 4 "Kanguk Fm                      " "KK  " "KK  " "KK  "  16  8  9  44  46  39   0 "1715A"  0  0  0  0  0  0 0.01 0.30 0.01  2
 5 "Hassel Fm                      " "KH  " "KH  " "KH  "  23  9  9  39  46  44   0 "CHLEG"  0  0  0  0  0  0 0.01 0.50 0.01  2
 6 "Christopher Fm                 " "ALKC" "ALKC" "KC  "  24  9 10  44  46   0  39 "CHLEG"  0  0  0  0  0  0 0.01 0.30 0.01  2
 7 "Isachsen Fm                    " "KI  " "KI  " "KI  "  26 10 10  39  37  46  54 "CHLEG"  8  0  0  0  0  0 0.01 0.10 0.01  2
 8 "Deer Bay Fm                    " "JKDB" "JKDB" "JKDB"  36 10 10  46  44  39   0 "CHLEG"  0  0  0  0  0  0 0.01 0.30 0.01  3
 9 "Awingak Fm                     " "JA  " "JA  " "JA  "  40 10 11  39  46  44  37 "BOTH "  0  0  0  0  0  0 0.01 0.20 0.01  3
10 "Ringnes Fm                     " "JR  " "JR  " "JR  "  43 11 11  44  46  39   0 "CHLEG"  0  0  0  0  0  0 0.01 0.30 0.01  3
11 "Hiccles Cove Fm                " "JHC " "JHC " "JHC "  45 11 12  39  46   0   0 "CHLEG"  0  0  0  0  0  0 0.01 0.10 0.01  4
12 "McConnell Island Fm            " "JMI " "JMI " "JMI "  47 12 12  44  46  39   0 "CHLEG"  0  0  0  0  0  0 0.01 0.20 0.01  4
13 "Sandy Point Fm                 " "JSP " "JSP " "JWPK"  50 12 12  44  46  39   0 "CHLEG"  0  0  0  0  0  0 0.01 0.20 0.01  4
14 "Jameson Bay Fm                 " "JJS " "JJS " "JJS "  53 12 13  44  46   0   0 "1715A"  0  0  0  0  0  0 0.01 0.40 0.01  4
15 "Bjorn Fm                       " "lTrB" "lTrB" "lTrB"  70 15 16  39  37  44   0 "CHLEG"  0  0  0  0  0  0 0.01 0.10 0.01  5
16 "Trold Fiord Fm                 " "PTF " "PTF " "PTF " 150 17 17  39  52  37  46 "BOTH "  0  0  0  0  0  0 0.01 0.20 0.80  5
17 "Assistance and Trold Fiord Fms " "PAT " "PAT " "PAT " 155 17 18  39  52  37  46 "BOTH "  0  0  0  0  0  0 0.01 0.20 0.80  5
18 "Assistance Fm                  " "PA  " "PA  " "N/A " 159 18 18  39   0   0   0 "CHLEG"  0  0  0  0  0  0 0.01 0.20 0.30  5
19 "Belcher Ch. and Sabine Bay Fm  " "PBS " "N/A " "PBS " 162 18 19  39  50  37  46 "CHLEG"  0  0  0  0  0  0 0.01 0.30 0.60  5
20 "Belcher Channel Fm             " "PBC " "PBC " "N/A " 165 18 19  50  39  46   0 "CHLEG"  0  0  0  0  0  0 0.01 0.20 0.70  6
21 "Sabine Bay Fm                  " "PSB " "N/A " "N/A " 169 18 18  39  37  52   0 "CHLEG"  0  0  0  0  0  0 0.01 0.10 0.50  6
22 "Canyon Fiord Fm                " "CPCF" "CCF " "CCF " 125 19 21  39  37  38  47 "CHLEG"  1  6  0  0  0  0 0.01 0.95 0.95  6
23 "Otto Fiord Fm                  " "COF " "COF " "COF " 129  8 21  67  66  50  51 "CHLEG"  7  0  0  0  0  0 0.40 0.85 0.85  7
24 "Griper Bay Subgroup            " "DGB " "N/A " "DGB "  85 23 24  39  46  44  37 "CHLEG"  0  0  0  0  0  0 0.20 0.20 0.50  8
25 "Parry Islands Fm               " "DPI " "DPI " "DPI "  90 23 23  39  46  44  37 "CHLEG"  8  0  0  0  0  0 0.20 0.20 0.50  8
26 "Beverly Inlet Fm               " "uDBI" "uDBI" "uDBI"  96 23 24  39  46  44  54 "CHLEG"  0  0  0  0  0  0 0.20 0.20 0.50  8
27 "Hecla Bay Fm                   " "DHB " "DHB " "DHB " 105 24 24  39  46  37  54 "BOTH "  0  0  0  0  0  0 0.01 0.10 0.60  8
28 "Weatherall Fm                  " "DW  " "DW  " "DW  " 109 24 24  39  46  44   0 "CHLEG"  0  0  0  0  0  0 0.01 0.01 0.20  8
29 "Cape De Bray Fm                " "DCB " "N/A " "DCB "  60 24 24  44  46  39   0 "CHLEG"  0  0  0  0  0  0 0.01 0.20 0.40  8
30 "Blackeley & Cape De Bray Fms   " "DBC " "N/A " "DBC "  63 24 24  44  39  46   0 "CHLEG"  0  0  0  0  0  0 0.01 0.20 0.40  8
31 "Blue Fiord Fm                  " "DC  " "DC  " "DC  "  68 24 25  50  51   0   0 "CHLEG"  0  0  0  0  0  0 0.30 0.01 0.60  9
32 "Bathurst Island Fm             " "DB  " "DB  " "DS  "  75 26 27  46  39  44  51 "1715A"  0  0  0  0  0  0 0.40 0.20 0.70  9
33 "Cape Phillips Fm               " "OSCP" "OSCP" "OSCP" 172 24 29  44  50  51   0 "CHLEG"  2  0  0  0  0  0 0.80 0.70 0.60  9
34 "Thumb Mtn & Irene Bay Fms      " "OTM " "OTI " "OC  " 176 29 30  50  51  67  44 "BOTH "  4  0  0  0  0  0 0.70 0.30 0.60 10
35 "Ibbet Bay Fm                   " "ODIB" "N/A " "EDCI" 179 24 31  44  52  46  51 "CHLEG"  1  2  3  4  5  6 0.99 0.99 0.99 10
36 "Cass Fiord & Cape Clay Fms     " "EOC " "EDCL" "N/A "   4 31 32  51  50  52  44 "1715A"  0  0  0  0  0  0 0.80 0.50 0.60 11
```

Table B - Lithology Look-up Table

```
ID Rock Types
TITLE Melville Island - Bedrock Geology
MAPID MIBEDROC
WINDOW 00 0 0 0 0
TABTYPE 4
FTYPE free
KEYFIELD 1
KEYBASE 0
NRECORD 65
 1   3 4.000000 0    recno RECORD NUMBER
 2  60 40.00000 0  ROCKTYPE ROCK TYPE
 3   3 4.000000 0  sediment Sediment Classification
 4   3 4.000000 0   igneous Igneous Classification
 5   3 4.000000 0  metamorp Metamorphic Classification
 6   3 4.000000 0  extrusiv Extrusive Classification
DATA
 0 "Outside Study area                "    0    0    0    0
 1 "NOT IDENTIFIED                    "    0    0    0    0
 2 "GRANITOID                         "    0    1    0    0
 3 "GRANITE                           "    0    1    0    0
 4 "GRANODIORITE                      "    0    1    0    0
 5 "TONALITE                          "    0    1    0    0
 6 "QUARTZ SYENITE                    "    0    1    0    0
 7 "QUARTZ MONZONITE                  "    0    1    0    0
 8 "QUARTZ MONZODIORITE               "    0    1    0    0
 9 "QUARTZ DIORITE                    "    0    1    0    0
10 "SYENITE                           "    0    1    0    0
11 "MONZONITE                         "    0    1    0    0
12 "MONZODIORITE                      "    0    1    0    0
13 "DIORITE                           "    0    1    0    0
14 "GABBRO                            "    0    1    0    0
15 "DIABASE                           "    0    1    0    0
16 "AMPHIBOLITE                       "    0    1    0    0
17 "ALASKITE                          "    0    1    0    0
18 "PYROXENITE                        "    0    1    0    0
19 "SYENOGRANITE                      "    0    1    0    0
20 "QUATRZ-EYE PORPHRY                "    0    1    0    0
21 "QUARTZ FELDSPAR PORPHYRY          "    0    1    0    0
22 "ALKALI GRANITE                    "    0    1    0    0
23 "FELSIC VOLCANICS                  "    0    1    0    1
24 "INTERMEDIATE VOLCANICS            "    0    1    0    1
25 "MAFIC VOLCANICS                   "    0    1    0    1
26 "FELSIC-INTERMEDIATE VOLCANICS     "    0    1    0    1
27 "INTERMEDIATE-MAFIC VOLCANICS      "    0    1    0    1
28 "FELSIC-MAFIC VOLCANICS            "    0    1    0    1
29 "TRACHYTE                          "    0    1    0    1
30 "RHYOLITE                          "    0    1    0    1
31 "QUARTZ LATITE                     "    0    1    0    1
32 "DACITE                            "    0    1    0    1
33 "ANDESITE                          "    0    1    0    1
34 "BASALT                            "    0    1    0    1
35 "RHYODACITE                        "    0    1    0    1
36 "TUFF                              "    0    1    0    1
37 "CONGLOMERATE                      "    1    0    0    0
38 "BRECCIA                           "    1    0    0    0
39 "SANDSTONE                         "    1    0    0    0
40 "ARENITE                           "    1    0    0    0
41 "QUARTZITE                         "    1    0    0    0
42 "ARKOSE                            "    1    0    0    0
43 "GREYWACKE                         "    1    0    0    0
44 "SHALE                             "    1    0    0    0
45 "ARGILLITE                         "    1    0    0    0
46 "SILTSTONE                         "    1    0    0    0
47 "REDBEDS                           "    1    0    0    0
48 "UNDIFFERENTIATED SEDIMENTS        "    1    0    0    0
49 "CALCAREOUS SANDSTONE              "    1    0    0    0
50 "LIMESTONE                         "    1    0    0    0
51 "DOLOMITE                          "    1    0    0    0
52 "CHERT                             "    1    0    0    0
53 "IRON FORMATION                    "    1    0    0    0
54 "COAL                              "    1    0    0    0
55 "SURFICIAL                         "    1    0    0    0
56 "SLATE                             "    0    0    1    0
57 "PHYLLITE                          "    0    0    1    0
58 "SCHIST                            "    0    0    1    0
59 "GNEISS                            "    0    0    1    0
60 "PARAGNEISS                        "    0    0    1    0
61 "ORTHOGNEISS                       "    0    0    1    0
62 "MYLONITE                          "    0    0    1    0
63 "UNDIFFERENTIATED METASEDIMENTS    "    0    0    1    0
64 "UNDIFFERENTIATED METAVOLCANICS    "    0    0    1    0
65 "SKARN                             "    0    0    1    0
66 "GYPSUM                            "    1    0    0    0
67 "ANHYDRITE                         "    1    0    0    0
68 "QUATERNARY SEDIMENTS              "    1    0    0    0
```

Table C - Age Look-Up Table

```
ID age
TITLE AGE TABLE
MAPID ?
WINDOW 00 0 0 0 0
TABTYPE 1
FTYPE free
KEYFIELD 1
KEYBASE 0
NRECORD 51
 1  3 4.000000 0    recno AGE CLASS
 2  0 7.100000 0  ageinma YEARS ma
 3 40 20.000000 0     name AGE NAME
DATA
   0      0.0 '             UNDATED'
   1      0.0 '            HOLOCENE'
   2      0.0 '         PLEISTOCENE'
   3      2.0 '            PLIOCENE'
   4      6.0 '             MIOCENE'
   5     22.0 '           OLIGOCENE'
   6     36.0 '              EOCENE'
   7     58.0 '           PALEOCENE'
   8     65.0 '     LATE CRETACEOUS'
   9     88.0 '      MID CRETACEOUS'
  10    118.0 '    EARLY CRETACEOUS'
  11    145.0 '       LATE JURASSIC'
  12    160.0 '        MID JURASSIC'
  13    176.0 '      EARLY JURASSIC'
  14    195.0 '       LATE TRIASSIC'
  15    210.0 '        MID TRIASSIC'
  16    225.0 '      EARLY TRIASSIC'
  17    235.0 '        LATE PERMIAN'
  18    250.0 '         MID PERMIAN'
  19    260.0 '       EARLY PERMIAN'
  20    280.0 '       PENNSYLVANIAN'
  21    290.0 '   MID CARBONIFEROUS'
  22    315.0 '       MISSISSIPPIAN'
  23    345.0 '       LATE DEVONIAN'
  24    360.0 '        MID DEVONIAN'
  25    370.0 '      EARLY DEVONIAN'
  26    395.0 '       LATE SILURIAN'
  27    412.0 '        MID SILURIAN'
  28    422.0 '      EARLY SILURIAN'
  29    435.0 '     LATE ORDOVICIAN'
  30    460.0 '      MID ORDOVICIAN'
  31    472.0 '    EARLY ORDOVICIAN'
  32    500.0 '       LATE CAMBRIAN'
  33    515.0 '        MID CAMBRIAN'
  34    540.0 '      EARLY CAMBRIAN'
  35    570.0 '      NEOPROTEROZOIC'
  36   1000.0 '     MESOPROTEROZOIC'
  37   1800.0 '    PALEOPROTEROZOIC'
  38   2600.0 '        LATE ARCHEAN'
  39   3000.0 '         MID ARCHEAN'
  40   3500.0 '       EARLY ARCHEAN'
  41      0.0 '             UNDATED'
  42      0.0 '             UNDATED'
  43      0.0 '             UNDATED'
  44      0.0 '             UNDATED'
  45      0.0 '             UNDATED'
  46      0.0 '             UNDATED'
  47      0.0 '             UNDATED'
  48      0.0 '             UNDATED'
  49      0.0 '             UNDATED'
  50      0.0 '             UNDATED'
```

Table D - Mineral Type Look-up Table

```
ID Mineral Occurrence Types
TITLE Melville Island - Bedrock Geology
MAPID MIBEDROC
WINDOW 00 0 0 0 0
TABTYPE 4
FTYPE free
KEYFIELD 1
KEYBASE 0
NRECORD 10
 1  3 4.000000 0     recno RECORD NUMBER
 2 60 40.00000 0  ROCKTYPE ROCK TYPE
DATA
 0 "No known occurrences              "
 1 "Cu - Copper                       "
 2 "Pb - Lead                         "
 3 "Zn - Zinc                         "
 4 "Ba - Barite                       "
 5 "P  - Phosphorous                  "
 6 "F  - Fluorite                     "
 7 "S  - Sulphur                      "
 8 "Coal                              "
 9 "Natural Gas                       "
10 "Oil                               "
```

Table E - Proximity to Faults Classification and Fuzzy Membership Table

```
ID mifaltbf
TITLE Fault Buffer Fuzzy Membership Values
TABTYPE 4
FTYPE free
KEYFIELD 0
DATAFILE mifaltbf.dat
 1 3 1.000000 0    mifaltbf Fault Buffer Class
 2 1 4.000000 0       fzmvt Missisipi Valley Type Fuzzy Membership
 3 1 4.000000 0     fzsedcu Sediment Copper Fuzzy Membership
 4 1 4.000000 0     fzsedsh Sediment Hosted Sulphide Fuzzy Membership
 5 31 11.000000 0    legend Fault Buffer Legend
DATA
1 0.40 0.20 0.60 "0 - 2 km    "
2 0.15 0.05 0.25 "2 - 4 km    "
3 0.05 0.01 0.10 "4 -8 km     "
4 0.01 0.01 0.01 "8 - 16 km   "
5 0.01 0.01 0.01 "16 - 32 km "
6 0.01 0.01 0.01 "32 - 64 km "
7 0.01 0.01 0.01 "> 64 km     "
```

Table F - Proximity to Unconformities Classification and Fuzzy Membership Table

```
ID unconbf
TITLE unconbf
TABTYPE 4
FTYPE free
KEYFIELD 0
DATAFILE unconbf.dat
 1 3 1.000000 0     unconbf Unconformity Buffer Class
 2 1 5.000000 0       fzmvt Mississippi Valley Type Fuzzy Membership
 3 1 4.000000 0     fzsedcu Sediment Copper Fuzzy Membership
 4 1 4.000000 0     fzsedsh Sediment Hosted Sulphides Fuzzy Membership
 5 31 11.000000 0    legend Unconformity Buffer Legend
DATA
1 0.60 0.30 0.20 "0 - 2 km    "
2 0.05 0.10 0.10 "2 - 4 km    "
3 0.01 0.01 0.01 "4 - 8 km    "
4 0.01 0.01 0.01 "8 - 16 km   "
5 0.01 0.01 0.01 "16 - 32 km "
6 0.01 0.01 0.01 "> 32 km     "
```

Table G - Mineral Occurrence Table

```
ID min12
TITLE Mineral Occurences Fuzzy Correlations
MAPID min12
WINDOW mi 2288 1584 20208 14048
TABTYPE 2
FTYPE free
KEYFIELD 0
KEYBASE 0
NRECORD 9
 1  5 15.000000 0   morton Morton number
 2  1 8.500000 0       lat Latitude, degrees
 3  1 10.500000 0      long Longitude,degrees
 4  3 3.000000 0       loc Reference Locality
 5 35 6.000000 0     host Host Fm. / Member
 6 35 10.000000 0        el Elements
 7  4 6.000000 0 bedclass Bedrock Class (appended)
 8  4 6.000000 0 fzandmvt MVT - Fuzzy AND
 9  4 6.000000 0  fzormvt MVT - Fuzzy OR
10  4 6.000000 0 fzsummvt MVT - Fuzzy SUM
11  4 6.000000 0 fzgammvt MVT - Fuzzy GAMMA (.85)
12  4 6.000000 0 fzandscu Sediment Copper - Fuzzy AND
13  4 6.000000 0  fzorscu Sediment Copper - Fuzzy OR
14  4 6.000000 0 fzsumscu Sediment Copper - Fuzzy SUM
15  4 6.000000 0 fzgamscu Sediment Copper - Fuzzy GAMMA
16  4 6.000000 0 fzandssh Sediment Sulphide - Fuzzy AND
17  4 6.000000 0  fzorssh Sediment Sulphide - Fuzzy OR
18  4 6.000000 0 fzsumssh Sediment Sulphide - Fuzzy SUM
19  4 6.000000 0 fzgamssh Sediment Sulphide - Fuzzy GAMMA
DATA
        921359f 75.91944 -116.52222  3 '   OSD' '       Cu'   35   6   8  10   9   2   8  10   6   6   8  10   7
        924b103 75.95000 -116.32917  4 '   OSD' '       Cu'   35   6   8  10   9   2   8  10   6   6   8  10   7
        960aad3 75.98611 -114.96666  7 '   OSD' '       Ba'   35   6   8  10   9   2   8  10   6   6   8  10   7
        960ab23 75.98528 -114.96250  6 '   CPC' '        F'   35   6   8  10   9   2   8  10   6   6   8  10   7
        97034dd 75.95916 -113.91250  1 '   CPC' '       Cu'   22   5   8  10   8   2   9  10   7   5   8  10   8
        98463f8 76.16028 -116.32917  5 '   OSD' '  Zn,Pb,F'   30   2   8  10   6   1   8   8   1   2   8  10   6
        c1875e5 75.85555 -111.86944  2 '   OTM' '       Ba'   34   3  10  10   9   1  10  10   1   3  10  10   8
        d1eb2c7 75.91666 -107.75000  8 '   OSC' '       Pb'   22   5   6  10   6   1   9  10   6   5   6  10   7
        f0c0cb4 76.75833 -108.56583  9 '   COF' '        S'   23   3   8  10   7   2   8  10   5   3   8  10   7
```

APPENDIX C - MAP MODEL EQUATIONS

```
E fzandmvt Mississippi Valley Type Lead-Zinc - Fuzzy AND
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
c4 = min(c1,c2,c3);
c4
```

```
E fzandscu Sediment Copper - Fuzzy AND
c1 = table('mibedroc',class(MIBEDROC),'fzsedcu');
c2 = table('unconbf',class(UNCONBF),'fzsedcu');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedcu');
c4 = min(c1,c2,c3);
c4
```

```
E fzandssh Sediment Hosted Sulphide - Fuzzy AND
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
c4 = min(c1,c2,c3);
c4
```

```
E fzormvt Mississippi Valley Type Lead-Zinc - Fuzzy OR
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
c4 = max(c1,c2,c3);
c4
```

```
E fzorscu Sediment Copper - Fuzzy OR
c1 = table('mibedroc',class(MIBEDROC),'fzsedcu');
c2 = table('unconbf',class(UNCONBF),'fzsedcu');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedcu');
c4 = max(c1,c2,c3);
c4
```

```
E fzorshs Sediment Hosted Sulphide - Fuzzy OR
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
c4 = max(c1,c2,c3);
c4
```

```
E fzsummvt Mississippi Valley Type Lead-Zinc - Fuzzy SUM
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
c4 = c1+c2+c3-(C1*C2*C3);
c4

E fzsumscu Sediment Copper - Fuzzy SUM
c1 = table('mibedroc',class(MIBEDROC),'fzsedcu');
c2 = table('unconbf',class(UNCONBF),'fzsedcu');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedcu');
c4 = c1+c2+c3-(c1*c2*c3);
c4

E fzsumssh Sediment Hosted Sulphide - Fuzzy SUM
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
c4 = c1+c2+c3-(c1*c2*c3);
c4

E FZGAMMVT Mississippi Valley Type Lead-Zinc - Fuzzy Gamma
gamma=0.85;
c1 = table('mibedroc',class(MIBEDROC),'fzmvt');
c2 = table('unconbf',class(UNCONBF),'fzmvt');
c3 = table('mifaltbf',class(MIFALTBF),'fzmvt');
fprod=c1*c2*c3;
fsum=1-((1-c1)*(1-c2)*(1-c3));
out=pow(fsum,gamma)*pow(fprod,(1-gamma));
out

E FZGAMSCU Sediment Copper - Fuzzy GAMMA
gamma=0.85;
c1 = table('mibedroc',class(MIBEDROC),'fzsedcu');
c2 = table('unconbf',class(UNCONBF),'fzsedcu');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedcu');
fprod=c1*c2*c3;
fsum=1-((1-c1)*(1-c2)*(1-c3));
out=pow(fsum,gamma)*pow(fprod,(1-gamma));
out

E FZGAMSSH Sediment Hosted Sulphide - Fuzzy GAMMA
gamma=0.85;
c1 = table('mibedroc',class(MIBEDROC),'fzsedsh');
```

```
c2 = table('unconbf',class(UNCONBF),'fzsedsh');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedsh');
fprod=c1*c2*c3;
fsum=1-((1-c1)*(1-c2)*(1-c3));
out=pow(fsum,gamma)*pow(fprod,(1-gamma));
out

E badfuzz Sediment Hosted Sulphide - Fuzzy GAMMA
gamma=0.95;
c1 = table('mibedroc',class(MIBEDROC),'fzsedsh');
c2 = table('unconbf',class(UNCONBF),'fzsedsh');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedsh');
fprod=c1*c2*c3;
fsum=1-((1-c1)*(1-c2)*(1-c3));
out=pow(fsum,gamma)*pow(fprod,(1-gamma));
out

E REDBEDS Extract Redbeds from SEDCUFZ
c1 = {class(SEDCUFZ) if class(DEPSEQ)==6, 0};
c1


E totfuzzy Total Fuzzy Values
c1 = table('mibedroc',class(MIBEDROC),'fzsedsh');
c2 = table('unconbf',class(UNCONBF),'fzsedsh');
c3 = table('mifaltbf',class(MIFALTBF),'fzsedsh');
out=c1+c2+c3;
out

E UNIQFZMV Unique Conditions Fuzzy Logic - MVT Potential
a = field('mibedroc');
b = field('mifaltbf');
c = field('unconbf');
fza = table('mibedroc',a,'mvtfz');
fzb = table('mifaltbf',b,'mvtfz');
fzc = table('unconbf',c,'mvtfz');
d = min(fza, fzb, fzc) ;
e = max(fza, fzb, fzc) ;
f = fza+fzb+fzc-(fza*fzb*fzc);
gamma=0.95
g=pow(fza*fzb*fzc,1-gamma);
g=g*pow(1-(1-fza)*(1-fzb)*(1-fzc),gamma);
result(fza, fzb, fzc, d, e, f, g)
```

```
UNCONF Separate Unconformities from Faults
:Create an unconformities file from a depositional age
:boundaries file (DEPBOUND.MAP) and MIFAULTS.MAP.
UC={class(DEPBOUND) if class(MIFAULTS)==0, 0};
UC

E BOOLEAN Boolean Modelling for MVT Potential
c1 = {1 if class(mibedroc)==35, 0};
c2 = {1 if class(depbound)==1, 0};
out=c1 or c2;
out

E BINWTS Weighted Binary Model for any type
sumw=2+3+5;
c1 = {2 if class(mibedroc)> 30, 0};
c1 = {3 if class(unconbf)<=2, 0};
c3 = {5 if class(mifaltbf)<=1, 0};
out=(c1+c2+c3)/sumw ;
out

E MVTPOT Create MVT Potential Map
c1 = {class(fzandmvt) if class(fzandmvt) > 1, 0};
c1
```

APPENDIX D - DATA INPUT PROCEDURES

CARTOGRAPHIC LAYERS - Shoreline - MIBASE.MAP / .VTX/TOP
Drainage - MIDRAIN.VTX/TOP

The cartographic base was constructed using data from the Digital Chart of the World (DCW). DCW data is available in two primary formats; Vector Product Format (VPF) from the official CD-ROM product, and an unofficial ARC/INFO version made available to the Geographic Information Division (GID) from ESRI (ARC/INFO Vendor). Several problems were encountered when data was extracted from the CD-ROM product. Mostly, there is a lack of coverage in some areas for key features required of the MRM, such as drainage, and in some cases, duplication of features in several feature levels was encountered. (N.B. See the special note at the end of this section for an update of this problem)

Because of the problems with the CD-ROM version, the unofficial version of DCW provided by ESRI to GID was used. Although this data still requires some topological editing and cleaning, coverage for the features of interest is much superior than the official CD-ROM version. The procedures for the acquisition and importation of this data are indirect but straight forward and are summarized as follows:

Procedures for Importing DCW data into SPANS format.

Conversion - Convert from ARC/INFO (.E00) to SPANS (VEC/VEH)
Importation - Import VEC/VEH to VTX/TOP
Cleaning - Clean with VECED.EXE
Merging - Combine all tiles into one with VMERGE.EXE
Application - Transform/Legend/Dictionary

CONVERSION

The conversion process involves coverting the ARC/INFO (.E00) format files to SPANS vector archive format (VEC/VEH). This is done using the SPANS Vector Interface Utility:

IMPORT/ARCEXPORT/Decompressed

This process produces one VEC/VEH file pair for each of the twelve original files with the same name as the source. The table below lists the files created with their source files. Notice the file prenames are preserved for proper lineage purposes.

Feature	Tile	Source File	Converted Files
Shoreline	EL13	EL13PONE.E00	EL13PONE.VEC/VEH
	EL23	EL23PONE.E00	EL23PONE.VEC/VEH
	EL33	EL33PONE.E00	EL33PONE.VEC/VEH
	EM11	EM11PONE.E00	EM11PONE.VEC/VEH
	EM21	EM21PONE.E00	EM21PONE.VEC/VEH
	EM31	EM31PONE.E00	EM31PONE.VEC/VEH
Drainage	EL13	EL13DNNE.E00	EL13DNNE.VEC/VEH
	EL23	EL23DNNE.E00	EL23DNNE.VEC/VEH
	EL33	EL33DNNE.E00	EL33DNNE.VEC/VEH
	EM11	EM11DNNE.E00	EM11DNNE.VEC/VEH
	EM21	EM21DNNE.E00	EM21DNNE.VEC/VEH
	EM31	EM31DNNE.E00	EM31DNNE.VEC/VEH

IMPORTATION

The imporation process involves converting the SPANS vector archive format (VEC/VEH) to SPANS vector working format (VTX/TOP). This process is also straight forward with one minor file editing requirement. When the SPANS vector module creates the VEC/VEH files from the .EOO files, it places a '?' in the line of the header file (.VEH) to indicate that projection is not known, when actually the coordinates are in lat/lon which is **Projection 0.** Therefore, the header file (.VEH) for each file pair must be edited to indicate this. Once this is done, the following procedure is performed:

SPANS - TRANSFORM / IMPORT / VECTOR

This process creates 12 new file pairs with the extension VTX/TOP. Each file was given the same prename (<prename!>.VTX/TOP) as the original to allow lineage in the importation process. To be sure that the process has worked, the files were displayed in SPANS using the following procedure:

VIEW / DATATYPES/ VECTOR / E***PONE.VTX/TOP (Coastline)
/ E***DNNE.VTX/TOP (Drainage)

(NOTE: the * indicate all tiles, but during the process, each file must be entered individually).

This was done for all files and it displayed very well showing no tile boundary gaps. However, there were portions of data which coverage was outside the area of interest, and the data is still stored in six separate tiles. The next step was performed to remove the unwanted portions of the data from these 12 files, and merge them together to form 2 clean and continuous layers of Coastline and Drainage.

CLEANING

This procedure deals with the removal of unwanted data from each file. The process can be done in one of two ways using either TYDIG or VECED.

TYDIG APPROACH

To use TYDIG, the VEC/VEH format files are imported into TYDIG using an dummy table calibration (TYDIG requires a calibration with the digitizing table in order to display the data even though this data is from a digital source and not a hard copy map). Once in TYDIG, the unwanted data may be removed either by deleting each entity one by one, or by exporting the data according to the Feature and Level.

With DCW data this process is complicated since the ESRI version of the data is not entirely clean, or properly coded at the 'Level' level (see below in **VECED APPROACH**). Secondly, since the data has already been imported into VTX/TOP format, this approach requires circling back in the file conversion process to repeat previous vec/veh -> vtx/top importation procedure. The VECED approach allows the VTX/TOP data to be edited directly without needing to repeat this process.

VECED APPROACH

VECED is an editing utility provided by Tydac Technologies which allows vector data in VTX/TOP format to be edited directly. It is a set of files which must reside in its own directory and operates only in DOS or in a DOS Screen in OS/2. This is a low level unsupported freebee from Tydac and while it is not an official module of SPANS, it does the job nicely. A twelve page manual is provided and is very easy to follow. The most manageable way of working with it is to copy the file pairs to edit into the VECED directory, clean them, then copy them back to the application directory. The files are deleted from the VECED directory once the job is finished.

Each file from the DCW data was read into VECED and unwanted portions were removed using the ARC/SEARCH/DELETE sequence of mouse/menu commands. Once the data is edited, it is a good idea to display the data again in SPANS GIS to be sure everything is ok. The next step is to merge all files for each Feature into one file so that two continuous coverages of Coastline and Drainage are created.

MERGING

This process involves the use of another utility provided by Tydac Technologies - VMERGE.EXE. This program resides in the VECED directory and runs in the OS/2 prompt screen. The command format is as follows:

```
VMERGE   <newfile> <listfile>
```

where <newfile> is the name given to the new VTX/TOP file pair to be created and <listfile> is an ASCII text file which lists the files that will be merged. For the DCW data for Melville Island, the command was as follows:

```
VMERGE   MIBASE    PONELIST
```

where MIBASE is the name given to the coasline file pair (VTX/TOP), and PONELIST is the list of all the files with PONE in its name (without extensions).

APPLICATION

TRANSFORM

The development of the Data Model identified which Data Structures or file formats each would need to be created for each layer. SPANS allows a given layer to exist in a variety of formats depending on the foreseen operations which will be applied. For Melville Island the Coastline was transformed to the quadtree format (.MAP) since it will be used as the stable base (MIBASE.MAP) for overlay operations on all other data layers. The Drainage layers, however, will only be used for display purposes for the time being, and therefore are only represented in the vector (VTX/TOP) format.

The Coastline (MIBASE.VTX/TOP) was transformed to the quadtree format (MIBASE.MAP) using the TRANSFORM / DATATYPES / VECTORS to../ MAP process. The quad level chosen was 15 to maximize the resolution of the coastline.

LEGEND

The legend entries for each of these layers, one must keep in mind the use of the legends. Since the coastline and drainage will only be used for display purposes, the legend will be constructed during the map making process in SPANS MAP during the final stages of the project.

DATA DICTIONARY

While it is not crucial, it is always useful to maintain all important data layers in the application dictionary. This allows the data to be organized according to the data type, its structure, and its useage.

SPECIAL NOTE:

With respect to the original problem with the official CD-ROM version of DCW, DCW representatives have traced the problem to a limitation imposed by DOS and its linkage to CD-ROM's. Apparently, when DOS reads the data dictionary from the CD-ROM, it only allows a maximum of 500,000 entities to be read at any one time. Therefore, if the user has selected an area where there are more than this amount in the actual database, then not all will display, and consequently, not all will be copied during the conversion process. To get around this problem, the user must copy the tiles of interest to the local hard-drive, and operate VPFVIEW on the hard disk. This way, all data is copied and read properly.

They were not aware of problems relating to the duplication of some features among different feature classes. Also, while the unofficial ESRI version is displayable, the topology is incomplete in some tiles. This was the case with the drainage features of the southern tiles of the study area.

Because of the latter complication, it is speculated that neither the official CD-ROM nor the unofficial versions are complete in some areas (esp. northern Canada), although, it will require further investigation and testing of procedures to subtantiate this. The newer ESRI version of DCW works with a different data indexing scheme, in which it is concievable that all of the above problems may have been related to.

GEOLOGY Bedrock Geology (Class Level) - MIBEDROC.MAP / .VTX/.TOP
Bedrock Geology (Entity Level) - MIBEDENT.VTX/TOP
Structure (Faults) - MIFAULTS.VTX/TOP
Structure (Folds) - MIFOLDS.VTX/TOP

STABLE BASE PREPARATION

The geology layers were retraced from recent compilation work by Andy Okulitch (in progress). Four 1:1,000,000 scale maps were provided which showed bedrock lithology and structural features. Two bases were created to separate the structural features from the bedrock lithology for clarity. The bedrock lithology map contained 36 unit classes, and the structure map contained 5 classes of faults and 4 classes of folds.

The four source maps reveal some discontinuity in unit names and edge matching among the four sheets remained, therefore, a composite was retraced from the four maps (N.B. Corrections for the unit discrepancies are outlined below in the LEGEND RECTIFICATION). To do this, the originals were photo-enlarged to a scale of 1:500,000 for clarity in hand tracing and digitizing.

The four maps were spliced together to cover an area bounded by the following coordinates:

North Latitude = 77.0
South Latitude = 74.0
West Longitude = 118.0
East Longitude = 105.0

These coordinates formed the 'extents' portion of the SPANS universe specifications. The projection specifications are as follows:

Projection = Lambert Conformal Conic
Central Meridian = 111.5
Latitude of True Origin = 75.5
Northern Parallel = 76.3333333
Southern Parallel = 74.6666666

The original four maps were compiled using an edition of the NTS Series from EMR produced in the 1970's which covered all of Canada at a scale of 1:1,000,000. This series was produced in Lambert Conformal projection, where the projection parameters for each sheet are systematically different. This resulted in the composite of four quadrants with different projection specifications, which therefore required the data to be digitized in four parts. The projection specifications for these four quadrants are as follows:

Parameter \ Sheet	NE	SE	NW	SW
Central Meridian	100	104	124	120
Central Latitude	76.5	75	76.5	75
South Parallel	76.666666	72.666666	76.666666	72.666666
North Parallel	79.333333	75.333333	79.333333	75.333333

LEGEND RECTIFICATION

Some minor discrepancies in unit names and edge matching were discovered during the creation of the composite. In some cases, units or groups were differentiated on one sheet but not another. This is the case with the Belcher Channel & Sabine Bay Formations (PBS, PBC, PSB) and the Griper Bay Subgroup (DGB) - Parry Island Fm (DPI) and Beverly Inlet Fm (uDBI).

Three legends were used to rectify other uncertainties in the legend. Andy Okulitch provided a preliminary legend with the originals which some units on the map were not represented in the legend. The legend from MAP 1715A was used to supplement the missing information. In most cases there was strong agreement among all legends except for the following discrepancies:

1 - JSP - Sandy Point Fm - is mapped as JWPK on Prince Patrick Island on MAP 1715A.
2 - PSB - Sabine Bay Fm - is missing from AOK legend but is assumed to be Sabine Bay Fm from its abbreviation, stratigraphic position and close correlation with MAP 1715A.
3 - CPCF - Canyon Fiord Fm - AOK maps this unit as CCF, which implies a Carboniferous age limit.
4 - DC - Blue Fiod Fm - mapped as a limestone equivalent to Blue Fiord Fm on MAP 1715A.
5 - OTM - Thumb Mountain Fm - AOK legend indicates Thumb Mountain and Irene Bay Formations although these units are differentiated on the hard copy map.
6 - O-DIB - Ibbet Bay Fm - assumed to be Ibbet Bay Fm from stratigraphic position and correlation with MAP 1715A.

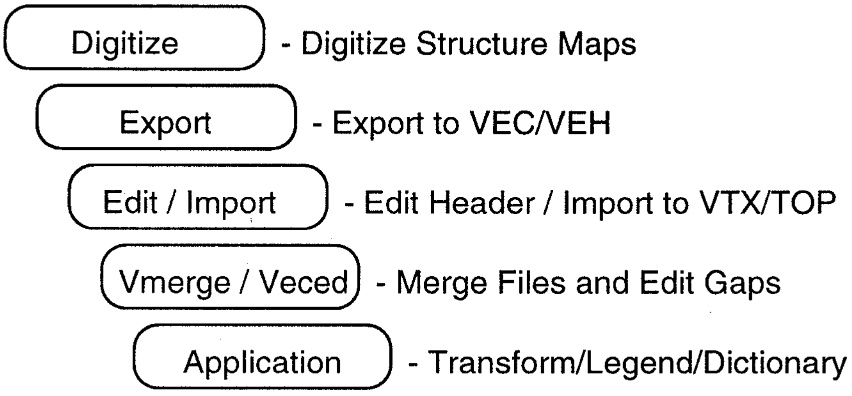
The complete legend is represented as MIBEDROC.TBA with full descriptions in **APPENDIX A - DATA TABLES**.

DIGITIZING

STRUCTURE - MIFAULTS.VTX/TOP MIFALTBF.MAP
- MIFOLDS.VTX/TOP MIFOLDBF.MAP

As stated above, the resulting hard copy map contained four different projection parameters which required each quadrant to be digitized separately. TYDIG was used to digitize the map. The set of procedures are summarized as follows:

Data Input Procedures for Structure Layers



Digitize - Digitize Structure Maps
Export - Export to VEC/VEH
Edit / Import - Edit Header / Import to VTX/TOP
Vmerge / Veced - Merge Files and Edit Gaps
Application - Transform/Legend/Dictionary

DIGITIZE

Each quadrant was digitized in four projects - NWSTRUC, NESTRUC, SESTRUC, and SWSTRUC (.HST, .HDR, .FMT, CRD, DIR) respectively. All structural features were feature coded to distiguish the structural features as follows:

LEVEL	FEATURE	DESCRIPTION
1 - FAULTS	1	Vertical Faults
	2	Normal Faults
	3	Faults with same unit on both sides but not visible at map scale
	4	Normal faults with same unit on both sides
	5	Approximate or assumed
2 - FOLDS	1	Anticlines (defined)
	2	Anticlines (approximate)
	3	Synclines (defined)
	4	Synclines (approximate)

EXPORT

At this stage of the project, only the simplified structure is considered. Therefore, when the files were exported from TYDIG to VEC/VEH they were exported only on the LEVEL type, and not the full FEATURE type. This produced the following eight files:

NWFAULTS.VEC/VEH
NEFAULTS.VEC/VEH
SWFAULTS.VEC/VEH
SEFAULTS.VEC/VEH

NWFOLDS.VEC/VEH
NEFOLDS.VEC/VEH
SWFOLDS.VEC/VEH
SEFOLDS.VEC/VEH

If in the future, a more in depth analysis of the structure is required at the FEATURE LEVEL, the files can be restored in TYDIG and re-exported according to LEVEL and FEATURE LEVEL.

EDIT / IMPORT

The next step required was to IMPORT these files into SPANS to produce the working VTX/TOP equivalents, however, a bug in TYDIG's export routine was encountered during this process. When each set of files was exported from TYDIG, the header file recorded the total number of records for the whole structure file and not just the number in a given LEVEL. Therefore, the number of entities in each file were counted and this value was replaced in the vector header file. (N.B. This bug was reported to personnel on the TYDAC HOTLINE). The files were then imported into VTX/TOP format.

VMERGE / VECED

Once the files were imported into the working VTX/TOP format, they were MERGED using TYDAC's 'VMERGE' utility. The procedure used here is the same as that explained previously in the **CARTOGRAPHIC** section. The files were then read into VECED where some minor editing was performed to JOIN lines accross sheet boundaries. This produced two uniform coverages of structure which are stored as MIFAULTS.VTX/TOP and MIFOLDS.VTX/TOP.

APPLICATION

TRANSFORM

It is desirable to store the structure layers in both VTX/TOP and MAP format. The VTX/TOP format will be used for display purposes and preparation of the final map in SPANS MAP, whereas the MAP format will be a transformed format of structure to show the proximity to structural features required by the mineral potential models. As a result the structure is represented and stored as follows:

FAULTS	- MIFAULTS.VTX/TOP	MIF????BF.MAP
FOLDS	- MIFOLDS.VTX/TOP	MIFOLDBF.MAP

LEGEND

As with the cartographic layers, the vector format of these data types will be symobolized in SPANS MAP upon the construction of the final map. The legends for the MAP format files were constructed with tables which describe the buffer intervals, and their respective fuzzy membership values for each of the three mineral potential models. These tables are presented in APPENDIX B - DATA TABLES.

DATA DICTIONARY

As with the cartographic layers, each of these structure layers was indexed in the application dictionary.

BEDROCK GEOLOGY

The digitizing process taken was the simplified approach to creating a fully topological vector database of the bedrock lighology. This process involves the following set of procedures:

Procedure for Bedrock Geology Map Data Input

Digitize - Digitize geology as separate arcs and point centroids
Export - Export from TYDIG to VEC/VEH
Import - Import to VTX/TOP
Transform - Transform Vectors to Polygons
Transform Map - Transform Polygons to Map
Append Class - Append Unique Polygon Class to Centroids
Reclassify - Reclassify Unique Polygons from Table
Application - Transform/Legend/Dictionary

The only key problem encountered with this process is a problem with missing units in the final map. Two things to check for are that the centroid points were entered only once for each unique area on the map, and that all nodes are clean nodes, that is that they do not have any overshoots.

Mineral Occurrences

The mineral occurrences were entered simply by preparing a table with an ASCII editor of those listed by Harrison (1991). A table header was created using the external PNTBA.EXE program, and appended to the top of the table. The file was then imported into SPANS indicating the fields which contained that latitude and longitude. The process reindexed the occurrences according to Morton sequence, and appended the Morton number column to the front of the table. The table was then exported to replace the original.