Mineral Exploration in the Drummond Basin North Queensland, Using Spatial Analysis in a GIS

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ABSTRACT

The risks of developing mineral resources need to be known as accurately as possible. This process should start at the pre-discovery stage and continue through feasibility to the development stage. Until recently, this type of analysis was carried out manually, leading to subjective judgements. With GIS and resource estimation software now available on personal computers, probabilistic models can now be generated. A program of digital data compilation was completed in the Drummond Basin in North Queensland to allow the use of more probabilistic data analysis techniques at the pre-discovery exploration stage. A GIS was created and spatial analytical techniques employed to assess the potential of the area, and to test current geological models. Prospectivity mapping, using weights of evidence techniques was carried out at approximately 1:100,000 scale. The initial work involved database compilation, which highlighted errors and gaps in the database.

The Drummond Basin provided important lessons in database compilation and management, and allowed for a review of geological models and exploration methodologies. This analysis allowed the comparison of disparate datasets and associations not easily recognisable between these datasets. The results of this work increased the confidence in the exploration models and techniques currently in use. The calculation of the prior probabilities produced a correlation matrix of variables comprising the geological model. This allowed an objective assessment of individual prospects, which proved a useful exploration management tool. Finally, working with GIS datasets highlighted the need for good quality data and data management. This has become a problem, as databases are presently available from a diverse number of groups, resulting in variable data quality and standards. No matter how sophisticated your analytical software if your data is poor the result will be of a similar quality. This applies to all aspects of the exploration industry from spatial mapping (GIS) to resource modeling.

Keywords and phrases**:** prospectivity analysis, weights of evidence, epithermal, gold mineralisation, Queensland, exploration models

1.0 INTRODUCTION

It is important that risks of developing mineral resources are known as accurately as possible. This process starts at the pre-discovery exploration stage and should continue through feasibility to the development stage. The task of any Exploration Group is to use diverse spatial data sets at a variety of scales to produce accurate economic estimates of the mineral potential of areas chosen for exploration. Until recently this type of analysis has been carried out manually and on an ad hoc basis (e.g., Henley 1997), leading to intuitive judgements being made that have no statistical basis. With GIS and resource estimation software now available on personal computers this task can be automated and consequently these estimations have become considerably more sophisticated (Partington 1999, Partington 1998, Bonham-Carter 1997; Singer 1995; Knox-Robinson and Robinson 1993), allowing probabilistic models to be generated.

Many mining companies have built up extensive exploration geological databases, which represent significant assets to the company, that have taken millions of dollars to compile (Partington 1999). In recent times programs of digital data compilation have been undertaken to allow the use of more probabilistic data analysis techniques, moving away from the traditional expert-system methods. The GIS is the perfect management tool for compiling spatial data.

A prospectivity map (e.g. Bonham-Carter 1997) of the Yandan area in the Drummond Basin was compiled (Figure 1), using digital data collected by Ross Mining NL. The techniques used for the analysis of these data will be described, and the results of the analysis presented, with a general discussion on issues relating to this type of analysis in relation to exploration potential.

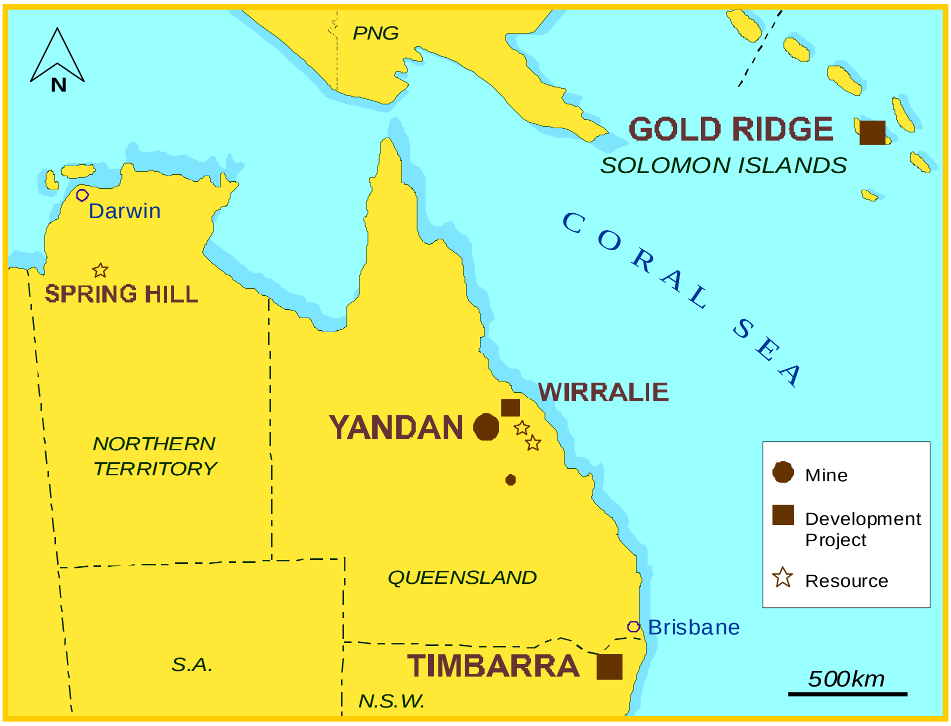

Figure 1. Location of the study area in the Drummond basin, showing the main mines.

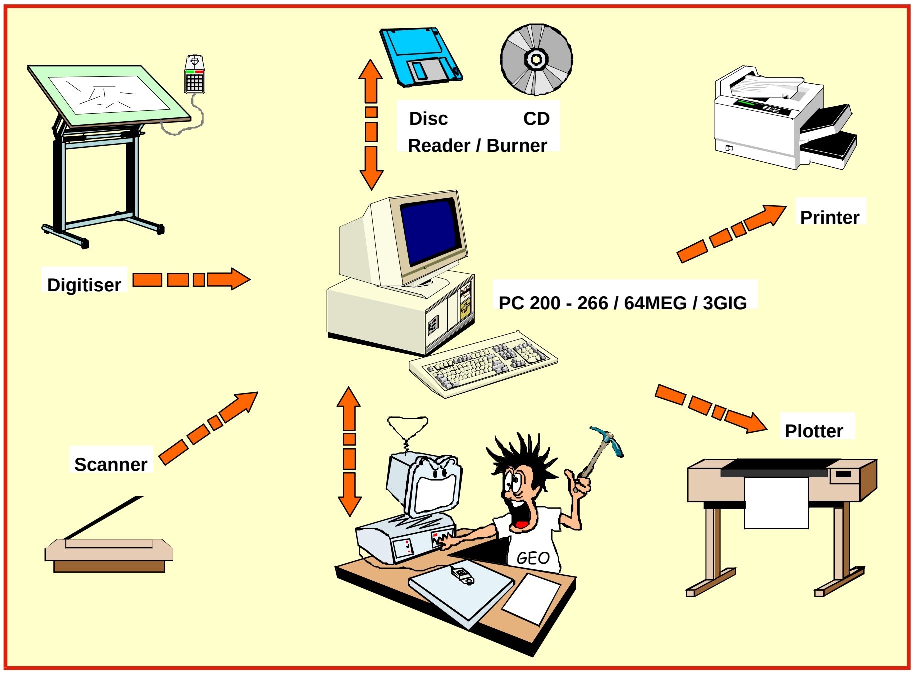

Figure 2. Hardware used to collect and analyse the Drummond Basin data. Note the field geologist is still the most important part of the system

2.0 DATABASE AND SOFTWARE

A flow diagram showing typical data capture and management hardware systems used to develop the prospectivity map is shown in Figure 2 and typical database-GIS software relationship are shown on Figure 3. Access was used as the main database. ER Mapper and the MapInfo GIS software were all used for GIS analysis. MapInfo in particular was used for geochemical data, geological mapping, cadastral data, and tenement data manipulation. All raster information, such as magnetic data and satellite imagery, were processed through ER Mapper. All packages are easily linked through internal drivers saving time and errors through importing and exporting data. The Discover software utility developed by ENCOM was used in conjunction with MapInfo for gridding and contouring and basic statistical analysis and graphing.

3.0 PROSPECTIVITY MAPPING IN THE DRUMMOND BASIN

Prospectivity mapping, using weights of evidence techniques (c.f., Bonham-Carter 1998), was carried out at approximately 1:100,000 scale. The initial work involved database compilation, which highlighted errors and gaps in the database. It also highlighted the need for more detailed geological work to be carried out, particularly understanding the time dimension in relation to volcanic events and fault movements. These data used in a GIS can be used as a form of 4D geological mapping, using time as the fourth dimension. This should be done in any future studies to develop more realistic exploration models.

Gold mineralisation in the Drummond Basin is associated with epithermal centres and is lithologically and structurally controlled (Figure 4), occurring in well-defined stratigraphic positions often associated with sinters. The mineralisation is fault controlled and has been found using various geochemical techniques. There appears to be two phases of mineralisation, an earlier phase related to Devonian volcanism and a later economically less significant phase that overprints the epithermal gold mineralisation related to Carboniferous granite intrusion.

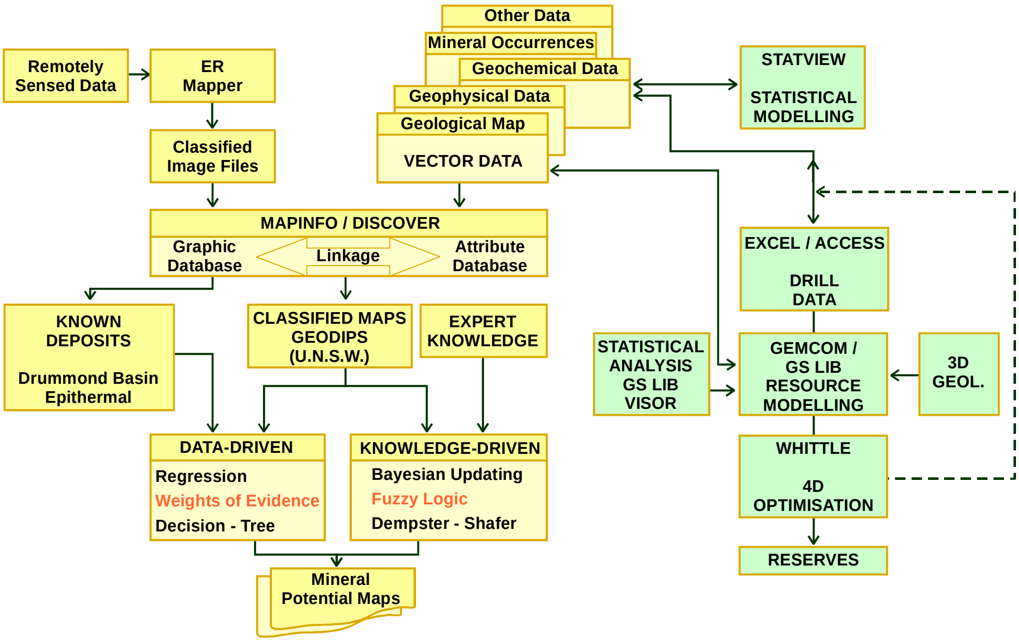

Figure 3. Flow diagram of software "Toolbox" used for this study. Note seven separate packages were used in the analysis, highlighting the need for an integrated exploration management software

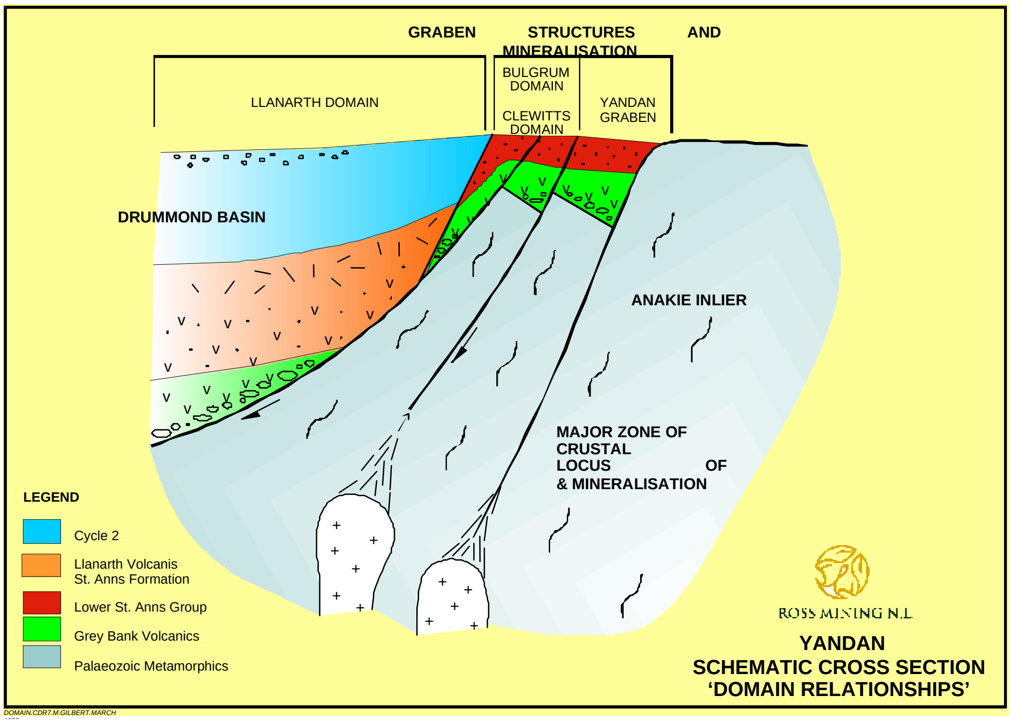

Figure 4. Geology of epithermal mineralisation in the Yandan area of the Drummond Basin.

These features were used to construct a well-defined geological model (Figure 4) to be tested by weights of evidence analysis. The elements of this analysis and results of the prior probability weights of evidence analysis are given in Table 1.

Initial work consisted of reviewing, checking data and excluding all prospects that were related to later Carboniferous mineralisation. Point data and vector data were then converted into raster images using numerical coding in MapInfo (e.g., Table 2). All the datasets were then imported into the University of New South Wales Geodips software package for analysis by weights of evidence and fuzzy logic techniques (Taylor 1998). A raster cell size of 400 metres by 400 metres, which approximates the area covered by a mineral deposit, was used in the analysis.

Element	Area km2	Points	C	Stud(C)
Magnetic Mid Range	9176.99	68	0.1712	0.5467
Radiometrics U Mid Range	6513.48	59	0.6895	2.7134
Rock Anomalies Buffered To 400m	77.51	3	2.0223	3.4358
Rhyolite	**268.02**	**6**	**1.5016**	**3.5372**
Radiometrics Total Mid Range	4592.08	51	0.9184	3.9485
Radiometrics K Mid Range	**1903.98**	**30**	**1.0653**	**4.6124**
Radiometrics Th Mid Range	5395.06	63	1.3718	5.0193
N Faults Buffered To 1700m	2431.5	32	1.2456	5.4576
Anakie Contact Buffer	2537.82	36	1.3992	6.2256
N Faults Buffered To 1800m	2668.12	38	1.4393	6.4282
E-NE Fault Intersections	757.59	20	1.8427	7.1362
NE Faults Buffered To 1100m	815.22	21	1.831	7.205
Andesite	**49.5**	**6**	**3.2063**	**7.5494**
All Fault Intersections	2119.88	39	1.7625	7.8794
NE-NW Fault Intersections	318.26	15	2.3727	8.2815
Tuff	**2105.81**	**41**	**1.8703**	**8.3612**
All Faults Buffered To 2900m	479.09	21	2.386	9.3883
E-NW Fault Intersections	**2272.83**	**51**	**2.2956**	**9.8699**
NW Faults Buffered To 1400m	**2035.16**	**50**	**2.3707**	**10.265**
Stream Anomalies Buffered To 800m	**2267.27**	**57**	**2.6415**	**10.6929**
Cycle 1	**1304.93**	**46**	**2.6609**	**11.7643**
Sinters Buffered To 2700m	**330.14**	**38**	**3.7022**	**16.5307**

Table 1. Prior probability weights of evidence results. Note the higher the Stud(C) value, as defined by Bonham-Carter 1997, the better the correlation the variable has with known mineralisation.

ID	Map Symbol	Cycle Code	Age	Geology	Geology Code
2	Cls	5	Carboniferous	Sandstone	8
4	Dcl	3	Devonian	Tuff	7
7	Cud	2	Carboniferous	Diorite	4
3	Plq	6	Permian	Adamellite	3
17	Plp	2	Permian	Sandstone	2
1	EOc	1	Palaeozoic	Schist	1
53	Cuv	2	Carboniferous	Rholite breccia	6
122	Cubn	2	Carboniferous	Andesitic Pyroclastics	5

Table 2. An example of reclassifying a vector data set into a raster data set in MapInfo.

The raster images were converted into binary maps using Geodips and buffering of various linear data including fault orientations and intersections carried out to determine the optimum distance for the greatest number of prospects (Count) from the feature (Figure 5). These were then analysed to determine the prior-probability weights of evidence scores using similar techniques as Bonham-Carter 1997. This table was compiled and analysed to highlight statistically the features that correlated best with the epithermal gold prospects (Table 1). The Geodips software was then used to create post-probability weights for those features that appeared to be most important in hosting mineralisation (Table 3).

A series of tests were then carried for the assumption of conditional independence. It is clear from the current

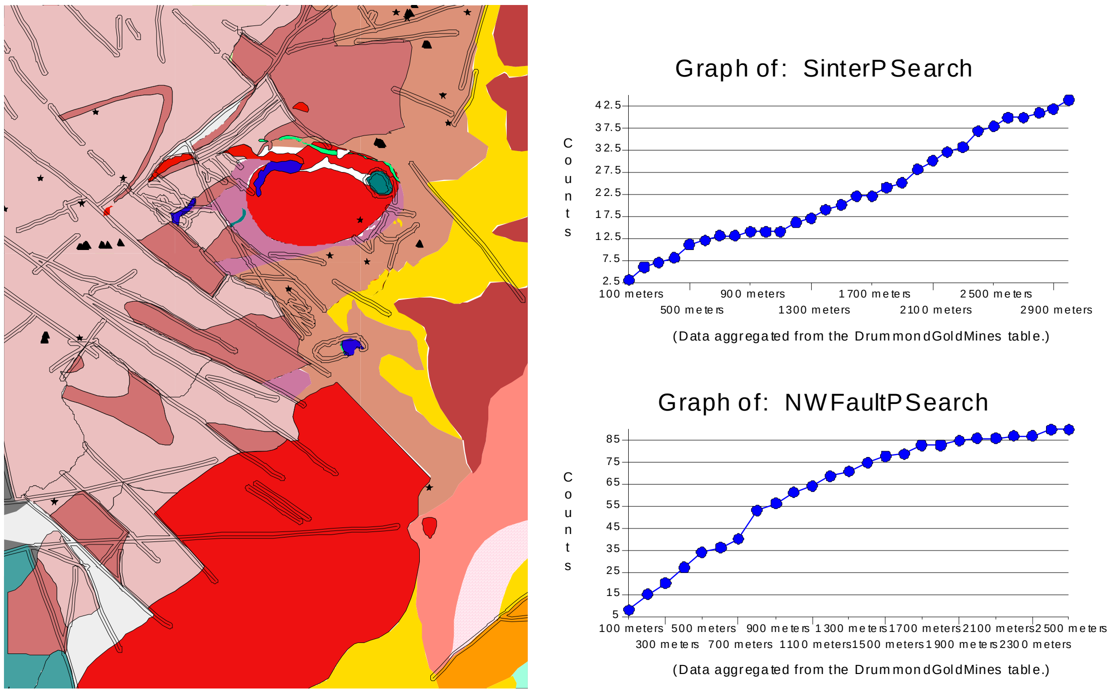

Figure 5. Proximity analysis used to constrain fault, sinter and geochemical data in the prior probability weights of evidence analysis.

data set that this assumption cannot be met, as is the case for many geological datasets. Several variables were combined to reduce this problem, and a final prospectivity map produced again using Geodips (Figure 6). This map was then plotted with known prospects. Additional prospective areas were also highlighted.

4.0 PRACTICAL CONSIDERATIONS IN THE USE OF GIS IN EXPLORATION

The end result of the Drummond Basin study, although useful, was not as important as the analysis. This provided some important lessons and provided a focus on geological models and exploration methodologies. This analysis allowed the comparison of disparate datasets and associations not easily recognisable between these datasets. This work increased the confidence in the exploration models and techniques currently used in the Drummond Basin.

The calculation of the weights of evidence prior probabilities produced a correlation matrix of variables comprising the geological model. This allowed an objective assessment of the model and those features that should be concentrated on during exploration. Some interesting and unexpected results were returned. It has always been assumed that fault intersections control mineralisation in the Drummond Basin, and that there is some link between north westerly and north easterly structures. The weights of evidence show that faults are important, but north westerly structures are the most important. Fault intersections are less relevant.

Rock chip samples give a poor correlation with known mineralisation where-as stream sediment sampling gives good correlations. This has allowed an objective assessment on the merits of various geochemical techniques.

Finally sinters have the best correlation with mineralisation, confirming the basic geological model. This part of the exercise was most useful as it focused attention on database quality and the exploration models being used.

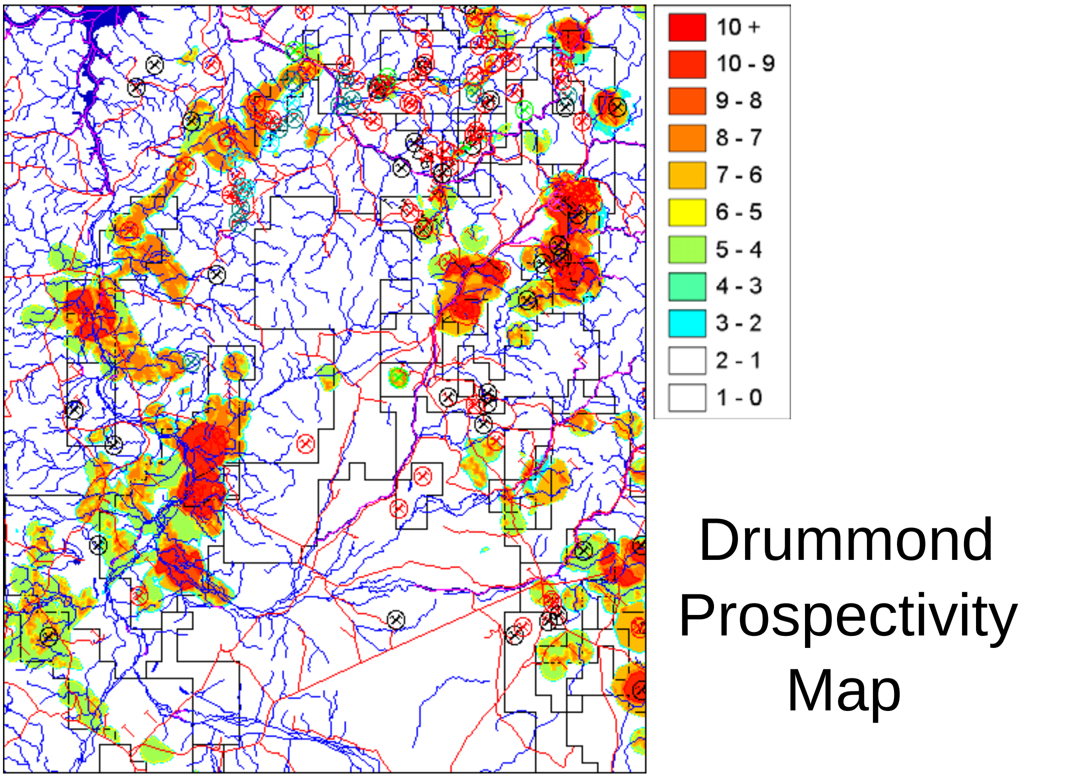

Figure 6. Post probability weights of evidence prospectivity map of the Yandan area, plotted with known prospects and tenement holdings.

The poor results from the conditional independence tests suggest that the final prospectivity map is not accurate, and as discussed by Bonham-Carter (1997) probably overestimates prospective areas. This is not regarded as a major problem at the exploration stage as other exploration techniques can be used to target at a more detailed level. In addition, a comparison of the post probability scores for each prospect (Table 3) has correctly ranked the size and importance of the prospects with known production. Although the result is not accurate in detail it allows a good regional ranking of an areas prospectivity. This has allowed a review of the tenement position in the area and confirmed the importance of areas to be targeted by exploration.

Prospect Name	East	North	Production Au Oz	Prospectivity
Wirralie	526920	7665240	400000	9
Yandan	497925	7642428	280000	9
Glen Eva Project	546100	7630000	85000	7
Police Creek Prospect	540000	7638500	80000	5
Mt Coolon	536600	7632700	35000	5

Table 3. Ranking of prospects as derived from the post probability weights of evidence analysis. The analysis correctly ranked the prospects according to contained gold even though this variable was not used in the analysis.

5.0 CONCLUSIONS AND FUTURE DIRECTIONS FOR GIS ANALYSIS

It is clear that computer-based spatial analysis has arrived in terms of the exploration industry. Whether it is used as an intelligent drafting system or at a greater level of sophistication to derive estimates of the potential of areas to host mineralisation will depend on training and available software. Finally working with GIS datasets has highlighted the need for good quality data and data management. This has become a problem, as databases are presently available from a diverse number of groups, resulting in variable data quality and standards. No matter how sophisticated your analytical software if your data is poor the result will be of a similar quality. This applies to all aspects of the exploration industry from spatial mapping (GIS) to resource modeling.

Future work should include:

1. Improving data quality
2. Adding to the digital database
3. Developing better method for carrying out prospectivity analysis (i.e., an integrated software package).
4. Developing systems to allow a smooth transition from spatial data analysis at a regional scale to geostatistical data analysis at a resource development scale.

These systems should be used to improve estimations of the metal content of areas of the earth's crust, allowing better decisions with regard to land use, development and risk management.

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