RESOURCE ASSESSMENT USING A GEOGRAPHICAL INFORMATION SYSTEM: A PILOT STUDY IN THE SMITHERS AREA*

**By E.C. Grunsky, D.G. MacIntyre, B.C. Ministry of Energy, Mines and Petroleum Resources
and
T.A. Richards, Prospecting Ltd.**

KEYWORDS: Geographic information system, mineral resource assessment, Land Information Strategic Plan, Knowledge-based systems, multivariate data.

INTRODUCTION

Data that can be used for mineral resource assessment include, but are not limited to, geological maps, satellite imagery, regional geochemical data, mineral occurrence data, geophysical data, mineral titles data, digital elevation-contour data, planimetry and structural information, all of which can be digitized. Geologists now routinely acquire data using portable computers in base camps and in the field and this has been a common practice within the British Columbia Geological Survey Branch for a number of years (MacIntyre, 1991). Geological data are commonly stored in CAD-based files that record points, lines and polygons that describe geological features. Additional information that includes structural measurements and other descriptive features of field data are commonly stored in database management systems that have associated geographical coordinates. An integrated mapping program that has tied both the geological vector-based data with the attributes that describe the features at specific geographic locations has been implemented by the Ontario Geological Survey (Brodaric and Fyon, 1989). Such systems are a step towards an integrated approach to data capture and management in ways that were not previously possible.

The integration of spatially based data with attributes associated in a database management system is the foundation of a Geographical Information System (GIS). The development of GIS technology and software is a step toward an integrated system of data collection, management and, most importantly, analysis. The analytical tools that are being developed for spatial data are the most important features of GIS packages.

The use of spatially based digital data is not unique to geoscience. The proliferation of spatially based data prompted the British Columbia government to implement the Corporate Land Information Strategic Plan in order to provide a framework through which geographically based data could be stored, managed and disseminated within the land information infrastructure (DMR Group, 1989). The Geological Survey Branch will be participating in the implementation of the land information infrastructure and must be able to store, manage, model and disseminate geoscience information gathered or created by the Branch in digital form.

The Geological Survey Branch has embarked on a pilot project, funded by the Canada - British Columbia Partnership Agreement on Mineral Development to implement and assess the usefulness of a GIS. The main goal is to capture and integrate the wealth of digital information available for a mineral resource assessment study in the Smithers area. The implementation of a GIS will also be used to meet the requirements and assist in the implementation of the land information strategic plan. As geological data are, for the most part, geographically based, the use of a GIS is particularly well suited to geological applications. A previous study by Bartier and Keller (1990) integrated stream-sediment geochemistry with bedrock geology using a GIS and was shown to be a superior means of examining the data.

The assessment of spatially based data using automatic methods is not new. Previously, studies of spatially related geological phenomena were applied to particular datasets that were assembled for specific applications (*e.g.*, geochemical datasets). Assessments of gold deposits in the Abitibi belt of Ontario were carried out by Agterberg and Kelly (1971). They modelled the probability of a gold deposit occurring within a given area, based on the distribution of gold deposits over the entire area. More recently, studies of data integration and assessment using GIS have been carried out in other provinces and countries (George and Bonham-Carter, 1989; Bonham-Carter *et al.*, 1988; Rock *et al.*, 1990). The main purpose of data integration is to co-register spatially based information so that the data can be interrogated using automatic or manual techniques of analysis.

Resource assessment of spatially based data requires the integration of information onto a common set of georeferenced coordinates and the ability to examine and evaluate the data by choosing one or more "layers" of information. One of the most challenging problems is accurate coding of the data. Most maps and digital data are coded with the Universal TransMercator projection (UTM) coordinates which, in North America, are based on the 1927 North American Datum (NAD27). This datum is determined from parameters which define flattening of the geoid. Adoption of the 1983 North American Datum (NAD83) has resulted in a new set of parameters for geocoding. Converting between the two standards is not a difficult procedure (B.C. Ministry of Lands and Parks, 1991), however, knowing which datum was used is important. Errors introduced in coding will cause errors in data modelling and analysis, particularly with raster-based images where the offset between two layers can result in shifts of several pixels.

* Canada - British Columbia Partnership Agreement on Mineral Development.

SELECTION OF THE GEOGRAPHICAL INFORMATION SYSTEM

Aronoff (1989) presents a general overview of geographical information systems. The review describes their concepts, features and capabilities. Van Driel and Davis (1989) and Agterberg and Bonham-Carter (1989) contain papers that describe methods of data integration and the application of GIS to specific geological problems. Bartier (1991) has reviewed the requirements and features for a successful GIS implementation for use in mineral resource evaluation in British Columbia. The choice of the right GIS is complex. Bruce and Davidson (1991) outline a systematic process for selecting a system based on user requirements. Image analysis systems which are raster-based can complement vector and raster-based GIS packages (Bonham-Carter, 1989) particularly when satellite imagery is used.

The Geological Survey Branch selected a commercial microcomputer-based GIS package, TERRASOFT® as the initial GIS package for resource assessment (Note: *the Branch does not endorse the use of any particular commercial Geographical Information System*). The selection of the TERRASOFT system was based on the comparison of four GIS packages in which the cost, ease of implementation, ease of training and compatibility with the land information infrastructure strategy of the British Columbia government were the main considerations. The package is being evaluated through the Mineral Resource Assessment Study and may not be the only GIS package that will be used.

GEOGRAPHICAL INFORMATION MANAGEMENT, DATA INTEGRATION AND RESOURCE ASSESSMENT OF THE SMITHERS (93L) AREA

Richards (in preparation) has developed a systematic set of guidelines for a manual mineral potential assessment that are based on a study of the Smithers area map sheet (93L) (Tipper and Richards, 1976; Richards and Tipper, *in preparation*). The guidelines were derived from a mineral potential evaluation scheme devised by McLaren (1990) and based on the presence of anomalous regional geochemistry, the presence of mineralization and conditions of favourable geology. Richards' scheme departs from McLaren's in that the assessment of mineral potential is not based on the presence or absence of known mineral occurrences or regional geochemical data. It is instead, primarily based upon the fundamental premises of the geological controls on the formation of hydrothermal mineral deposits, and mineral deposit models. The presence of mineral deposits and regional geochemistry are secondary factors. The quality of the map created by this scheme is dependent upon the quality of the geological map used to derive the mineral potential map.

The assessment process follows three stages:

(1) Creation of a base map using the fundamental characteristics required for the formation of hydrothermal mineral deposits. The basic premises that control the deposition of a hydrothermal mineral deposit are: (a) all hydrothermal mineral deposits require a conduit for the flow of hydrothermal solutions, (b) they all require a porous medium for mineral deposition and (c), they all require a heat source. The base map is created by outlining features that may represent conduits, depositional sites, sources of heat, and includes faults, linears, and their intersections and their proximity to intrusive bodies.

(2) Creation of one map, derived from a set of mineral potential maps based upon the geologic controls implied by the various mineral deposit models. Included in the Smithers study were the models that define epithermal, mesothermal, prophyry, volcanogenic massive sulphide and shale-hosted mineral deposits. Known mineral deposits and regional geochemistry may modify this map.

(3) Creation of a final mineral potential map by combining the two base maps. Known mineral deposits modify the final map.

The final map combines all the stratigraphic, structural, intrusive and metamorphic elements that control hydrothermal mineralization, as well as known mineralization (Richards and Desjardins, *in preparation*), all plotted on a single plane – the mineral potential map. These systematic rules define the foundation for a knowledge-based or expert-system approach using a GIS.

Considering the attributes required to define the potential presence of a mineral deposit, the Smithers area is a logical choice for a GIS-based assessment of the mineral resource potential. The area is well mapped by the Geological Survey Branch and the Geological Survey of Canada, and has been the subject of various studies carried out by universities and exploration geologists. The area also includes a wide variety of mineral deposits related to a number of metallogenic events (at least three: Jurassic, Late Cretaceous and Eocene). In addition, regional geochemical survey and MINFILE® data are available for the area. Terrain resource information data (TRIM) from the Ministry of Lands and Parks are available in digital form. Numerous land-use issues are being considered in the area.

KNOWLEDGE-BASED SYSTEMS AND RESOURCE ASSESSMENT

Resource assessment of multiple datasets requires a systematic approach based on a structured analysis of the information. The analysis procedure requires integration of both qualitative (*e.g.*, rock texture) and quantitative data (geochemical analysis). Most systems have the ability to manage three-dimensional data with varying degrees of complexity. Historically, the most common applications of three-dimensional data are in ore deposit modelling. More recently, digital elevation models (DEM) have been incorporated into a few limited geological studies. For the initial part of this study, our investigations will be restricted to the two-dimensional map plane.

Geological data can be composed of points, lines and polygons. Points usually define locations where specific attributes are recorded, as in a geochemical analysis representing several elements, or it may be a structural measurement such as a strike and dip. Qualitative attributes may represent features such as the texture of a rock or a visual estimate of clast abundance recorded within a very small area which can be considered to be a single point. Data attributes that are recorded for a point may also represent attributes associated with a polygon within which the point lies. The most common linear features on geological maps are faults, which represent the surface trace of three-dimensional planes. The attributes that may define features such as the type of fault can be useful in map-pattern assessment and have an influence on the way that relationships of patterns are perceived.

Polygons represent areas that describe a particular rock type or geologic unit. They can have attributes that contain qualitative (rock texture), quantitative (geochemical abundances) or binary (present/absent) information. This information may also be univariate (only rock texture was observed) or multivariate (several elements within a geochemical analysis). The complexity of relationships based on the attributes of polygons may require the use of a knowledge-based or expert system to decipher less obvious trends.

The spatial analysis of multivariate quantitative data has been described by Brower and Merriam (1989), Grunsky and Agterberg (1988), Royer (1988) and Wackernagel (1988). Their methods are capable of reducing the number of variables required to describe systematic relationships within the data. They are commonly applied to multielement geochemical data and can assist in interpreting the multi-element signatures by reducing the number of maps required to view systematic trends in the data (magmatic trends, alteration trends, etc.).

Assessment of qualitative (descriptive) data presents a challenge. Currie and Ady (1989a) discuss the importance of the semantic relationships between geological units (*e.g.*, dike *intrudes* sediment). Thus, the relationships between various data types require a set of rules that describe the semantic relationship between them. Once the semantic rules are established, then a meaningful interpretation or analysis can be performed. In normal manual analysis the semantic relationships are implicitly understood or intuitively perceived by the investigator. In an automatic analysis scheme, these relationships must be encoded into the system. Inclusion of the semantic relationships has been termed "extended GIS" (Currie and Ady, 1989b). This requires an elaborate set of rules for evaluation.

Evaluation of binary coded data (present or absent) for mineral resource evaluation can be carried out by the "weights of evidence" modelling method (Agterberg, 1989; Bonham-Carter *et al.*, 1988, Bonham-Carter and Agterberg, 1990). The possiblity of finding mineral deposits can be assessed by using the presence or absence of features that define the conditions for the formation of a mineral deposit.

PROJECT PLAN

Data have been imported into the TERRASOFT system from the digital topographic data files of the Ministry of Lands and Parks. These include contour data, streams, lakes, glaciers, and road data. A digital elevation model will also be incorporated into the system. Data that define the land-use boundaries of the area have also been entered. A database consisting of mineral titles information will also be incorporated. The geological data are currently being digitized from existing maps and converted from the UTM coordinates of NAD27 to NAD83. Regional geochemical data from the Smithers area (Matysek, 1988 and the mineral inventory database (MINFILE) will be imported into the system. The use of the regional geochemical data will require a catchment-basin analysis and would also benefit from the incorporation of the digital elevation model. The acquisition of aeromagnetic and landsat satellite imagery is currently being investigated.

The mineral resource assessment of the data will be carried out using the analysis facilities available with the TERRASOFT GIS package. Additional spatial analysis and knowledge-based interrogation will be developed within TERRASOFT or exported to other systems where appropriate. It is planned that the mineral resource assessment will use the systematic criteria established by Richards (*in preparation*), as a model for determining the mineral potential of the area. Many of the analytical methods mentioned above show promise as resource assessment tools and the use of GIS as a practical tool for resource potential evaluation will be studied.

REFERENCES

Agterberg, F.P. (1989): Systematic Approach to Dealing with Uncertainty of Geoscience Information in Mineral Exploration; *in* Application of Computers and Operations Research in the Mineral Industry 21st International Symposium, *American Society of Mining Engineers*, pages 165-178.

Agterberg, F.P. and Bonham-Carter, G.F., Editors, (1989): Statistical Applications in the Earth Sciences: *Geological Survey of Canada*, Paper 89-9.

Agterberg, F.P. and Kelly, A.M. (1971): Geomathematical Methods for Use in Prospecting: *Canadian Mining Journal*, Volume 92, No. 5, pages 61-72.

Aronoff, S. (1989): Geographical Information Systems: A Management Perspective; *WDL Publications*, Ottawa.

Bartier, P.M. (1991): Investigation into Development and Implementation of Natural Resources Geographical Information Systems (GIS): Case Study Geological Survey of British Columbia; unpublished M.Sc. thesis, *University of Victoria*.

Bartier, P.M. and Keller, C.P. (1991): Integrating Bedrock Geology with Stream-sediment Geochemistry in a Geographic Information System (GIS): Case Study NTS 92H; *in* Geological Fieldwork 1990, *B.C. Ministry of Energy, Mines and Petroleum Resources* Paper 1991-1, pages 315-321.

B.C. Ministry of Lands and Parks (199): NAD27 to NAD83 Conversion in British Columbia, National Transformation, Version 1.1, includes 1 diskette, unpaginated.

Bonham-Carter, G.F. (1989): Comparison of Image Analysis and Geographic Information Systems for Integrating Geoscientific Maps, *in* Statistical Applications in the Earth Sciences, Agterberg, F.P. and Bonham-Carter, G.F., Editors, *Geological Survey of Canada,* Paper 89-9, pages 141-155.

Bonham-Carter, G.F. and Agterberg, F.P. (1990): Application of Microcomputer-based Geographical Information System to Mineral-potential Mapping; *in* Microcomputer Applications in Geology 2, Hanley, J.T. and Merriam, D.F., Editors, *Computers & Geology,* Volume 6, pages 49-74.

Bonham-Carter, G.F., Agterberg, F.P. and Wright, D.F. (1988): Integration of Geological Datasets for Gold Exploration in Nova Scotia; *Photogrammetry and Remote Sensing,* Volume 54, No. 11, pages 1585-1592.

Brodaric, B. and Fyon, J.A. (1989): OGS FIELDLOG: A Microcomputer-based Methodology to Store Process and Display Map-related Data; *Ontario Geological Survey,* Open File Report 5709, 73 pages, 1 magnetic diskette.

Brower, J.C. and Merriam, D.F. (1989): Geological Map Analysis and Comparison by Several Multivariate Algorithms; *in* Statistical Applications in the Earth Sciences, Agterberg, F.P. and Bonham-Carter, G.F., Editors, *Geological Survey of Canada,* Paper 89-9, pages 123-134.

Bruce, B. and Davidson, D. (1991): GIS for Decision Makers: An Exercise in Operational Risk Management; *Proceedings of the Eighth Thematic Conference on Geological Remote Sensing,* Denver, Colorado, April 29 - May 2, 1991.

Currie, A. and Ady, B. (1989a): GEOSIS Project: Knowledge Representation and Data Structures for Geoscience Data; *in* Statistical Applications in the Earth Sciences, Agterberg, F.P. and Bonham-Carter, G.F., Editors, *Geological Survey of Canada,* Paper 89-9, pages 111-116.

Currie, A. and Ady, B. (1989b): Extended GIS – An Enriched Model Used to Represent Geoscience Spatial Data; *Proceedings of the GIS National Conference,* Ottawa, 1989.

DMR Group (1989): A Corporate Land Information Strategic Plan for the Government of British Columbia: Land Information Infrastructure.

George, H. and Bonham-Carter, G.F. (1989): An Example of Spatial Modelling of Geological Data for Gold Exploration, Star Lake Area, Saskatchewan; *in* Statistical Applications in the Earth Sciences, Agterberg, F.P. and Bonham-Carter, G.F., Editors; *Geological Survey of Canada,* Paper 89-9, pages 157-169.

Grunsky, E.C. and Agterberg, F.P. (1988): Spatial and Multivariate Analysis of Geochemical Data from Metavolcanic Rocks in the Ben Nevis Area, Ontario; *Mathematical Geology,* Volume. 20, No. 7, pages 825-861.

McLaren, G.P. (1990): A Mineral Resource Assessment of the Chilko Lake Planning Area; *B.C. Ministry of Energy, Mines and Petroleum Resources,* Bulletin 81.

MacIntyre, D.G. (1991): Computer Assisted Mapping in the British Columbia Geological Survey – Progress to Date and Predictions for the Future; Proceedings of the Second Canadian Conference on Computer Applications in the Mineral Industry, Vancouver, Canada, September 15-18, 1991, Volume II, Poulin, R., Pakalnis, R.C.T and Mular, A.L., Editors; *The University of British Columbia* and the *Canadian Institute of Mining, Metallurgy and Petroleum,* pages 61-68.

Matysek, P.F. (1988): Regional Sediment and Water Geochemical Reconnaissance Data, British Columbia, NTS 93L; *B.C. Ministry of Energy, Mines and Petroleum Resources,* Regional Geochemical Survey RGS-17, *Geological Survey of Canada,* Open File 1361.

Richards, T.A. *(in preparation):* An Outline of Guide Lines for the Construction of Regional Mineral Potential Maps; *B.C. Ministry of Energy, Mines and Petroleum Resources.*

Richards, T.A. and Tipper, H.W. (*in preparation*): Smithers Map-sheet (93L); *Geological Survey of Canada,* Open File Series, 1:250 000.

Richards, T.A. and Desjardins, P.J. (*in preparation*): Mineral Inventory, Smithers Map-area (93L), 1991; *B.C. Ministry of Energy Mines and Petroleum Resources.*

Rock, N.M.S., Shellabear, J.N., Wheatley, M.R., Poulinet, R. and Groves, D.I. (1990): Microcomputers in Mineral Exploration: A Database For Modeling Gold Deposits in the Yilgarn Block of Western Australia; *in* Microcomputer Applications in Geology 2, Hanley J.T., Merriam, D.F., Editors, *Computers & Geology,* Volume 6, pages. 199-222.

Royer, J.J. (1988): Geochemical Data Analysis; *in* Statistical Treatments for Estimation of Mineral and Energy Resources, Fabbri, A.G., Chung, C.F. and Sinding-Larsen R., Proceedings NATO Conference, Il Ciocco, Italy, July 1986, *Reidel,* Dordrecht, pages 89-112.

Tipper, H.W. and Richards, T.A. (1976): Smithers Map-sheet (93L); *Geological Survey of Canada,* Open File 351, 1:250,000.

Van Driel, J.N. and Davis, J.C., Editors (1989): Digital Geologic and Geographic Information Systems; *in* Short Course in Geology: Volume 10, *American Geophysical Union,* 62 pages.

Wackernagel, H. (1988): Geostatistical Techniques for Interpreting Multivariate Spatial Information; *in* Statistical Treatments for Estimation of Mineral and Energy Resources; Fabbri, A.G., Chung, C.F. and Sinding-Larsen R., Proceedings NATO Conference, Il Ciocco, Italy, July 1986, *Reidel,* Dordrecht, pages 393-409.