Yukon regional mineral potential by deposit models

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ABSTRACT

The results from four separate regional mineral potential assessments initiated by the Yukon Government from 1999 to 2001 are presented as mineral potential maps for specific deposit models. A quantitative method was used for the prediction of undiscovered deposits based on 44 mineral deposit models applicable to the Yukon. A panel of industry experts predicted the probability of discovering new deposits of each type within individual pre-defined tracts of land. Their predictions were based on all available geoscientific and mineral exploration data, combined with their own knowledge and experience. A statistical simulator produced scores for each tract for each individual deposit model, and these were given relative rankings. The accuracy of mineral potential maps is limited by the quality and quantity of geoscientific and mineral exploration history data, and by the level of geological knowledge at the time of the assessments. The mineral potential of a region should be re-evaluated when there is a significant advance in the knowledge of the geology of the region or when new data becomes available.

RÉSUMÉ

Les résultats de quatre évaluations distinctes du potentiel minéral régional entrepris par le gouvernement du Yukon de 1999 à 2001 sont présentés sous forme de cartes du potentiel minéral pour des modèles gîtologiques spécifiques. Pour prédire les gîtes non découverts, on a utilisé une méthode quantitative basée sur 44 modèles applicables au Yukon. Un groupe d'experts de l'industrie ont prédit la probabilité de découverte de nouveaux gisements pour chaque type dans des bandes de terrain prédifinies. Leurs prédictions étaient basées sur les données géoscientifiques et les données d'exploration minérale actuelles, combinées à leurs propres connaissances et expérience. Un simulateur statistique a produit des pointages pour chaque bande et pour chaque modèle, ce qui a permis de les classer. L'exactitude des cartes sur le potentiel minéral est limitée par la qualité et la quantité des données recueillies au cours de travaux géoscientifiques et d'exploration minérale et par le niveau des connaissances géologiques au moment des évaluations. Il faudrait réévaluer le potentiel minéral d'une région lorsqu'on aura accompli des progrès importants dans la connaissance de la géologie de la région ou lorsque de nouvelles données seront accessibles.

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INTRODUCTION

This contribution summarizes the results from four separate regional mineral potential assessments initiated by the Yukon Government from 1999 to 2001. The assessments were designed to assist in land use planning exercises, but also may be of interest to the mineral exploration industry. Data are presented as 18 maps; each one illustrates the mineral potential of a different deposit model. In addition to the mineral potential maps, this paper provides detailed information on the purpose, methodology and limitations of the mineral assessment process. This information is now available as a CD open file (Bradshaw and vanRanden, 2003).

REGIONAL MINERAL POTENTIAL ASSESSMENTS

Regional mineral potential studies have been completed over the majority of Yukon (with the exception of the northernmost Yukon and southwest of the Alaska Highway). Regional mineral potential was assessed in four phases (Fig. 1). These regional mineral resource assessments were conducted using a quantitative method for prediction of undiscovered deposits that was developed by the United States Geological Survey (USGS). This method is based on 39 mineral deposit types (i.e., mineral deposit models of Cox and Singer, 1986) and their probability of being hosted in a particular geological environment. The British Columbia Geological Survey (BCGS) modified the deposit models defined by the USGS and added others to best fit the geological and metallogenic setting of the southern Canadian Cordillera (Lefebure and Ray, 1995; Lefebure and Höy, 1996). For the Yukon assessments, the deposit models utilized by the BCGS were further modified to incorporate Yukon deposits (Fonseca and Abbott, in press). This method is best suited for regions such as Yukon where vast tracts of land commonly lack complete geological characterization and may contain a variety of mineralization styles. Although this method of mineral assessment is not without limitations, it yields reproducible and unbiased results.

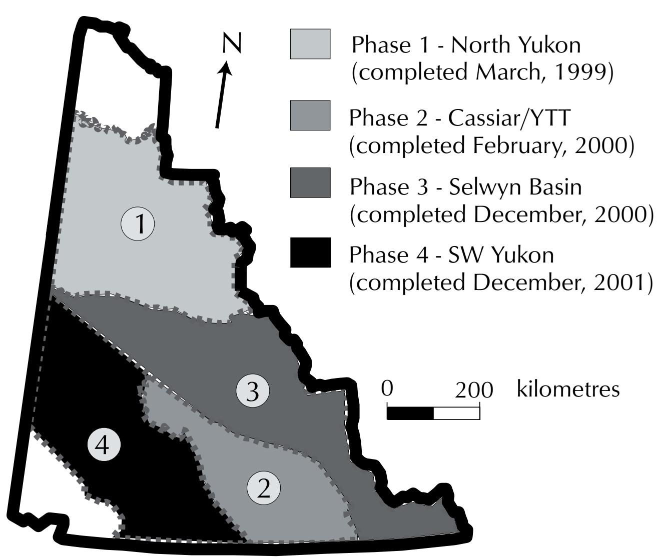


Figure 1. *Locations and completion dates of Yukon regional mineral assessment phases.*

MINERAL POTENTIAL

The mineral potential of a region describes the probability for the existence of undiscovered metallic mineral deposits. This mineral potential is based on the current state of geoscientific knowledge, and its accuracy is dependent upon the availability and quality of geoscientific data (also supplemented by the mineral exploration history records). Regional mineral resource assessments utilize the following geoscientific and mineral exploration data: (1) bedrock geology maps at 1:250 000 and 1:50 000 scale (digital compilation by Gordey and Makepeace, 1999); (2) regional airborne geophysical surveys (Lowe et al., 1999); (3) regional stream sediment, lake sediment (RGS), and till surveys (Héon, 2003); and (4) exploration history (Deklerk, 2002). These regional assessments were based on existing, publicly available data. Mineral potential of a region is a 'snapshot in time' and should be re-evaluated when there is a significant advance in the knowledge of the geology and the mineral deposit types in the region, or when new base data (e.g., RGS data) becomes available.

ASSESSMENT METHODOLOGY

Each mineral resource assessment consists of seven phases: (1) compilation, (2) definition of tracts, (3) preparation of deposit models, (4) assessment workshop, (5) data entry, (6) statistical simulation, and (7) ranking.

COMPILATION

Yukon Digital Geology (Gordey and Makepeace, 1999) was used as the geological base map at 1:250 000 scale. The overall accuracy of this compilation on a regional scale is considered to be very good, although the geology in some areas is based on studies done as long as

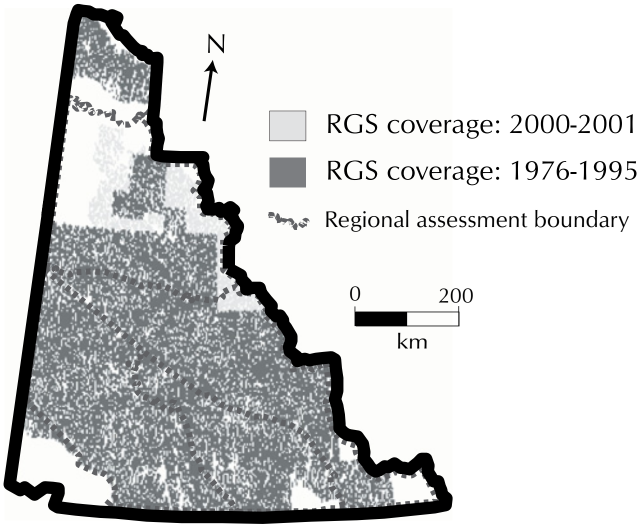


Figure 2. *Yukon regional geochemical survey (RGS) coverage.*

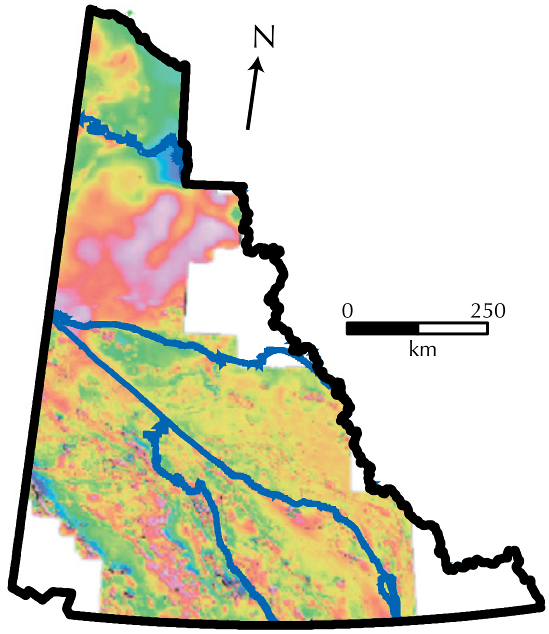


Figure 3. *Yukon airborne magnetic geophysical coverage.*

60 years ago. The Yukon Digital Geology compilation includes many recent 1:50 000-scale maps produced by the Yukon Geological Survey (YGS), and 1:250 000-scale maps produced by the Geological Survey of Canada (GSC).

Regional stream sediment geochemical surveys (RGS) have been completed over a large part of the Yukon Territory and have been digitally compiled (Héon, 2003). Median values were calculated for 21 diagnostic elements, and multiples of the medians were reported on 1:250 000-scale geochemical maps for each element. At the time of the mineral assessments, geochemical coverage was absent or incomplete in the following 1:250 000-scale map sheets: NTS 95C and 95E in southeast Yukon; NTS 106B, 106C, 106E, 106F, and 106L in northeast Yukon; and NTS 116F, 116G, 116H, 116I, 116J, 116K, 116N, 116O and 116P in north Yukon. RGS coverage has improved considerably since the completion of the regional mineral assessments, especially in the north Yukon (Fig. 2).

Aeromagnetic coverage is available for most of the Yukon (Fig. 3; Lowe et al., 1999). There is little or no geophysical coverage for NTS 106C, 106D, 106E and 106F in northeast Yukon. Most flight lines in the southern Yukon are at 0.8-km spacing. Flight lines in the north Yukon (north of ~65° latitude) are at 2-km spacing. Digital data was captured by digitizing contoured analog data, because most surveys are 1950-1960 vintage. Coloured maps illustrating the variations in the aeromagnetic total residual field were provided for each of the assessments (Lowe et al., 1999).

Mineral occurrences from the Yukon MINFILE database (anomalies, showings and deposits; Deklerk, 2002) were plotted on geological and geochemical maps to highlight areas of known mineralization and past exploration activity. Summaries and original descriptions of the mineral occurrences in each assessment area, which include deposit type, status, commodities, work history, and geological description, were provided to the estimators as supplements to the geology and geochemistry maps.

TRACTS

The Yukon Territory was divided into four large regions (each corresponding to a distinct mineral assessment phase) based on the large scale geological environment (e.g., Selwyn Basin). The area of each assessment phase was separated into a large number of tracts of approximately equal area (~1000 km^2). Tracts were defined on the basis of the regional geology. Tract boundaries are most commonly geological contacts (more specifically faults, lithologic contacts, or limits of Quaternary cover). A few tracts were assigned arbitrary boundaries, such as drainage patterns or roads, in order to maintain similar areas.

DIGITAL DEPOSIT MODELS

Tonnage and grade curves for 44 metallic mineral deposit types were utilized for the regional assessments. These deposit models are described by Fonseca and Abbott (in press).

ASSESSMENT WORKSHOPS

Assessment workshops hosted by the Yukon Geology Program took place in Whitehorse following the data compilation for each of the four phases. Five industry geologists (hereafter referred to as 'the estimators'), with considerable field experience and knowledge of the geology and mineral deposit models applicable to each region, participated in the assessment workshops. The following procedure was used for each of the four assessments: (1) for each tract, the estimators decided on the mineral deposit models that could potentially occur; (2) for each mineral deposit model, and for each individual tract, the estimators evaluated the percent probability (from 100 to 0) of discovering new deposits of that type in that tract; (3) for each tract, the estimators recorded their confidence (from 100 to 0 percent) in the current knowledge of the geology; and, (4) for each mineral deposit model, and for each tract, each estimator evaluated the relative knowledge and experience of each of the other four estimators and distributed 100 points between them. No estimates were made for non-metallic minerals such as diamonds, asbestos, emeralds and rhodonite. Likewise, potential for placer gold deposits and gravel deposits was not evaluated.

STATISTICAL SIMULATION AND RANKING

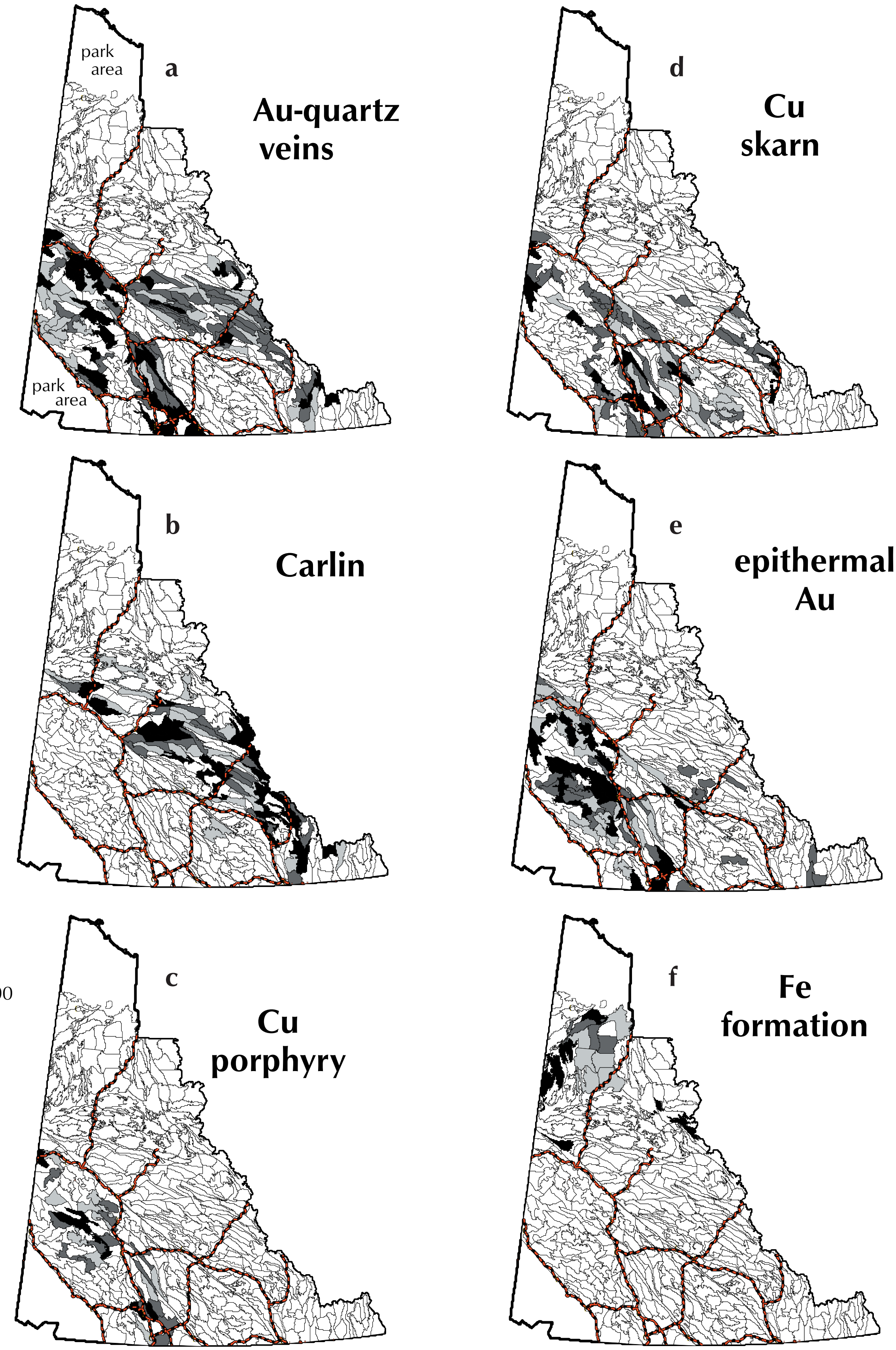
Data provided by the estimators were entered into a spreadsheet. Measurements of tract confidence and confidence level for undiscovered deposits were digitized in AutoCAD, and then copied to the spreadsheet. The data were then converted to a single evaluation for each tract/deposit model combination. The Monte Carlo Mark 3b simulator used the data to produce metal tonnages at the 90%, 50%, 10%, 5% and 1% confidence level intervals for each tract. The tonnages represent a combination of all possible mineral deposit models that could potentially occur within a given tract. These tonnages were then converted to dollar values using 10-year average prices for each of the commodities that are dictated by the relevant mineral deposit models. A 'confidence index' were derived from each of these dollar values by dividing the dollar value that corresponds to each confidence interval by the tract area. A 'confidence score' was calculated for each of the confidence level intervals by sorting and ranking the confidence index for each tract (i.e., the lowest confidence index has a score of 1, and the highest has a score equal to the total number of tracts). A final confidence score, referred to as 'sum score', was then calculated for each tract using the individual confidence scores weighted according to the 90%, 50%, 10%, 5% and 1% confidence level intervals. The sum score value was then ranked from highest to lowest, and defined the rank intervals used on the mineral potential maps.

For this compilation, the data provided by the estimators from all four regional assessments were used to calculate, in the same manner as described above, the potential for each tract to host a particular deposit type (i.e., a new 'sum score' was calculated for every tract that was assessed for a given deposit model). This value was used to rank the relative potential for each deposit type throughout the Yukon.

MINERAL POTENTIAL MAPS BY DEPOSIT MODELS

The mineral potential of the Yukon is ranked on 18 maps (Figs. 4a-r) using 18 individual deposit models. Of the 44 deposit models utilized in the 4 regional assessments, these 18 deposit types were deemed the most beneficial for publication as mineral potential maps. Relative rankings are from higher to lower and are illustrated using three categories for purposes of simplicity and ease of display. The maps show the relative potential, from higher to lower, for each tract to contain a specific deposit type. Every tract that was assessed for a given deposit model is ranked, and therefore tracts defined during different assessment phases are now ranked relative to one another. Tracts that were not assessed for a given deposit model are not ranked, and are displayed as white tracts on the respective mineral deposit model map. It should be emphasized, however, that no tract has zero potential and it still may be possible for a mineral deposit of a specific type to exist within a tract not assessed for that deposit model.

Figure 4. *Yukon mineral potential maps by deposit models:*
*(**a**) gold-quartz vein deposits;*
*(**b**) Carlin-type deposits;*
*(**c**) copper porphyry deposits;*
*(**d**) copper skarn deposits;*
*(**e**) epithermal gold vein deposits;*
*(**f**) iron formation deposits.*
Park areas were not assessed.



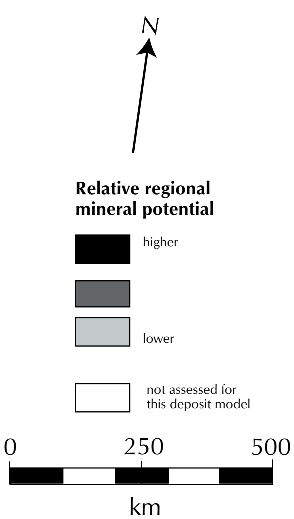


Figure 4. *(continued) Yukon mineral potential maps by deposit models:* ***(g)*** *polymetallic manto deposits;* ***(h)*** *molybdenum porphyry deposits;* ***(i)*** *lead-zinc skarn deposits;* ***(j)*** *plutonic-related gold deposits;* ***(k)*** *polymetallic vein deposits;* ***(l)*** *sedimentary-exhalative (SEDEX) deposits. Park areas were not assessed.*

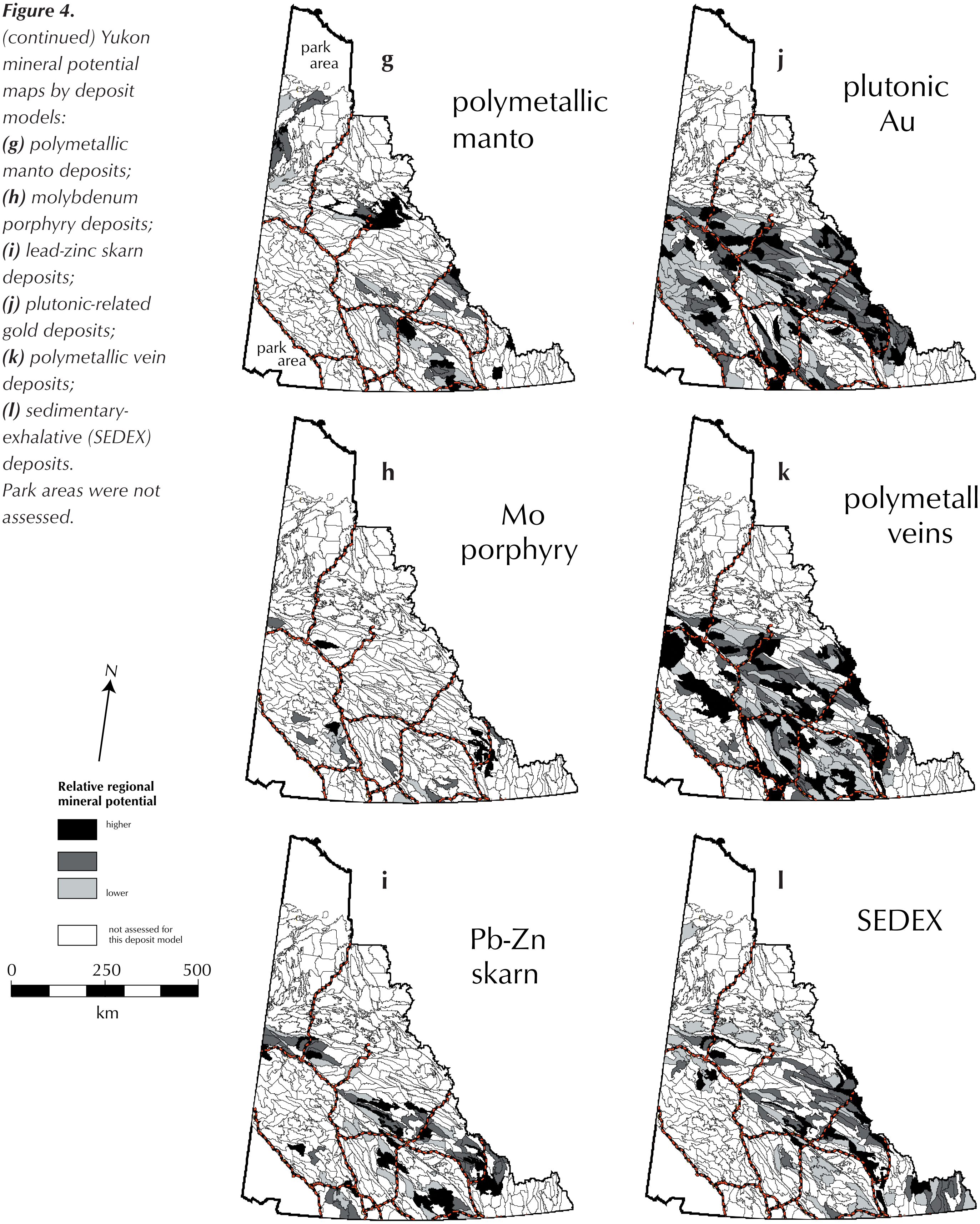
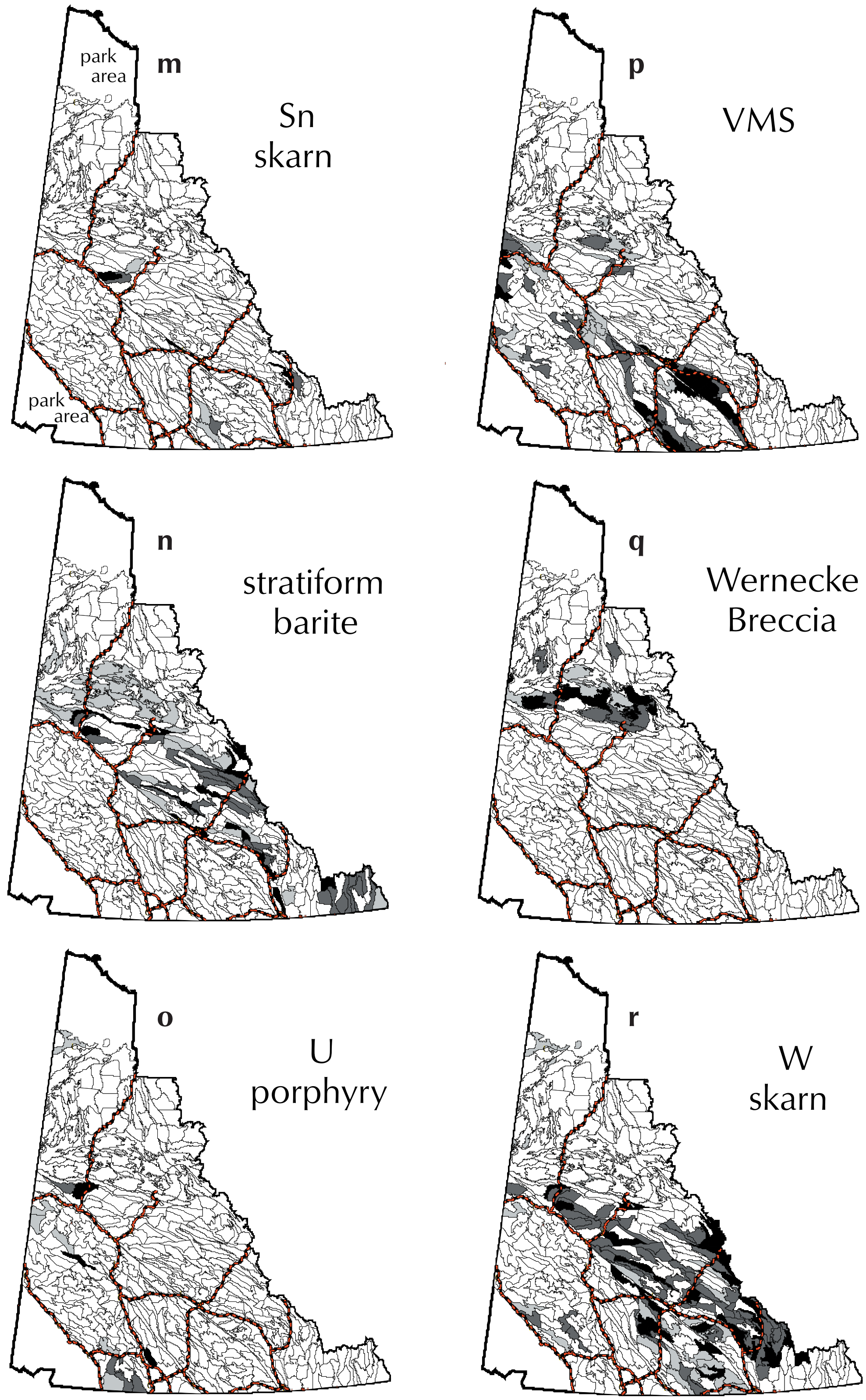
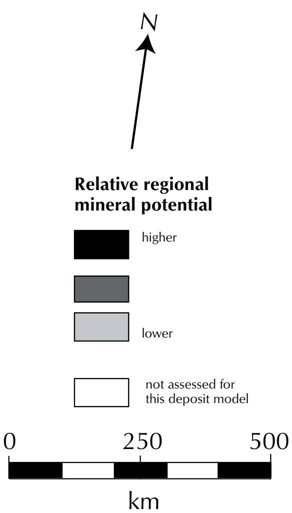


Figure 4.
(continued) Yukon mineral potential maps by deposit models:
***(m)** tin skarn deposits;*
***(n)** stratiform barite deposits;*
***(o)** uranium porphyry deposits;*
***(p)** volcanogenic massive sulphide (VMS) deposits;*
***(q)** Wernecke breccia deposits; and*
***(r)** tungsten skarn deposits.*
Park areas were not assessed.





LIMITATIONS OF REGIONAL MINERAL ASSESSMENTS

The primary limitation of mineral potential studies is that they are based on geological knowledge and data that was available at the time of the assessments. Rankings are subject to change as more data becomes available and geological knowledge improves. Although the estimators recorded their confidence in the current knowledge of the geology for each tract, it was not possible to integrate this information into the simulator. Furthermore, there may be potential in Yukon for deposit models that have not yet been recognized. Most commonly, tracts with limited baseline data were ranked as lower potential. For example, many tracts in the North Yukon were either not assessed or were found to have lower potential for most mineral deposit types. This is, at least partly, because of the relatively low level of geological knowledge and lack of baseline data (e.g., RGS) at the time of the North Yukon assessment.

Mineral potential assessments are also limited by the quality of the data on which they were based. For example, RGS data collected in 1976 does provide important information, but has not benefited from recent advances in the science of geochemistry and may prove to be unreliable for certain elements due to improvements in our understanding in how to collect and analyse samples. The number, locations, and types of mineral occurrences (from the Yukon MINFILE database, Deklerk, 2002), although controlled primarily by geology, also depend on the amount of exploration work done, which in turn depends on ease of access, price of commodities, and other non-scientific issues. Also, information pertaining to geology and mineral deposit models from the MINFILE database may require updating, particularly where derived from properties not recently worked.

Despite the limitations, quantitative regional mineral assessments yield reproducible and unbiased results. The deficiencies are a direct consequence of the fact that the mineral potential of a region is a 'snapshot in time' and should be re-evaluated when there is a significant advance in the knowledge of the geology and the mineral deposit types in the region, or when new base data (e.g., RGS data) becomes available.

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