Evaluation of Mineral Inventories and Mineral Exploration Deficit of the Interior Plateau Beetle Infested Zone (BIZ), South-Central British Columbia

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KEYWORDS: mountain pine beetle, Interior Plateau, geology, mineral inventory, mineral potential, mineral exploration, MINFILE, ARIS

INTRODUCTION

Mountain pine beetles are a natural disturbance agent within the forests of western North America, where they are known to range from British Columbia to northern Mexico (Amman and Logan, 1998). They were first described in South Dakota as the "pine destroying beetle of the Black Hills", and measures were taken to control their spread as early as 1902 (Hopkins, 1905). Outbreaks of mountain pine beetle are a natural phenomenon. Recorded infestations in British Columbia date back to 1913 (Unger, 1993), and tree scar evidence for infestations dates back hundreds of years (Taylor and Erickson, 2003).

It is human interference with the normal succession of forest fires, a principal regulator of forest ecosystem health and creator of barriers to disease transmission (e.g. Hirsch *et al.*, 2001), that has rendered the pine forests of Interior British Columbia susceptible to an outbreak of mountain pine beetle of historically unprecedented scale.

In an area extending north from Kamloops to Smithers and east from the Coast Mountains to the Rocky Mountain Trench, pine is the most widespread commercial tree species, and pine beetle infestation was essentially continuous in 2004 (BC Ministry of Forests and Range, 2005a; Figure 1). We refer to this area as the Beetle Infested Zone (BIZ). The BC Ministry of Forests (MoF) predicts that only about 10% of the already diminished 2006 volume of pine will be left standing by 2016 (Eng *et al.*, 2006). Accelerated timber harvests have brought temporary economic prosperity to many forestry-dependent communities within the BIZ, but harvest levels will likely begin to decline by 2015 (BC Ministry of Forests and Range, 2005a). Anticipating an economic downturn in the forestry sector within the BIZ, the provincial government is supporting economic diversification throughout the region. Work presented here and by other reports in this volume, is part of that provincial effort (*e.g.* Andrews and Russell, 2007; Logan *et al.*, 2007; Mihalynuk et al., 2007; Schiarizza and Macaulay, 2007).

Accelerated timber harvest, attendant overburden disturbance, needle loss and forest fires should yield unprecedented opportunities to discover never-before-seen bedrock outcrops within the BIZ. Cospatial with the BIZ is a geological province that has historically been avoided by mineral explorationists, mainly because of lack of outcrop and extensive veneers of Cenozoic volcanic deposits with no known economic mineralization. However, sparse exposures of basement rocks throughout the BIZ show that the pre-Cenozoic geological and metallogenic fabric of the province continue in the subsurface, and so too should the

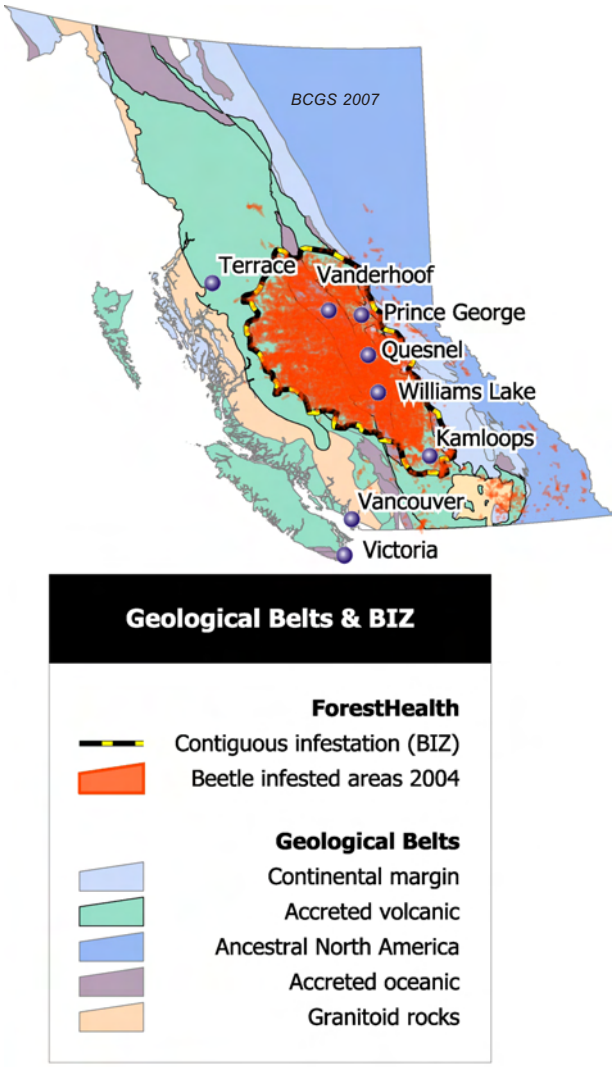

Figure 1. Location of the area of mountain pine beetle infestation, based on the BC Ministry of Forests and Range (2005) Forest Health Survey for 2004. The area of contiguous infestation, shown by the dashed outline, is herein referred to as the Beetle Infested Zone (BIZ).

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rich mineral endowment both south and north of the BIZ (Fig 1). A principal objective of the BIZ Project is to demonstrate that application of conventional and nonconventional exploration techniques can be successfully applied to large tracts of the BIZ. Field-based results of the first season of the BIZ project are available as GeoFile 2007-5.

This report is concerned with estimating the value of past (Fig 2) mineral exploration expenditures, and measuring disparities in mineral production or inventories between geological belts outside the BIZ and those within the BIZ. Such disparities are herein attributed primarily to a relative lack of exploration within the BIZ.

ESTIMATES OF MINERAL ENDOWMENT

West of the ancestral North American continental margin, north-northwest-trending belts of ancient volcanic arcs form the principal geological fabric of British Columbia. Each belt is characterized by surprisingly consistent rock successions throughout the length of the province. Thus, the average mineral wealth demonstrated within the best exposed and most exhaustively explored parts of these belts can reasonably be expected within the least well exposed/explored parts. In this manner, mineral resource production, inventory, exploration and probabilistic estimates made for well-exposed parts of the belts outside the BIZ can be compared to those within the BIZ, and deficits can be largely attributed to lack of exploration, mainly as a result of extensive cover by young volcanic rocks or glacial deposits. A summary of mineral endowment measurement criteria, and mineral exploration, inventory and production deficit estimates for the BIZ, is presented in Table 1.

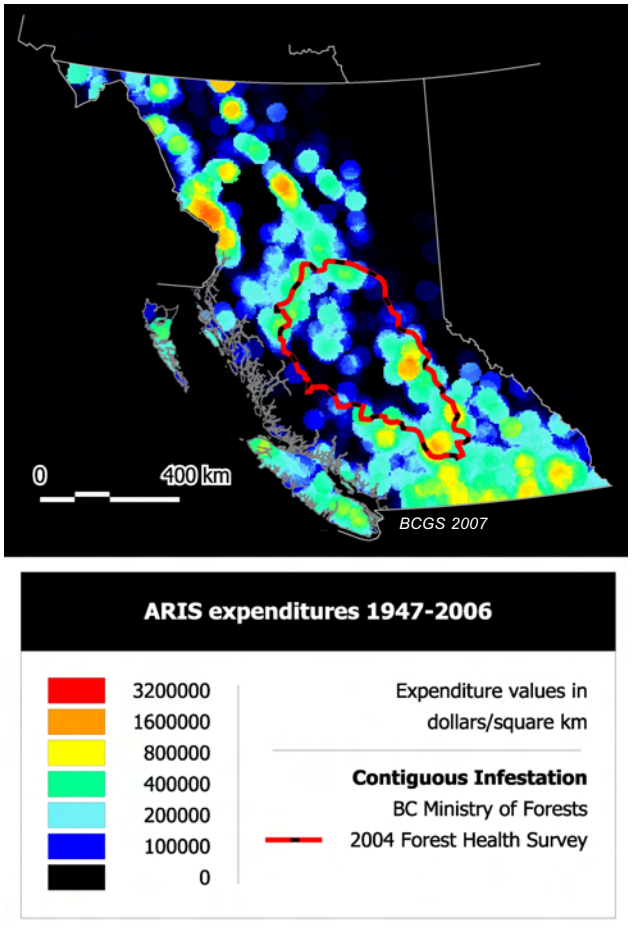

Figure 2. Contour plot showing the distribution of mineral exploration expenditures in British Columbia based on information captured within the Assessment Report Indexing System (ARIS) from its inception in 1947. The BIZ outline is shown for reference.

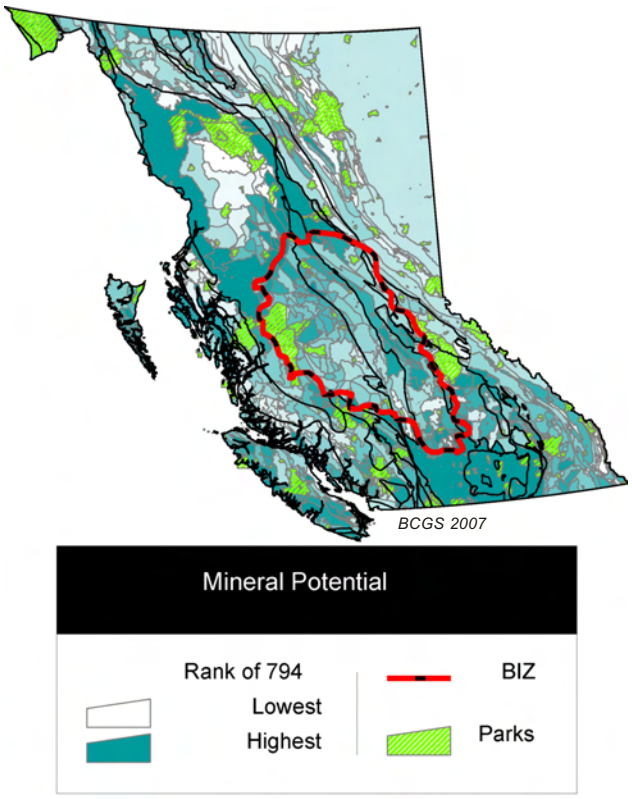

Figure 3. Mineral potential tracts and their relative ranking, based on the Mineral Resource Assessment (Level 1) results (*cf.* Kilby, 2004). Parklands and the BIZ are shown for reference. Much of the BIZ is underlain by tracts that have intermediate to high rankings.

Mineral Potential Project Data

Approximately 30 person-years of work between 1992 and 1997 were invested in the BC Geological Survey's Mineral Potential Project to help direct the establishment of park boundaries. This comprehensive assessment established British Columbia as the first province in Canada with a complete assessment of its mineral potential (Kilby, 2004). A decade later, these data continue to be useful in directing public policy, and they are used here as one method of estimating the undiscovered mineral wealth of the BIZ.

One of the first steps of the mineral potential evaluation was to divide the province into manageable land tracts of relatively uniform size defined principally on the basis of bedrock geology. Of the 794 mineral potential tracts thus defined, 150 fall entirely or largely within the BIZ (Fig 3). These tracts, taken to be representative of the BIZ, cover 158 000 km^2 — a good approximation of the 155 000 km^2 enclosed by the BIZ outline as determined from the BC Forest Health Survey (BC Ministry of Forests and Range, 2005a).

TABLE 1. COMPARISON OF METALLIC AND INDUSTRIAL MINERAL INVENTORIES AND MINERAL EXPLORATION WITHIN THE BIZ TO GEOLOGICAL BELTS ALONG STRIKE TO THE NORTH AND SOUTH

Estimation criteria	$millions			$/km^2
	Value	Average	Standard deviation	
BIZ (150 tracts, 158 000 km^2):				
Assessment Reports BIZ (I 2.2%)*	280	0.047	0.23	1770
Assessment Reports BIZ (I 4.24%)#	430	0.073	0.34	2720
Metal Inventory BIZ	5470	36	120	34640
Industrial Minerals Inventory BIZ	3020	20	120	1910
Past Production BIZ	1610			10220
Exploration Efficacy Index (EEI) *((\$Inventory+\$Production)/\$Exploration)*	17			
South of BIZ (61 tracts, 48 000 km^2):				
Assessment Reports south of BIZ (I 4.24%)	275	0.052	0.14	5730
Metal inventory south of BIZ	4680	77	200	97500
Industrial Mineral inventory south of BIZ	1640	27	110	34100
Past Production south of BIZ	2240			46600
EEI south of BIZ	31			
BIZ to Bowser Basin (40 tracts, 37 000 km^2):				
Assessment Reports BIZ to Bowser (I 4.24%)	142	0.08	0.22	3840
Metal Inventory BIZ to Bowser	1960	49	96	53000
Industrial Mineral inventory BIZ to Bowser	102	2.6	9.3	2760
Past Production BIZ to Bowser	32			860
EEI BIZ to Bowser	15			
North of BIZ (125 tracts, 82000 km^2):				
Assessment Reports north of BIZ (I 4.24%)	604	0.13	0.43	7370
Metal Inventory north of BIZ	7740	60	180	94400
Industrial Mineral inventory north of BIZ	280	2.2	17	3410
Past Production north of BIZ	910			11100
EEI north of BIZ	15			
BIZ deficits ([N+S]/2-BIZ) per km^2:				
Exploration in BIZ (ARIS)				3830
Metal Inventory BIZ (Mineral Potential)				61310
Industrial Mineral inventory (Mineral Potential)				16850
Production				18630

Two estimates of inflation were used to adjust past expenditures: * an accepted modern inflation rate of 2.2%; # an inflation rate of 4.24% based on the calculated mean of the percentage change in the Consumer Price Indexes as provided by Statistics Canada for the years 1946 to 2006 (Figure 4). Assessment Reports with records of expenditures were required in BC starting in 1947.

Production and mineral inventory data used as part of the Mineral Potential Project were based on a 1986 compilation. Now 20 years out of date, the data remain useful from a comparative standpoint, even if the absolute numbers are no longer valid. Commodity prices used in the mineral potential evaluation were an average for the period 1981–1990 (*e.g.,* Au \$596/oz, Cu \$1.13/lb, Mo \$6/lb) and are comparable with commodity prices averaged over the past decade, although lower than prices for most of 2006.

Estimating undiscovered mineral resources is a difficult and contentious exercise. Part of the Mineral Potential Project involved computer simulation of undiscovered mineral resources guided by probabilistic estimates from mineral exploration experts. Numbers of undiscovered deposits thus determined were tabulated at various confidence levels. For example, in the Cariboo region, estimated metallic mineral resources yet to be discovered at 90, 50, 10 and 1% confidence levels (in millions of 1986 Canadian dollars) were 1912, 68 997, 886 029 and 14 894 274, respectively (Kilby, 2004; the Cariboo region, which underlies a large portion of the BIZ, is shown in 5). It is stressed that the utility of these probabilistic estimates is in ranking mineral potential tracts, not in determining the present in-ground value of undiscovered mineral resources. Nevertheless, as noted by Kilby (2004), a consistent result of the probabilistic assessment process is that, at the 50% confidence level, about three-quarters of the province's mineral endowment remains to be discovered.

Comparative Mineral Endowment

Despite considerable challenges for exploration within the BIZ, there are many examples of past exploration success. Historic producers, such as those of the Quesnel Trough copper belt (*e.g.,* Copper Mountain, Iron Mask, Mount Polley, along the axis of the eastern accreted volcanic belt, Fig 1), Equity Silver and large deposits with outlined resources that have yet to be mined (*e.g.*, Prosperity), are a testimony to the mineral endowment of the area.

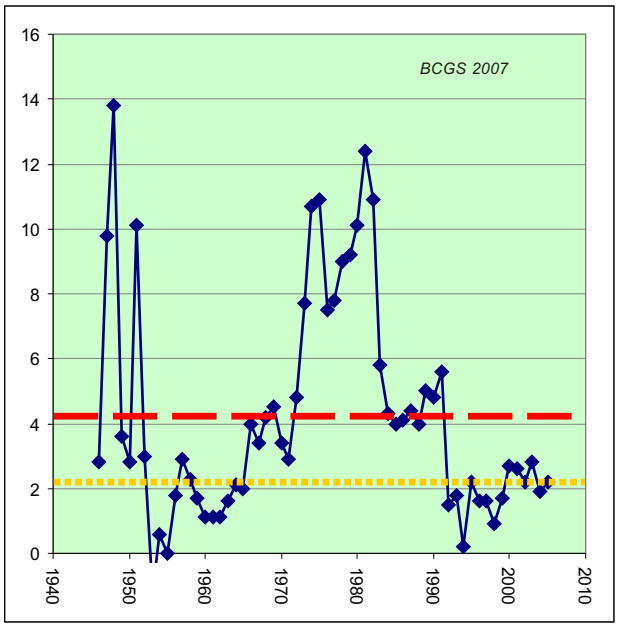

Figure 4. Annual change in Consumer Price Index as a monitor of inflation for the years 1946 to 2005. The average annual change in Consumer Price Index over this period is +4.24% (dashed red line). A commonly cited average rate of +2.2% is applicable to the last decade only (shown by the dotted yellow line). Source of data: Statistics Canada (2006).

Recognizing that geological belts continue from south to north of the BIZ, a qualitative visual estimate of undiscovered mineral wealth can be made by contouring the density of mineral occurrences, and comparing the area within the BIZ with areas along strike to the south and north. This can be easily accomplished using the province-wide MINFILE database of more than 12 000 mineral occurrences (MINFILE, 2006). For the purposes of presentation here, a grid (0.1° latitude by 0.2° degree longitude) was generated over the province and grid cells were coloured based on the number of MINFILE occurrences that they contain (Fig 5). An indication of the relative importance of MINFILE occurrences can be determined spatially by similarly contouring the distribution of mineral exploration expenditures (Fig 2). A recent data posting from the Assessment Report Indexing System (ARIS) is used (ARIS, 2006), with figures adjusted for an average inflation rate of 4.24% (Fig 4). Reporting mineral exploration activity in 'Assessment Reports' is one mechanism for maintaining mineral tenure within BC. A synoptic database of reports (available for download; ARIS, 2006), captures monetary expenditures since 1947. In 1997, it was estimated that only about 40% of mineral exploration expenditures in BC were recorded in ARIS (Wilcox, 1998)

In addition to the forgoing visual comparisons, quantitative analyses are presented here (Table 1), based on metallic and industrial mineral inventory and production figures from deposits within, north and south of the BIZ (MINFILE, 1995; *see* Fig 6 for areas covered). Mineral exploration expenditures recorded in ARIS since 1947 were compared for these same regions.

Results of Inventory and Exploration Expenditure Analysis

On a per square kilometre basis, mineral production values within the BIZ are $10 220, whereas those to the south and north of it are $46 600 and $11 100, respectively (1986 Canadian dollars; Fig 5). Almost 400% more production has been recorded within the populated, relatively well-explored and well-exposed southern part of the province, as compared with rocks of the BIZ that lie along strike. Past production within the BIZ is comparable with that in correlative rocks to the north; however, metal inventories in the north are nearly 300% of those within the BIZ ($94 400 versus $34 640/km^2), partly reflecting the difficulty of developing deposits within the remote north, but also underscoring the relative lack of exploration within the BIZ. For example, mineral exploration expenditures to the north along strike from the BIZ are nearly triple those within the BIZ. Exploration expenditures to the south are more than double those of the BIZ. The actual disparity is probably

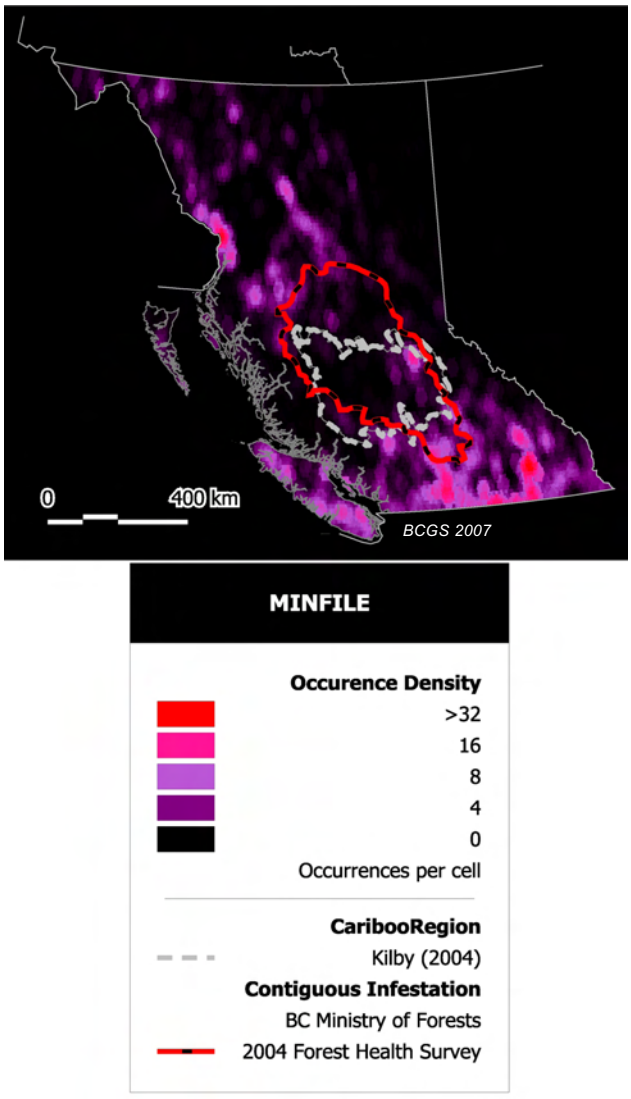

Figure 5. Number of mineral occurrences documented in MINFILE, shown as contoured density per 0.02 square degree grid cell. Also shown for reference is the Cariboo region, as defined in Kilby (2004), and the BIZ.

much greater because more of the exploration in the south predates the 1947 beginnings of expenditure capture by ARIS than is the case for the BIZ. In addition, perhaps as much as 60% of exploration work (*cf.* Wilcox, 1998), particularly regional work, is not filed for assessment and is therefore lost in this analysis.

An indication of how much exploration work in southern British Columbia predates ARIS can be estimated by comparing the ratio (Production + Inventories) / (ARIS expenditures) between regions. This ratio is essentially a measure of the efficacy of exploration. It is herein referred to as the Exploration Efficacy Index (EEI). Higher numbers indicate more inventory+production arising from each exploration dollar. South of the BIZ, the EEI is 31, versus 17 for the BIZ and 15 for areas to the north of the BIZ (Fig 6). Better infrastructure in the south can account for reduced exploration expenditures today. However, a lack of infrastructure 60 or more years ago (pre-1947) posed challenges in the south, as it now does in the central and northern parts of the province. It may be that mineral deposits were easier to find, and therefore investment in the first-pass mineral exploration was more fruitful, but most of the difference in EEI is herein attributed mainly to lack of capture of exploration expenditure data. If this is true, then an EEI of 17 to 20 for the south may be reasonable, and more accurate minimum exploration expenditures/km^2 would be at least 50% greater than those listed for 'South of the BIZ' (Table 1). Nevertheless, the conservative approach used herein considers only expenditures recorded in ARIS.

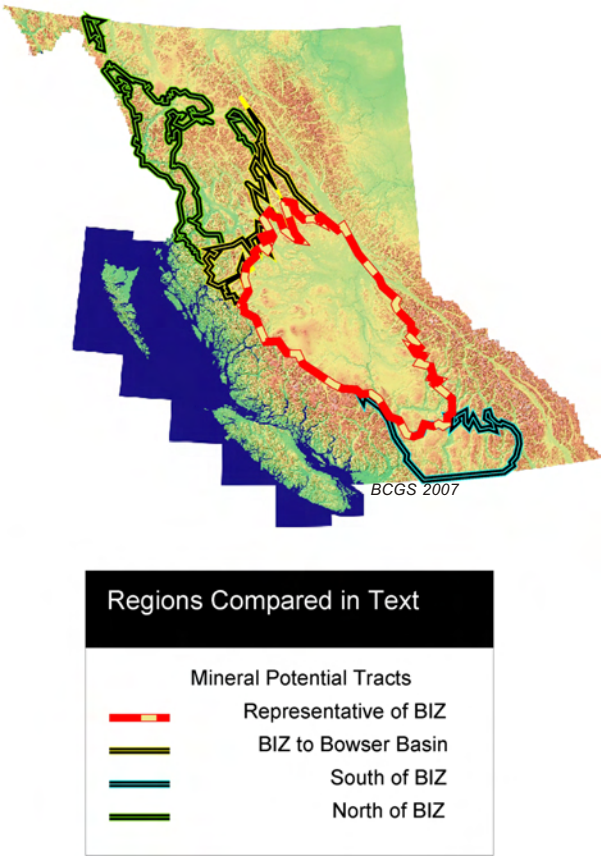

Figure 6. Regions compared within the analysis presented in this report. The area north of the BIZ is subdivided into south (yellow) and north (green) of the Bowser Basin. Major parks are excluded.

Exploration and inventory deficits within the BIZ can be crudely calculated by averaging the values from north and south of the BIZ and subtracting the values for the BIZ. Because this analysis includes pre-1947 data on mineral production, but not exploration expenditures, it gives only an indication of the minimum exploration expenditures required to find a density of deposits equivalent to the average outside the BIZ. For example, more than $3800 of exploration per km^2 will be required to bring the level of exploration up to the recorded average level of exploration along strike outside the BIZ. This translates into a minimum of nearly $600 million in exploration investment required in the BIZ to equal the average level of exploration in equivalent rocks to the north and south, as recorded by ARIS. Considering that maybe 40% of provincial mineral exploration expenditures are recorded in ARIS (likely less in the period between 1947 and 1997), a more accurate estimate of the current exploration expenditure deficit in the BIZ is probably about $1.5 billion.

NEXT STEPS

Perhaps the greatest impediment to attracting significant mineral exploration investment in the BIZ is the geological uncertainty posed by the extent and thickness of cover successions. Work presented elsewhere in this volume (Andrews and Russell, 2007; Mihalynuk, 2007; Mihalynuk et al., 2007) suggests that the perceived thick blanket of cover may be exaggerated. For example, a first generation 3-D model of the principal cover succession indicates that most of it is less than 25 m thick (Mihalynuk, 2007). Future work aimed at refining the 3-D geometry of the cover succession, and its affect on geochemical and geophysical signals, will be instrumental in targeting the next $1.5 billion invested in mineral exploration. Considering that an estimated three-quarters of the province's mineral wealth is yet to be discovered (Kilby, 2004), the mineral exploration prospects for the BIZ are bright indeed.

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