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THE PROBABILISTIC ESTIMATION OF MINERAL RESOURCES IN THE LIME PEAK - MT. PRINDLE AREA: PART 2

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INTRODUCTION

This quantitative assessment of the mineral resources of parts of the Steese National Conservation Area-North (SNCA-N) and the White Mountains National Recreational Area (WMNRA) was done under a cooperative agreement between the Alaska Division of Geological and Geophysical Surveys (ADGGS), the U.S. Bureau of Mines (USBM), and the Department of Geology, University of Alaska, Fairbanks. The quantitative estimates of mineral resource potential derived from this study will form the basis for an economic estimate of the value of those resources by the U.S. Bureau of Mines.

The assessment was performed to evaluate the mineral potential of land being placed in certain restrictive classification by the Bureau of Land Management (BLM). The assessment was requested by the mining industry of the Fairbanks and Circle Mining Districts in an effort to determine if major mineral resources are likely to be present in the areas in question.

BACKGROUND

This quantitative resource assessment using the ROCKVAL methodology was undertaken by the Alaska Division of Geological and Geophysical Surveys (ADGGS) and personnel from the University of Alaska in conjunction with the Bureau of Mines. A cooperative agreement between the Alaska Division of Geological and Geophysical Surveys and the U.S. Bureau of Mines was signed in 1987, requesting a ROCKVAL assessment on the Lime Peak-Mount Prindle area. Dr. Rainer Newberry of the Dept of Geology, University of Alaska, Fairbanks, was contracted by the ADGGS to participate in the evaluation. The reader is referred to White and others (1987) for a description of the ROCKVAL methodology.

The mineral potential for part of the Steese National Conservation Area-North (SNCA-N) and the White Mountains National Recreational Area (WMNRA) is assessed in this study. ADGGS investigators concentrated on a 550 square mile area, referred to in this report as the Lime Peak-Mount Prindle area, in the west-central Circle Quadrangle. The area includes parts of the Circle B-4, B-5, B-6, C-4, C-5, and C-6 15-minute quadrangles. The study area was previously known to contain tin, uranium, tungsten, and gold occurrences.

The assessment differs from previous ROCKVAL applications in that field and analytical work was designed specifically to address the problems of mineral potential and quantitative resource assessment. Instead of searching the literature for data, needed data was generated by field investigators. Three phases were involved in the current study, including: 1) field mapping, 2) analytical data acquisition and interpretation, and 3) the ROCKVAL analysis. The field mapping and data interpretation are reported elsewhere (Smith and others, 1987).

PRELIMINARY ASSESSMENT STRATEGY

1. Regional Favorability

The ROCKVAL process was started with the systematic interpretation for favorability for each of the deposit types. For the purposes of the resource estimation process, an area of interest is divided into distinct geologic trends known as 'plays' in the model terminology. A 'play' is an area of relatively consistent geologic character that is favorable to some consistent degree for the occurrence of a single deposit type.

The mineral assessment report (Smith and others, 1987) written previously defined the 'plays'. The area for each play was chosen on the basis of the geologic map (Smith and others, 1987) and analytical data (sediment and rock geochemical data).

Group consideration of regional favorabilities resulted in the following general assignments of probability for occurrence of appropriate deposits:

Very high favorability-	1
High favorability-	.80-.95
Moderate favorability-	.40-.79
Low favorability	0 - .39

The very high favorability plays encompass the least amount of area, and the low favorability plays encompass much largest tracts of land. Very high favorability implies that a specific deposit type is known to be present. Moderate favorability implies that some geological and/or geochemical indicators are present but no prospects are known. Low favorability areas are geologically broadly similar to moderate and high favorability areas, but lack strong geochemical indicators or prospects. Favorability criteria for each deposit type are presented in Appendix A.

2. Deposit densities

For each ROCKVAL play, a prospect probability distribution (i.e. number of prospects likely to be present at a given probability level) must be created. For those plays with known prospects, the number of known prospects would be the 100 percent probability level. Numbers of prospects for other less certain plays and for other probability levels were first estimated using generic "prospect density" curves (Appendix B, section I), as described for the NORWAAP project (Pessel and others, 1987). These generic curves were prepared by determining the number of prospects per square mile of geologically favorable terrane for a large number of world-wide districts of a particular deposit type. The generic prospect density curve for a particular deposit type is thus the number of expected prospects/square mile for each probability level. The size of a given play times the generic prospect density value for a particular probability level yields a trial value for number of prospects. Finally, calculated values for number of prospects were modified to reflect known geological considerations, where applicable.

3. Cut-off parameters

Cut-off parameters represent the minimum values for grade and tonnage which will be considered as potential resources by the simulation process. Cut-off values for grade and tonnage are deliberately set below those which are likely to be produced at current commodity prices. Cut-offs are based on the minimum size/grades found in the literature data for a given deposit type. A summary of the cut-off parameters for each deposit type is given in Appendix B, section II.

4. Grade and tonnage distributions

Probability distributions for grade and tonnage were estimated from compilations of literature data for the appropriate deposit type. Cox and Singer (1986) and Laznicka (1985) are excellent references for deposit data and were widely employed. 'Generic' distributions were modified where geological or geochemical indicators made it necessary.

5. Deposit favorabilities

Not all the prospects calculated/estimated from above would necessarily meet the grade/tonnage cutoffs. Estimation of the proportion likely to meet the cutoff was made by noting the proportion of prospects (used in generating the prospect distribution curve) which would meet the cutoffs. These 'generic favorabilities' were modified as appropriate by the appraisal committee.

DISCUSSION OF DEPOSIT TYPES

Tin-greisens

Granites that have the potential to contain tin greisen deposits are present in the Lime Peak-Mount Prindle area (see Burns and Newberry, 1987; and Newberry and others, 1987). These plutons include the Lime Peak, Quartz Creek and Mount Prindle plutons, and will be referred to in this report as the Hope granite suite. Tin greisen systems have been found at these plutons and are described in detail by Newberry and others (1987). The appraisal committee had excellent knowledge about the granites and their tin potential, having mapped and studied the plutons specifically to evaluate for tin potential.

The deposit model used is one which requires a favorable granite pluton to be formed by numerous intrusions; the latest and most evolved intrusions are most likely to produce tin mineralization. World-wide examination of tin greisens suggests that tin mineralization produces a vertical alteration pattern consisting of chlorite greisens above higher-grade zinnwaldite-topaz greisens. However, apparently not all chlorite greisens indicate a richer tin-greisen system at depth. Analytical data on the granitic rocks of the Lime Peak-Mount Prindle area were used to estimate the likelihood that the greisens are in fact associated with major mineralization using discriminant analysis (Johnson and Burns, 1988).

The plutons were divided into five different levels of regional favorability. A very high favorability play was defined as those areas having moderate to intense chlorite- or white-mica-greisen alteration and significant tin anomalies in mineralized rock, indicating that a richer greisen system might be present at depth. The very high favorability play included six small areas in the Lime Peak pluton with characteristics listed above. The total area involved was 10 square miles.

The high favorability play included all of the Lime Peak pluton (25 sq miles). Of the three plutons in the Hope suite, Lime Peak contains the most greisens and the highest grade greisens, and appears to be the most highly differentiated pluton--a known prerequisite for tin-greisen deposits.

A moderate favorability play (60 percent) was defined for the Mount Prindle pluton (about 22 sq miles). The pluton is thought to be very similar to the Lime Peak pluton, but has no indications that major greisens are present. Some moderate-grade greisen samples were collected from this pluton and a high-grade tin skarn is present along its southern contact.

The Quartz Creek pluton was divided into two plays. The northeast end (about 10 sq miles) was given a regional favorability of 40 percent. Although few indications of a tin-greisen system are present on the surface, minor geochemical anomalies typical of known tin deposits may suggest a greisen system may be present at depth.

The southwest end of the Quartz Creek pluton (about 17 sq miles) is thought to have low favorability (10 percent). No major greisens or strong indications of intrusions at depth were found.

For all the tin greisen plays, the same generic-based prospect distributions, grade distributions, and tonnage distributions were employed. Lower probabilities were estimated for W-Ta-Nb mineralization than for Sn-Ag mineralization, because the former appears relatively rare and the latter is quite common.

Skarns

Three types of skarn, tin, tin-tungsten, and tungsten, form in the Lime Peak-Mount Prindle area. As the formation of a skarn involves reaction of a carbonate with fluids associated with an intrusion of appropriate composition, skarn occurrences were modeled according to the type of associated pluton. The tin and tin-tungsten skarns are associated with the Hope granite suite, while the tungsten skarns are associated with the Pinnell Trail monzogranite. Skarn deposits were largely treated as described in Newberry (1986), with modifications as described below.

In each case, the number of possible prospects was based on miles of intrusive-carbonate contacts (Newberry, 1986; Hagen-Leveille, 1986) and ROCKVAL parameters were taken from Newberry (1986). Adjustments to generic values were based on abundance and thickness of carbonate rocks, as described in Newberry (1986).

Tin-skarn

Tin-skarn float and outcrop containing up to 1.8 percent Sn was found in the Hope Creek drainage south of the Mount Prindle pluton. This area consequently had a regional favorability of 1.0 for tin-skarn deposits. Some carbonate, necessary for skarn formation, is present in the area. However, the amount of carbonate known to be present is so small (1 percent) that only minor skarn formation could have occurred. The number of expected prospects is consequently small. A few large carbonate beds (< 20 meters thick) crop out 20 km away in the same sequence of metamorphic rocks, but known carbonate beds in the immediate vicinity are less than 1 m thick. These carbonate thickness and abundance parameters yield very low probabilities (< 1 percent) for exceeding the tonnage cutoff (Newberry, 1986; Hagen-Leveille, 1986). The net result of low prospect density and low probability for exceeding the tonnage cutoff is that there is appreciable tonnage of tin skarn deposits were estimated at very low probability fractiles.

Tin-tungsten skarn

Moderate amounts of placer scheelite and appropriate stream-sediment geochemical anomalies in drainages near the northeast end of the Quartz Creek pluton suggest that tin-tungsten skarns may be present in the area. Because no occurrences of W-Sn bearing skarn are known, the regional favorability was placed at 50 percent. Because generic data for Sn-W skarns were not developed by Newberry (1986)--Sn-W skarns are relatively rare world-wide--generic data for W skarns (Newberry, 1986) were modified by the inclusion of significant Sn as a primary commodity. Other parameters were used directly from the W skarn model of Newberry (1986). Tungsten skarns tend to be much smaller than tin skarns (e.g., Laznicka, 1985), so that the tonnage distribution model is considerably smaller than that used for the tin skarns of the Hope Creek area. Although some moderate-thickness (10 m) carbonate beds are present in this area and carbonate is present at a moderate abundance (5 percent), the overall low tonnage distribution causes this play to result in small resources.

W-skarn

The widespread occurrence of scheelite-bearing skarns in the Pinnell Trail area indicate that tungsten skarn deposits have a regional favorability of 1.0. Approximately one-half of the known prospects are large enough to be of interest. However, the small thickness and lateral extent of carbonates in the vicinity indicate that skarn deposits are unlikely to contribute a significant amount of tungsten to the endowment. More discussion can be found in Pessel and Newberry (1987).

Gold deposits

The lode-gold endowment of the Lime Peak - Mt. Prindle area is present in stratabound-volcanogenic, alkalic-related (including alkalic(?) tourmaline-gold), and tungsten skarn prospects and deposits. Of these various deposit types, only the tourmaline-associated deposits are known to contain sufficiently high grades (up to 4 oz/ton) to be considered highly favorable for possible development. However, anomalous values were found in samples collected from all of the other deposit types. Also, the many gold placers in and near the study area suggest the presence of lode resources.

Alkalic-related gold

The alkalic-related prospects are characterized by highly anomalous Te (0.2-14 ppm), F (500-2000 ppm) and Cr (100-500 ppm) abundances and by an association with relatively low-quartz, high K-feldspar rocks. These characteristics are common to alkalic-related gold deposits world-wide. The major types of prospects located during this study are gold-arsenopyrite-tourmaline veinlets associated with subalkalic dikes on Table Mountain and altered plutonic and hornfelsic samples near margins of alkalic(?) sills in the Hope Creek-Homestake Creek drainage. We chose a low grade-high tonnage model to describe these deposits as a more geologically likely mode for occurrence in the study area. The grade-tonnage model was based largely on data in Berger and Singer (1987). The prospect distribution model was based on districts in the Western U.S., mostly in Colorado, where alkalic-related gold deposits are common. Probabilities for exceeding grade and tonnage cutoffs were estimated from size and grade data for Colorado alkalic-related prospects.

Three favorability plays were designated for the ROCKVAL model: 1) high favorability, immediately surrounding known prospects in the Table Mountain and Hope-Homestake Creek areas, 2) moderate favorability in areas of known alkalic rocks surrounding the high favorability areas, and 3) low favorability in the vicinity of Bear Creek, where alkalic rocks, but no gold anomalies, are present.

Significant alkalic-related gold resources were determined for the Steese study area, in large part because prospects with gold grades in excess of 1 ppm are currently known and because there are favorable petrologic and geochemical indicators for these deposits.

Cleary Sequence gold

Geologic mapping the study area indicated the presence of lithologies similar to the Cleary sequence of the Fairbanks district. The Cleary Sequence contains both stratabound gold deposits and veins probably derived from stratabound(?) sources. Detailed sampling of Cleary sequence(?) lithologies in the study area indicated a few sulfidic stratabound zones slightly enriched in gold and some gold-bearing veins. Based on lithologic similarities but the absence of known stratabound gold, Cleary sequence(?) in the study area was assigned a regional favorability of 0.5 percent for stratabound gold deposits. A grade-tonnage model for such deposits was constructed based largely on Archean stratabound volcanogenic gold deposits, such as Agnico-Eagle, Quebec, and Homestake, South

Dakota. Prospect distribution was estimated from generic distributions for volcanogenic massive sulfide deposits. Probabilities for exceeding grade and tonnage cutoffs were estimated from geologic-geochemical data in the study area and the Fairbanks district. Only modest gold resources were estimated for Cleary sequence(?) sources in the study area, due to the uncertainty in their occurrence.

Other deposits

Uranium and rare-earth elements

Uranium and rare-earth elements (REE) may occur in association with the Hope granitic suite and with a syenite near the western boundary of the study area. The resources are thought to be minor and are discussed in more detail elsewhere (Pessel and Newberry, 1987).

Rare earth elements in veins are known to occur in syenites outside the study area to the west, and hence the favorability for occurrence is high. However, only a very small area of the syenite terrane is known to exist in the study area, so the amounts of potential resources are very low.

The uranium potential of the Hope granitic suite is low because of unfavorable alteration chemistry and known lack of geochemical indicators (Newberry and others, 1987). For this reason, the uranium and rare-earth element potential of the Lime Peak-Mount Prindle area is thought to be low, in spite of a relatively high background content of uranium.

CONCLUSIONS

In summary, we estimate, at the 50 percent level for probability of occurrence, that the Lime Peak - Mt. Prindle area contains significant amounts of tin, silver, and gold. Approximately three-quarters of the metal value is in the potential for tin-silver deposits, and about one-quarter in gold deposits. A comparison of areas on that basis indicates that the major areas of mineral resource interest are the Lime Peak pluton, the Hope Creek area, and the Table Mountain - Pinnell Trail area. The estimates indicate that parts of the Lime Peak - Mt. Prindle area would probably make attractive exploration targets for such resources.

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