DIGITAL DATA BASE APPLICATION TO PORPHYRY COPPER MINERALIZATION IN ALASKA - CASE STUDY SUMMARY

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Open File Report 82-801

1982

U.S. Department of Interior
Geological Survey

EROS Data Center
Sioux Falls, South Dakota

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ILLUSTRATIONS

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ABSTRACT

The purpose of this report is to summarize the progress in use of digital image analysis techniques in developing a conceptual model for assessing porphyry copper mineral potential. The study area consists of approximately the southern one-half of the 1° by 3° Nabesna quadrangle in east-central Alaska. The digital geologic data base consists of data compiled under the Alaskan Mineral Resource Assessment Program (AMRAP) as well as digital elevation data and Landsat spectral reflectance data from the Multispectral Scanner System. The digital data base used to develop and implement a conceptual model for porphyry-type copper mineralization consisted of 16 original data types and 18 derived data sets formatted in a grid-cell (raster) structure and registered to a map base in the Universal Transverse Mercator (UTM) projection. Minimum curvature and inverse distance squared interpolation techniques were used to generate continuous surfaces from sets of irregularly spaced data points. Processing requirements included: (1) merging or overlaying of data sets, (2) display and color coding of maps

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and images, (3) univariate and multivariate statistical analyses, and (4) compound overlaying operations. Data sets were merged and processed to create stereoscopic displays of continuous surfaces. The ratio of several data sets were calculated to evaluate relative variations and to enhance the display of surface alteration (gossans). Factor analysis and principal components analysis techniques were used to determine complex relationships and correlations between data sets. The resultant model consists of 10 parameters that identify three areas most likely to contain porphyry copper mineralization; two of these areas are known occurrences of mineralization and the third is not well known. Field studies confirmed that the three areas identified by the model have significant copper potential.

INTRODUCTION

Assessing mineral resource potential in an area is a complex problem and requires analyses of a variety of data types including geographic, geological, geophysical, and geochemical data. Singer and Mosier (1981) reviewed numerous methods used for mineral resource assessment and found that the most widely used methods are subjective and rely upon the experience and insight of the investigator. Recently, digital image analysis and multivariate analysis techniques have been applied to mineral resource appraisal (Agterberg, 1981) to quantify and statistically process different types of geoscience data.

The purpose of this paper is to summarize the progress of the use of digital image analysis techniques in developing a conceptual model for assessing porphyry-type copper mineral potential. The digital geologic data base consists of existing data compiled under the Alaskan Mineral Resource Assessment Program (AMRAP) in the Nabesna quadrangle, Alaska.

The study area used for the data base development consists of approximately the southern one-half of the 1° x 3° Nabesna quadrangle in east-central Alaska (fig. 1). Smaller areas in the vicinity of Orange Hill, Bond Creek (fig. 2), Baultoff Creek, and Horsfeld Creek were selected for development and testing of conceptual models. The study area, bounded on the northeast by the Denali fault and on the southwest by the Wrangell Mountains, includes the Nutzotin Mountains. Topography is rugged and elevations in the area range from 1,000 to 3,000 meters above sea level. Access to the study area by ground transportation is difficult, and aircraft are needed to reach much of the area.

The Nabesna quadrangle was selected for study because copper mineralization is known to occur in the area and a large amount of data was readily available. An interactive digital image processing system at the Earth Resources Observation Systems (EROS) Data Center was used for development of the digital data base because its statistical and arithmetic processing and display capabilities are appropriate for evaluating results of various conceptual models.

The objectives of the Nabesna digital data base project included:

(1) to demonstrate the use of a comprehensive spatial data analysis method that would result in a model identifying exploration targets for porphyry rocks and copper mineralization,

(2) to investigate existing data sources and conventional techniques for geographic referencing of data points,

(3) to determine types of displays showing intermediate outputs of analysis tasks, and

(4) to produce reasonably accurate final output maps of the original data, derived information, and model results.

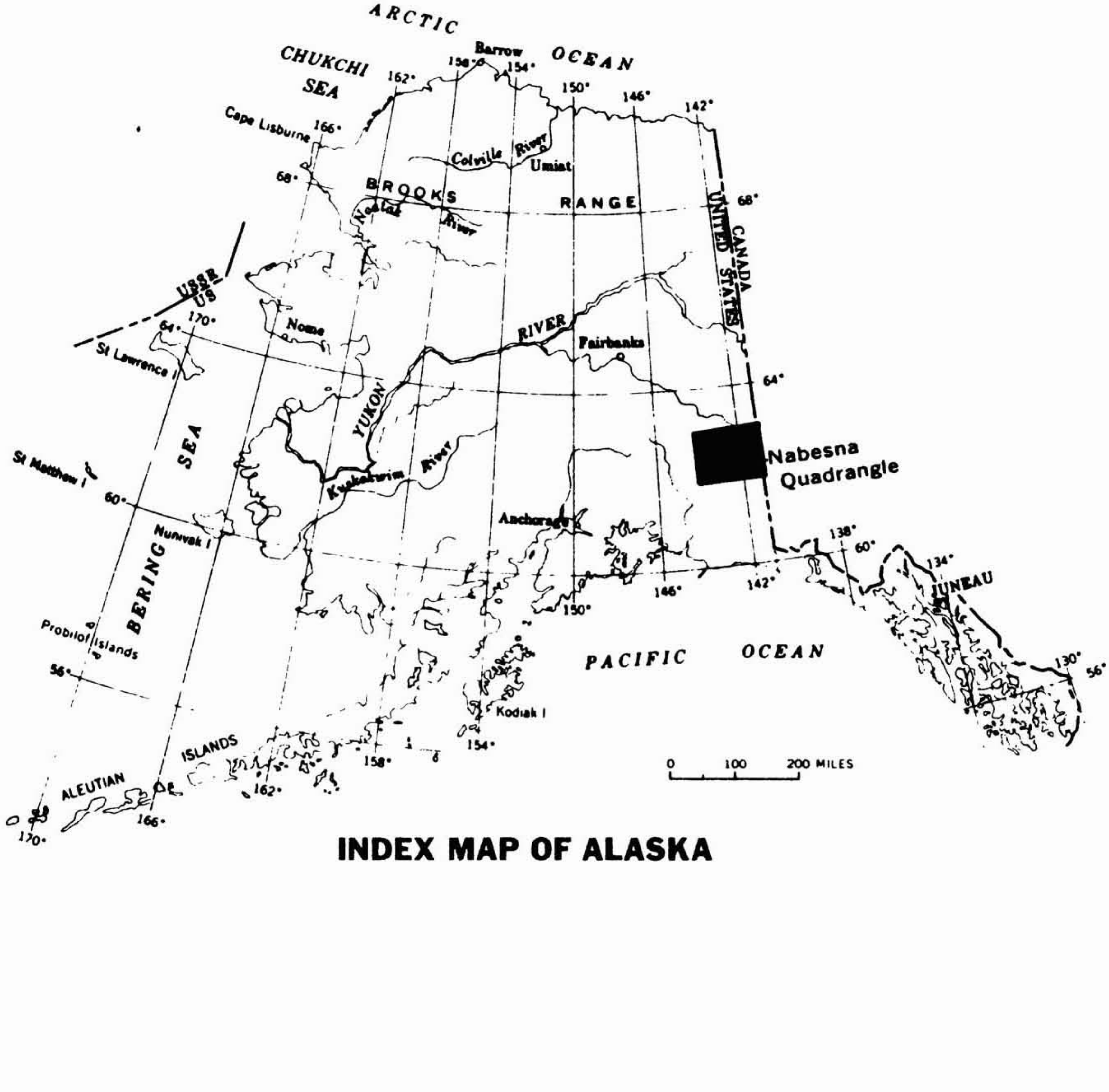


Figure 1.--Map showing location of Nabesna quadrangle, Alaska.

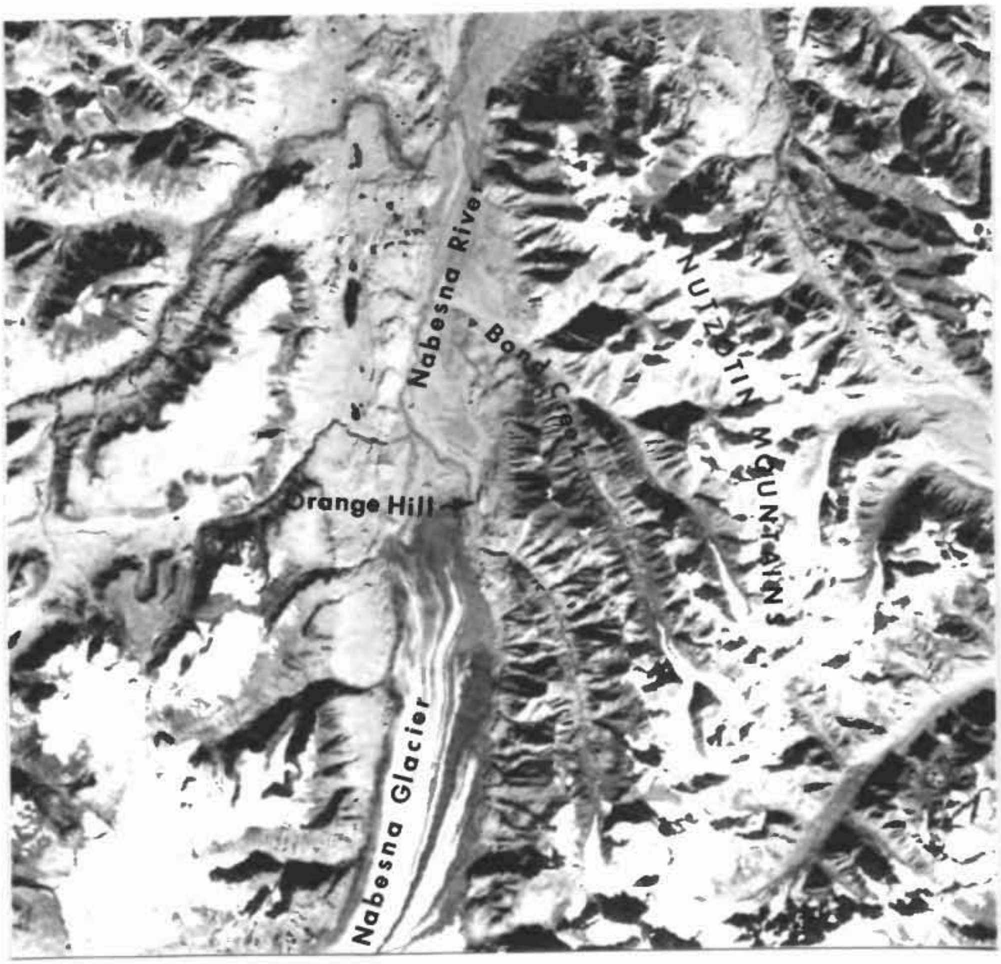


Figure 2.--A part of Landsat MSS Band 7 image (identification number 1422-20212, September 18, 1973) showing the detailed study areas in the vicinity of Orange Hill and Bond Creek, Nabesna Quadrangle, Alaska (original scale 1:250,000).

DATA BASE GENERATION

The digital data base used to develop and implement a conceptual model for porphyry-type copper mineralization consisted of 16 original data types and 18 derived data sets. Original data included:

- geophysical data (gravimetric and aeromagnetic).
- geochemical (stream sediment) concentrations of Cu, Ag, Au, Ni, Cr, Pb, Zn, Fe, Mn, and Mo.
- topographic data (elevations at regular gridded intervals).
- spectral reflectance data [four bands of Landsat multispectral scanner (MSS) data].
- geologic data (rock types, faults, and points of known mineral occurrences).
- administrative data (landownership and regulatory status).

Derived data sets included first and second derivatives and ratios of some of the original data.

The types of original data available and the analysis and output requirements influenced the design of the data base, and resulted in the selection of a raster data structure. The design dictated that the grid be registered to a map base and that cell size be large enough to allow rapid interaction and display, and yet small enough to allow maps to be generated at a scale that did not degrade the spatial resolution of the original data. It was determined that ground-equivalent cell sizes of 500 meters and 50 meters were appropriate for regional and site-specific analyses, respectively. Data entry involved the input of some data already in a digital format (topographic elevations, geochemical concentrations, and Landsat MSS data) and the digitizing of data existing only in map form (geophysical, geologic, and administrative). Topographic data were simply read in as a matrix of elevation values and geographic control points, and adjacent blocks of data were joined (mosaicked). Geochemical data were read as points, characterized by latitude and longitude locations and concentrations, in parts per million (ppm), for each of the 10 selected elements. Residual aeromagnetic values were only digitized where significant inflections (change in contour spacing) occurred along flight lines marked on the map (rather than digitizing the manually interpreted contours). A set of points locating the data highs and lows was digitized also, because the interpolation algorithm does not extrapolate beyond data minimums and maximums. All of the original data sets were registered to a map base in the Universal Transverse Mercator (UTM) projection.

A grid-cell (raster) format for the data base structure was adopted because it is efficient in performing data analyses and display functions. In this format the data are structured in a regularly spaced grid. Processing requirements included:

- merging or overlaying of data sets.
- display and color coding of maps and images.
- univariate and multivariate statistical analyses.
- compound overlay operations (modeling).

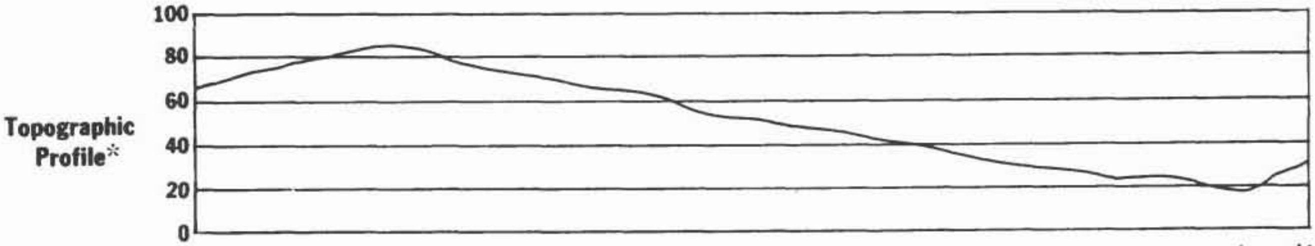
Several surface generation techniques were evaluated for interpolation of grid-cell values from a set of irregularly spaced data points. Minimum curvature interpolation was selected for generating continuous surfaces from the gravity and aeromagnetic data points because this technique is typically used. An inverse distance squared algorithm was selected for the geochemical data because (1) the inverse distance squared function honors the data points without filtering or smoothing, and (2) the inverse distance weighting function tends to control the zone of influence for individual data points.

DATA BASE PROCESSING

After the digital data base was generated and installed, data types were merged. For display purposes, the data were rescaled from their original range of values to fit the dynamic range (0-255) of the digital image display subsystem. Up to three different layers of the data base were combined and displayed simultaneously as a color composite on the color cathode-ray tube or displayed sequentially as black-and-white images by using a flickering technique. Discrete levels (such as high magnetic anomalies) were extracted from some data sets and displayed in combination with other data (such as geologic data or Landsat image). In this manner, anomalies in one data set were evaluated by reference to surface features and characteristics of other data sets. For example, the second derivative of gravity data was merged and displayed in combination with digital elevation data and geologic data to evaluate the effects of near-surface rock density variations and topographic relief. The flexibility in merging data sets that reside in the data base is limited only by the number of data base layers and the image display system capabilities.

Stereographic Landsat images were generated by introducing relief displacement proportional to the magnitude of other data set values (Batson and others, 1976), including residual aeromagnetic data, gravity data, geochemical data, and topographic data (fig. 3). Any continuous data set that is related spatially in x and y directions and varies in the z direction (vertical) can be processed to create stereoscopic views showing the morphology of the data set surface.

GENERATION OF ARTIFICIAL PARALLAX



* Units above are elevation values rescaled to an 8-bit range such that each unit equals 20 feet in elevation above an arbitrary datum.

Elevations of Landsat Pixels	71	74	78	81	84	81	78	74	71	67	64	57	55	52	47	44	41	38	36	32	28	25	25	21	20	25
Pixels in Original Image (Right)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Displacement	3 →	4 →	4 →	4 →	5 →	4 →	4 →	4 →	3 →	3 →	2 →	2 →	1 →	1 →	0	0	0	0	0	0	0 ←	1 ←	1 ←	2 ←	2 ←	1 ←
Pixels in Parallax Image (Left)				A	•	B	C	D	•	E_F	G	H_I	J_K	L_M	N_O	P	Q	R	S	T_U	V	W_X	Y	•	Z	

•Pixel Value Determined by Interpolation

E_F **Pixel Overlap, Right Pixel Replaces Left Pixel**

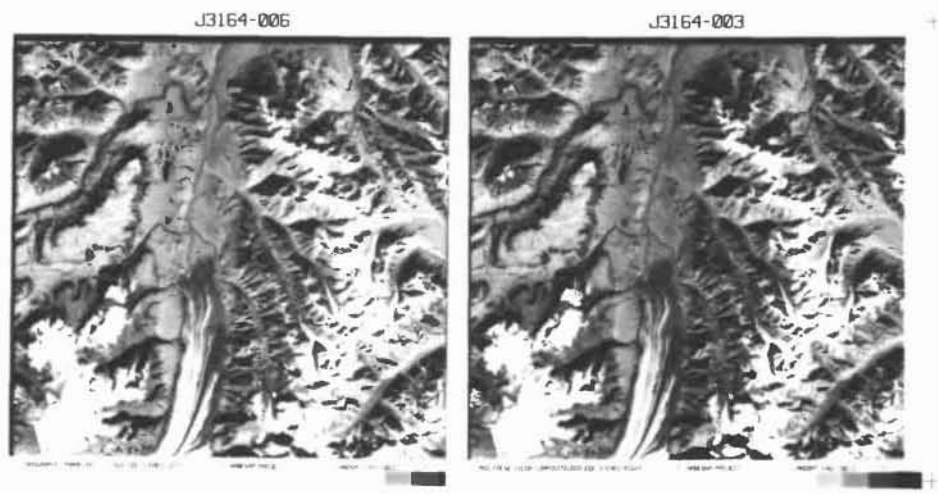


Figure 3.--The profile at the top shows elevations along a single line of data in the digital topography data set as illustrated in the matrix below the profile. Elevation values can be related to Landsat MSS pixels in the same spatial position. By applying stereographic generation equations, Landsat MSS pixels are shifted (displaced) to create relief displacement that is proportional to relief in the topographic profile. By generating a distorted image (left) and an undistorted image (right), a stereograph (bottom) can be made.

Several processing techniques were applied to the various data sets in an effort first to identify the relationships between variables by numerical correlation, and later to assist in developing quantitative weights for a mineral potential model. These methods included simple ratioing and more complex factor analysis.

Ratioing is an image processing operation whereby the values of one image are divided by the corresponding values of a second image. This yields an image (and a derived data set) in which values less than one indicate a positive difference, and values greater than one indicate a negative difference between the first data set and the second.

Special consideration is necessary to apply a ratioing algorithm to data sets that are measured in different physical units (for example, bouguer gravity, in milligals/residual magnetic intensity, in gammas). After ratioing, the original units of measure are irrelevant, and the results can only be interpreted in relative terms. The results of the ratio can be redistributed to a ramp cumulative distribution by an image processing function referred to as histogram equalization such that the value 128 is located at the mean of the resulting ratio data distribution with approximately equal number of cells in any part of the range 0 to 255. Alternatively, the range of the original data values can be linearly rescaled to 0 to 255 before ratioing, but this method does not assure optimal distribution of the data through the total range.

Factor analysis was used (1) to analyze complex relationships between the data sets and (2) to reduce the number of data sets by deriving a subset of factors which contain most of the variance information of the original data sets. Factor analysis equates information with variance, and therefore it was not useful for investigating the relative importance of the data sets.

A principal components analysis was applied to the geochemical data to generate a reduced number of data sets with separation between areas of high positive correlation and areas of inverse correlation.

RESULTS

Model parameters were quantified with arithmetic and statistical integration of the multivariate data sets. Bouguer gravity anomaly data, residual magnetic intensity data, the ratio of stream-sediment copper to chromium, and geochemical concentration of copper data were used to establish regional geologic environments favorable for porphyry copper occurrence. Topographic slope, solar incidence angle, and the ratio of Landsat MSS band 5 (0.6-0.7 μm) to MSS band 4 (0.5-0.6 μm) were used to isolate gossans (iron-rich surficial cover) by their characteristic red to yellow spectral reflectance. Known igneous intrusive bodies, distance to these intrusives, and distance to known mineral occurrences were used to quantify the likelihood of mineralization and to partially reinforce other model parameters. The resultant model has 10 parameters that identify three areas which are most likely to contain porphyry copper mineralization; two of these areas are known occurrences of mineralization (fig. 4). Field studies in August 1981 confirmed that the three areas identified by the model have significant copper potential.

CONCLUSIONS

The results of the study suggest several significant advantages of the digital data base and modeling approach: (1) intermediate products (such as stereoscopic images) that can be used to plan subsequent field data collection; (2) objective assessments of the mineral potential in an area; (3) regional appraisals of critical mineral resources that may not be practical by conventional methods; (4) quantification of the likelihood of

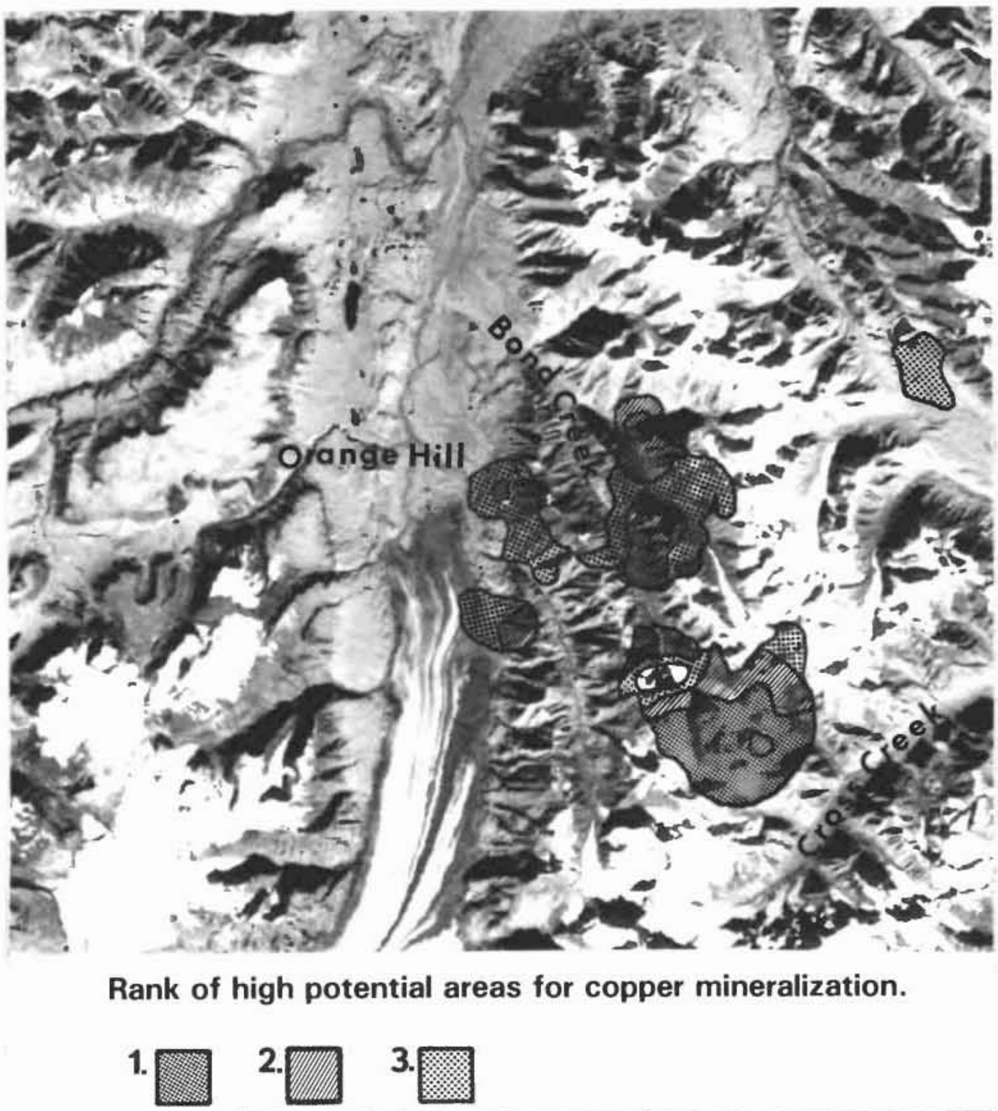


Figure 4.--Results of the porphyry copper model, superimposed on the Landsat subscene, indicate that the highest potential for copper mineralization occurs in the Cross Creek area. Copper mineralization in the Orange Hill and Bond Creek areas is known to occur and has been well documented. The potential for copper mineralization in the Cross Creek area was relatively unknown.

mineral occurrences; (5) results that are not limited by the expertise or the mathematical, statistical, and artistic skills of the scientist; and (6) a reduction in errors of omission and possibly a reduction in errors of commission.

The data base concept could be applied to a variety of mineral resources by incorporating other appropriate data sets (such as gamma-ray radiometric data for assessment of uranium potential) and using various models to objectively relate the data to the resource. The digital data base concept also should have significant applications for petroleum exploration.

Perhaps the greatest significance of the digital geologic data bases and modeling approach is the flexibility and relative ease with which the model can be revised and updated as new data sets are obtained or new concepts emerge. Also, obvious efficiencies can be gained in terms of data utilization, as well as consistency in results and spatial correlations from area to area.

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