Paper G 14

MINERAL EXPLORATION WITH ERTS IMAGERY

Stephen M. Nicolais, *Colorado School of Mines*

ABSTRACT

Ten potential target areas for metallic mineral exploration were selected on the basis of a photo-lineament interpretation of the ERTS image 1172-17141 in central Colorado. Of the ten target areas selected, five included the following mineral districts: the Breckenridge district, the Leadville-Climax-Alma area, and the Tomichi, Bonanza and Cripple Creek districts. An evaluation of bias indicated that prior geologic knowledge of the region had little, if any, effect on target selection. In addition, a contoured plot of the frequency of photo-lineament intersections was made to determine what relationships exist between the photo-lineaments and mineral districts. Comparison of this plot with a plot of the mineral districts indicates that areas with a high frequency of intersections commonly coincide with known mineral districts. The results of this experiment suggest that photo-lineaments are fractures or fracture-controlled features, and their distribution may be a guide to metallic mineral deposits in Colorado, and probably other areas as well.

INTRODUCTION

Mineral exploration is an often-cited potential application of orbital remote sensing data. However, before a new method, system or instrument is employed by industry, it must show potential use and economic feasibility. In this light, an experiment was designed to test the application of photo-lineament information obtained from ERTS imagery to the selection of potential target areas for mineral exploration. The objectives of the experiment were:

1) To select potential target areas based on the distribution of photo-lineaments and their intersections, as obtained from the ERTS image.

2) To evaluate the target areas.

3) To determine what relationships, if any, exist between the distribution of photo-lineament intersections and the location of mineral districts.

The test area was defined by a single ERTS image of central Colorado (Fig. 1), which includes a part of the Colorado Mineral Belt, and thus, several major mining districts. The northeast-trending mineral belt is characterized by intrusive porphyries of Late Cretaceous and early Tertiary age (1). Ore deposition, in most cases, was structurally controlled by faults and shear zones.

ANALYSIS AND RESULTS

Photointerpretation

Photointerpretation was performed on the 11 January 1973 image 1172-17141 (Fig. 2) using a Bausch & Lomb zoom stereoscope in both stereoscopic and monoscopic modes. The 9.5 x 9.5-inch positive transparencies of all four MSS bands were used; however, most of the data was obtained from band 7. This image was chosen over other images of the same scene because the topography is enhanced by the low-angle solar illumination (23° inclination) and snow cover in the mid-winter imagery. The first step of the experiment consisted of interpreting the ERTS image and plotting the photo-lineaments on an overlay (Fig. 3). Two types of elements were plotted: straight lineaments and curvilinear, or circular, features.

Target Area Selection

Potential reconnaissance target areas were selected on the basis of the lineament data obtained. Selections were made under the following assumptions:

1) We are looking for metallic mineral deposits

2) Mineralization is probably structurally related to faults and shear zones, which may, in turn, be spatially related to intrusive stocks, plugs and volcanic centers.

Target selection consisted of two steps. First, about 40 small, specific targets were chosen based on the numbers and kinds of photo-lineament intersections. Next, the 10 best target areas (Fig. 4) were selected from the first group. Each target area corresponds to a circular area on the ground about 14 km (9 mi) in diameter or approximately 165 sq km (64 sq mi). The 10 final target areas were broken down into three orders of priority (1, highest, etc.) based on the complexity, type and strength of the intersections and the presence or absence of curvilinear or circular features. Of these criteria, complex areas of intersections and intersections of photo-lineaments with curvilinear or circular features were felt to be the most important.

Target Area Evaluation

A map of Colorado mineral deposits (2) was used to evaluate the target areas. The location of the larger mineral districts and the selected target areas are shown in the overlay in Figure 5. Most of the annotated mineral districts have produced over $100,000 in metals; however the combined production of Climax, Leadville and Cripple Creek has been over $1,000,000,000 in precious and base metals. Other important mineral districts which have had production figures over $1,000,000 include Breckenridge, Kokomo, Alma, and Bonanza. Five of the 10 target areas coincide with the following mineral districts: Breckenridge, the Leadville-Climax-Alma area (covered by one target area), Tomichi, Bonanza, and Cripple Creek. These results were better than expected, so the influence of prior geologic knowledge of the test area on target selection was tested.

Bias in Target Selection

Copies of just the lineament interpretation were distributed to a test group of 15 Colorado School of Mines professors and graduate students. After being instructed on the basic assumptions made during the selection of the Phase I target areas (those chosen in the first part of the experiment), each member of the group was asked to select 10 circular, 14 kilometer-diameter target areas. Analysis of the test group's selections (Phase II target areas) showed a remarkably strong agreement for 8 target areas, 5 of which coincide with mineral districts; 4 of these 5 were also picked during Phase I of the experiment. The test group's successful targets (i.e. coincidence with a mineral district) are tabulated and compared with the successful Phase I targets in Figure 6. There is a fairly strong agreement among members of the test group for the target areas that outline the following mineral districts: the Leadville-Climax-Alma area, Tomichi, Monarch, Bonanza and Cripple Creek districts.

Statistical analysis was used to evaluate both the test group's results and the method of target selection used in the experiment. The probability of selecting one successful target area in ten tries by random process is .32; this value decreases to .01 for selecting five successful target areas. In addition, the probability of 5 people choosing the same successful target area by random process is a mere 1.4×10^{-7}. The analysis was performed by placing a square grid with the approximate dimensions of a target area (9-x9-mile squares) on the lineament interpretation and the mineral district overlays. The probabilities were calculated assuming that there are 12 chances for a target area to coincide with a mineral district and there are 70 possible choices (target areas-squares) which coincide with photo-lineaments occurring on the overlay.

Analysis of the test group's results indicate that bias had very little, if any, effect on the selection of the Phase I target areas, and suggests that some of the mineral districts are defined by photo-lineament information.

Photo-Lineaments and Mineral Districts

To determine what relationships exist between mineral districts and photo-linears, the frequency of photo-lineament intersections was plotted using a computer program originally designed to plot stereonet data in a form suitable for contouring. The contoured plot shows the density, or concentration, of all types of intersections on the photo-lineament overlay (Fig. 7).

The Cripple Creek district is well defined by a high density of lineament intersections, and the Kokomo, Climax-Alma, Goldbrick-Pitkin and Tomichi districts are moderately-well defined. The Leadville and Bonanza districts were not discriminated by this method. It should be noted that the Kokomo and Goldbrick-Pitkin districts do not coincide with the previously-selected Phase I target areas, but they are discriminated by a high density of photo-lineament intersections. It is also interesting to note that the 8 target areas that show good agreement among members of the test group, also coincide with areas having a high concentration of lineament intersections.

SUMMARY

A promising approach to the selection of mineral exploration targets using ERTS imagery has been demonstrated. This study reduced an original search area of 33,500 sq km (13,000 sq miles) to ten 165 sq km (64 sq mi) reconnaissance target areas that appear to have the structural relationships commonly associated with mineralization in this region. Major mineral districts exist in 5 of the 10 target areas selected. In addition, this experiment shows a definite correlation between some of the major mineral districts in this part of Colorado and areas having a high density of photo-lineament intersections as interpreted from ERTS imagery.

CONCLUSIONS

The results of this experiment suggest that photo-lineaments on ERTS imagery are fractures or fracture-controlled features and that their distribution may be a guide to metallic mineral deposits in Colorado, and probably other areas as well. Analysis of photo-lineament information contained on ERTS imagery can be a very valuable and inexpensive first step in any mineral exploration program, especially if it is used in conjunction with other sources of geologic information. Imagery acquired from space will

probably prove most useful in areas of the world in which less is known about the geology. Moreover, the favorable results of this study suggest that those target areas that do not correspond with known areas of mineralization may, in fact, be new targets for mineral exploration in Colorado.

ACKNOWLEDGMENTS

Support for this study was provided by the Colorado School of Mines/ERTS project, funded by NASA Contract NAS5-21778. Appreciation is extended to Daniel H. Knepper, Gary Raines and Drs. Donald Sawatzky and Milton Wiltse for their help and suggestions during this investigation.

REFERENCES

1. Ogden Tweto and P.K. Sims. Precambrian ancestry of the Colorado Mineral Belt. Geol. Soc. America Bull., v. 74, p. 991-1014. 1963.

2. J.W. Vanderwilt. Mineral Resources of Colorado, Plate 4. State of Colorado Mineral Resources Board, Denver, 547 p. 1947.

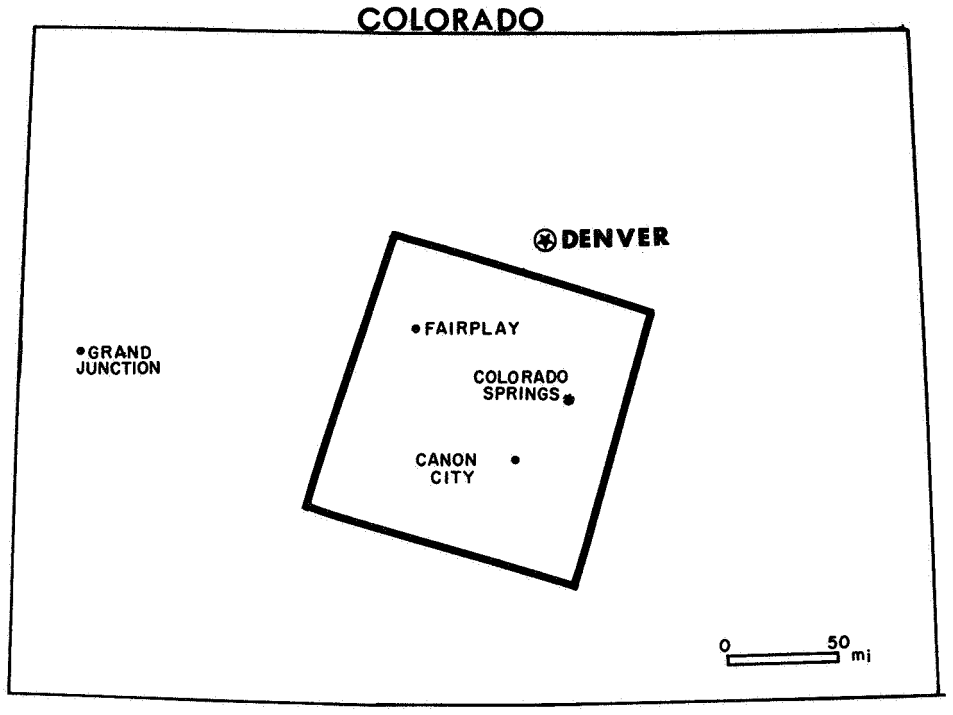

Figure 1. Colorado index map. Geographic location of the ERTS imagery used in this investigation.

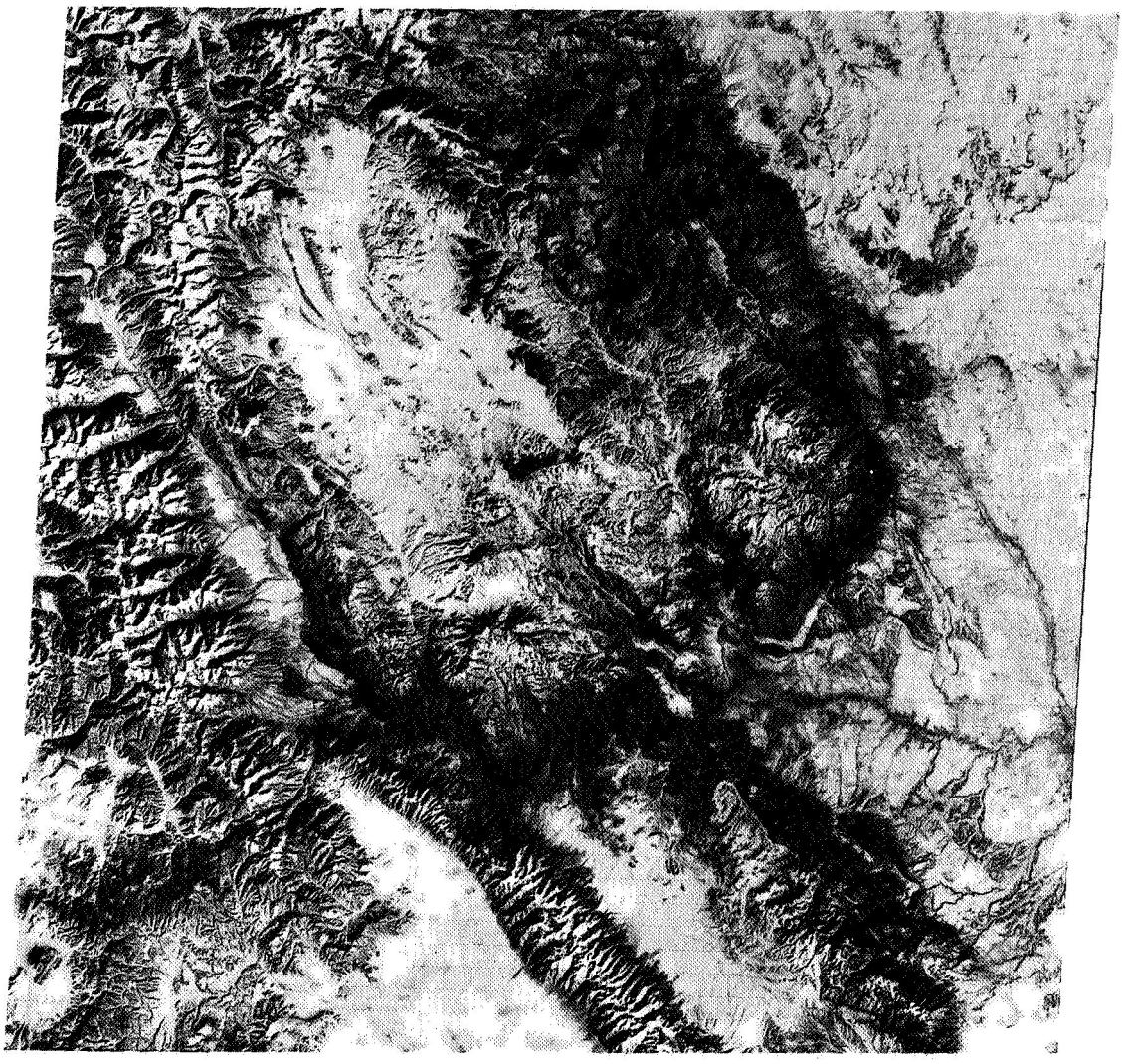

Figure 2. 11 January 1973 ERTS image 1172-17141-7.

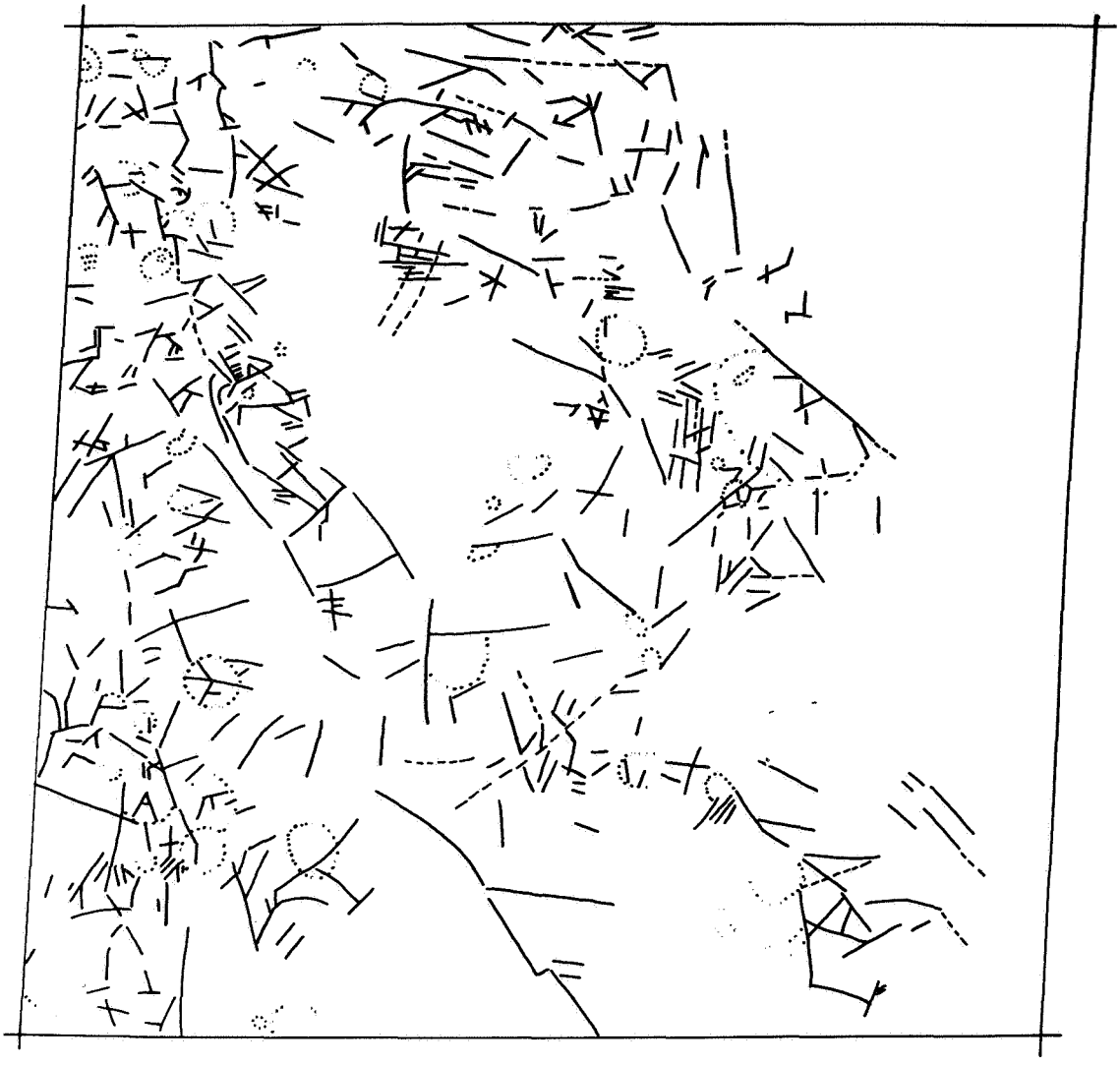

Figure 3. Photo-lineament overlay. Solid lines are well-defined linears; dashed lines are possible or moderately expressed linears; dotted lines are curvilinear or circular features.

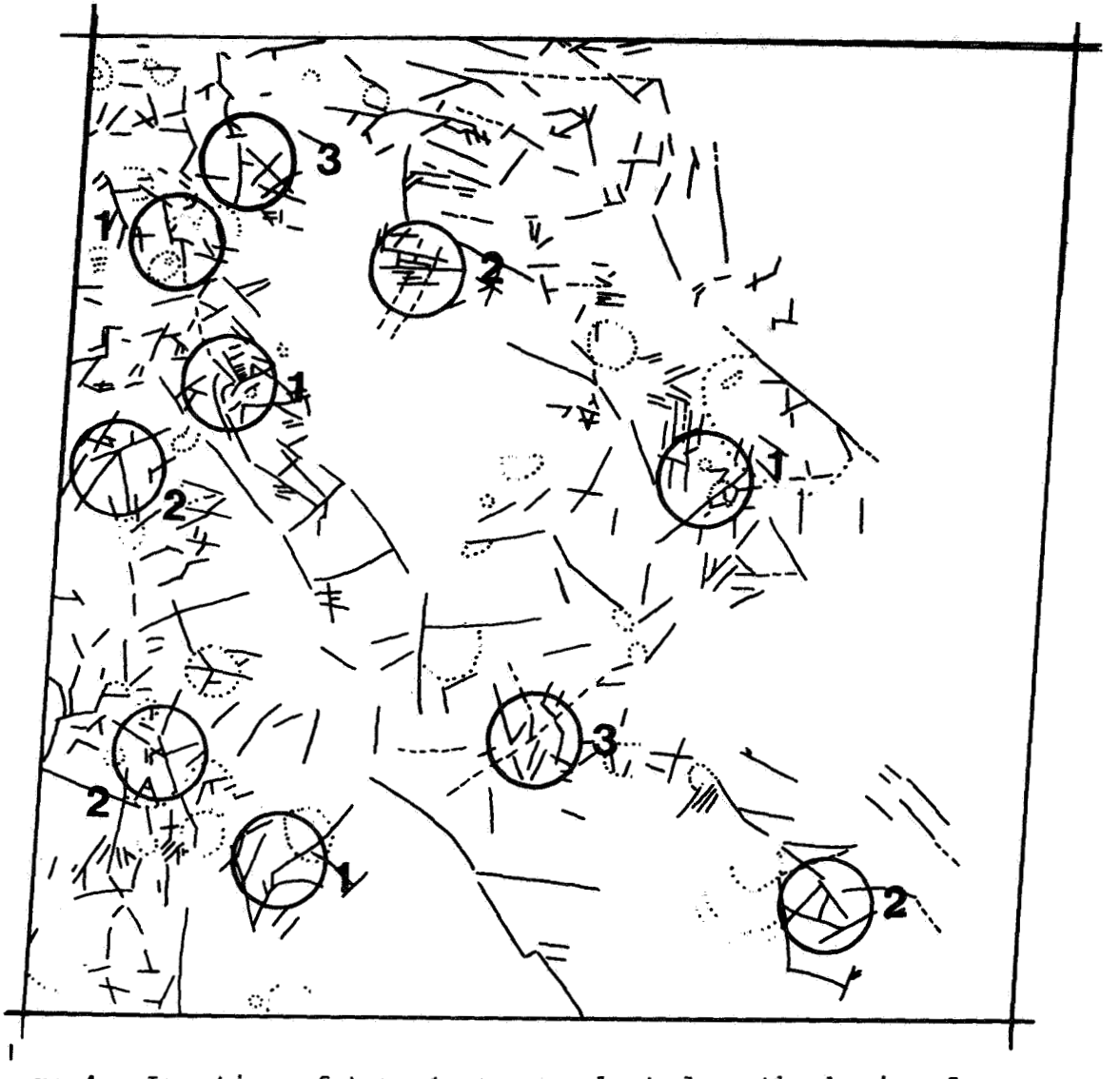

Figure 4. Location of target areas selected on the basis of photo-linears. The priorities (1, highest, etc.) are indicated by the number next to each target area.

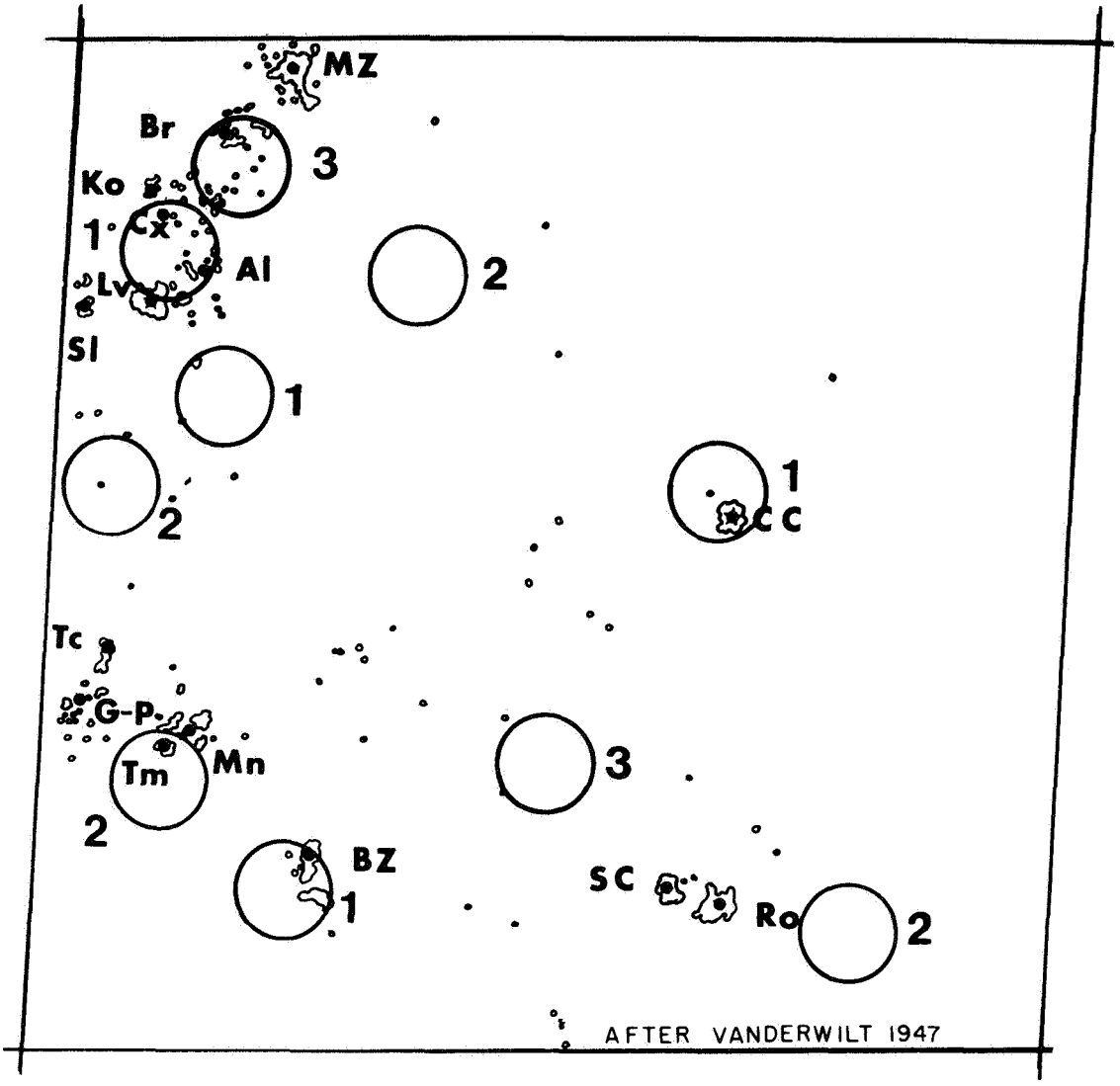

Figure 5. Location of major mineral districts and selected target areas. The small circles are isolated areas of mineral production, generally of low value. The larger mineral districts indicated by a black dot have irregular outlines and are annotated by an abbreviation: MZ-Montezuma, Br-Breckenridge, Ko-Kokomo, Cx-Climax, Al-Alma, Lv-Leadville, Sl-Sugarloaf, Tc-Tincup, G-P-Goldbrick-Pitkin, Tm-Tomichi, Mn-Monarch, BZ-Bonanza, CC-Cripple Creek, SC-Silver Cliff, Ro-Rosita.

TEST GROUP RESULTS

MINERAL DISTRICTS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	%
MONTEZUMA																	
BRECKENRIDGE												X				0	13
KOKOMO				X	X	X							X		X		31
CLIMAX	X			X	X	X	X	X		X	X		X	X	X	0	75
LEADVILLE	X		X	X	X	X	X	X	X	X	X			X		0	75
ALMA	X		X	X	X	X	X	X		X	X		X	X	X	0	81
SUGARLOAF																	
TINCUP									X								6
GOLDBRICK-PITKIN					X												6
TOMICHI			X		X	X		X			X	X		X	X	0	56
MONARCH	X	X			X	X	X			X				X			44
BONANZA	X					X	X	X		X				X		0	44
SILVER CLIFF																	
ROSITA																	
CRIPPLE CREEK			X	X		X	X	X	X	X		X	X	X	X	0	75

Figure 6. Test group's successful target areas. Each letter across the top corresponds to a member of the test group. Coincidence of a mineral district with a target area is indicated by the letter X. The letter O in column P represents the successful target area selections of Phase I. The last column indicates the percent agreement for successful target areas selected during Phase I and Phase II of the experiment.

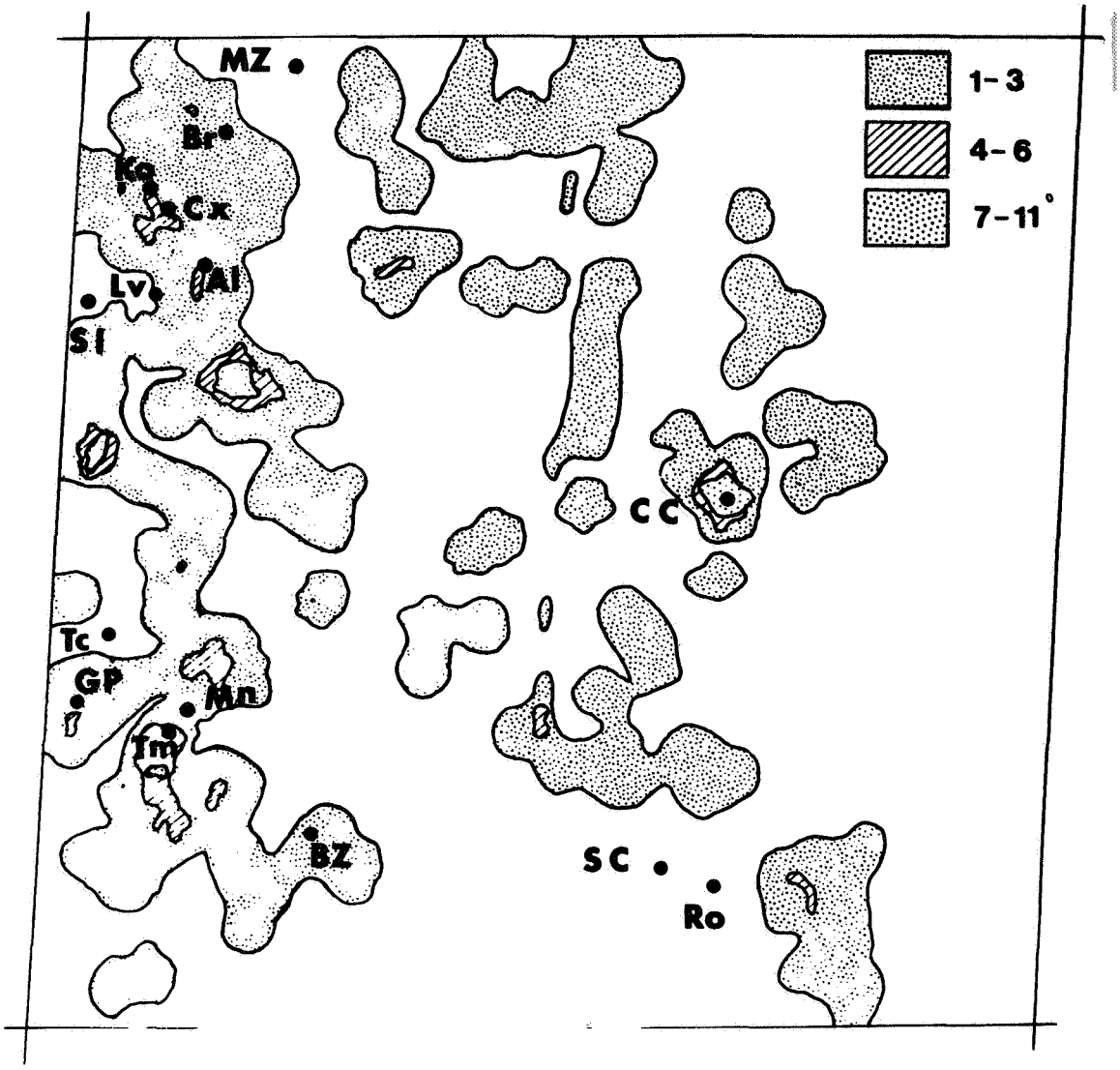

Figure 7. Density of photo-lineament intersections and the location of major mineral districts. The numbers in the legend represent the number of photo-lineament intersections per unit area.