DEPARTMENT OF THE INTERIOR

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Lineaments and Their Association with Metal Deposits, Ruby Mountains, Montana

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Introduction

This study analyzes lineaments mapped from satellite and radar images in relation to known metal deposits in the Ruby Mountain area, Montana. Lineaments are simple or composite linear features of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship, which differ distinctly from patterns of adjacent features and presumably reflect subsurface phenomena (O'Leary and others, 1976). These include faults, fractures, folds, scarps, material contrasts, and drainages. High concentrations of linear features have been closely linked to mineral deposits by Rowan and Wetlaufer (1981), Sawatzky and Raines (1981), and Turner and others (1982). The study area occupies almost 2100 km^2 in Madison and Beaverhead counties, Montana, and includes the proposed Ruby Mountain Wilderness which is being evaluated for mineral potential by the U.S. Geological Survey for the Bureau of Land Management. This report represents only one part of an assessment program which will include other geologic, geochemical, and geophysical investigations. In conjunction with these other studies, lineaments may help target areas with mineral potential.

Figure 1 shows the study area boundaries, the proposed wilderness, known metal deposits (keyed to Table 1), and hydrothermally altered areas (Segal and Rowan, in press). Talc deposits are common (Heinrich, 1960; Loen and Pearson, 1984) but were excluded from this report, which focuses on metals. Copper, manganese, and iron are the most common metals, although lead, nickel, chromium, and uranium are also present. Only the Amazon Mine (685 in Figure 1 and Table 1) and the Kelly Iron Mine (701 in Figure 1 and Table 1) have ever recorded production; both were inactive as of 1983 (Lawson, 1984).

General Geology

The Ruby Mountain area is dominated by Archean metamorphic rocks cut by northwest-trending faults up to 25 km long (Ruppel and others, 1983) (Figure 2). This terrain includes schist, biotite gneiss, quartzo-feldspathic gneiss, amphibolite, anthophyllite gneiss, calc-silicates, meta-pelites, and banded iron formations. The surrounding area is largely Tertiary valley fill (tuffaceous sandstone, siltstone, and conglomerate) and Quaternary alluvium, separated from the Archean rocks by major northeast-trending faults. North-trending faults are less distinct and are confined to the Tertiary rocks and Quaternary alluvium. Small areas of Tertiary volcanic rocks occur along the eastern edge of the metamorphic terrain.

Lineament Analysis

Lineaments can be conveniently mapped on a regional scale from satellite and airborne images. For the Ruby Mountains, two types of images were used: a Landsat-2 scene (I.D. 2229-17394) taken over Dillon, Montana, on September 8, 1975, and a proprietary synthetic aperture radar (SAR) image mosaic prepared by Aero Services from flights in December 1979. The Landsat image used was a color-infrared composite of channels 7, 5, and 4 contrast enhanced and printed as red, green, and blue, respectively. Lineaments were mapped from both types of images at a 1:250,000 scale covering the entire Dillon $1^{o} \times 2^{o}$ quadrangle as part of the U.S. Geological Survey's Conterminous U.S. Minerals Appraisal Program by Purdy and Rowan (in press). Landsat data is biased against detection of northwest trending lineaments and in favor of northeast trends, due to the southeastern solar illumination at the time of

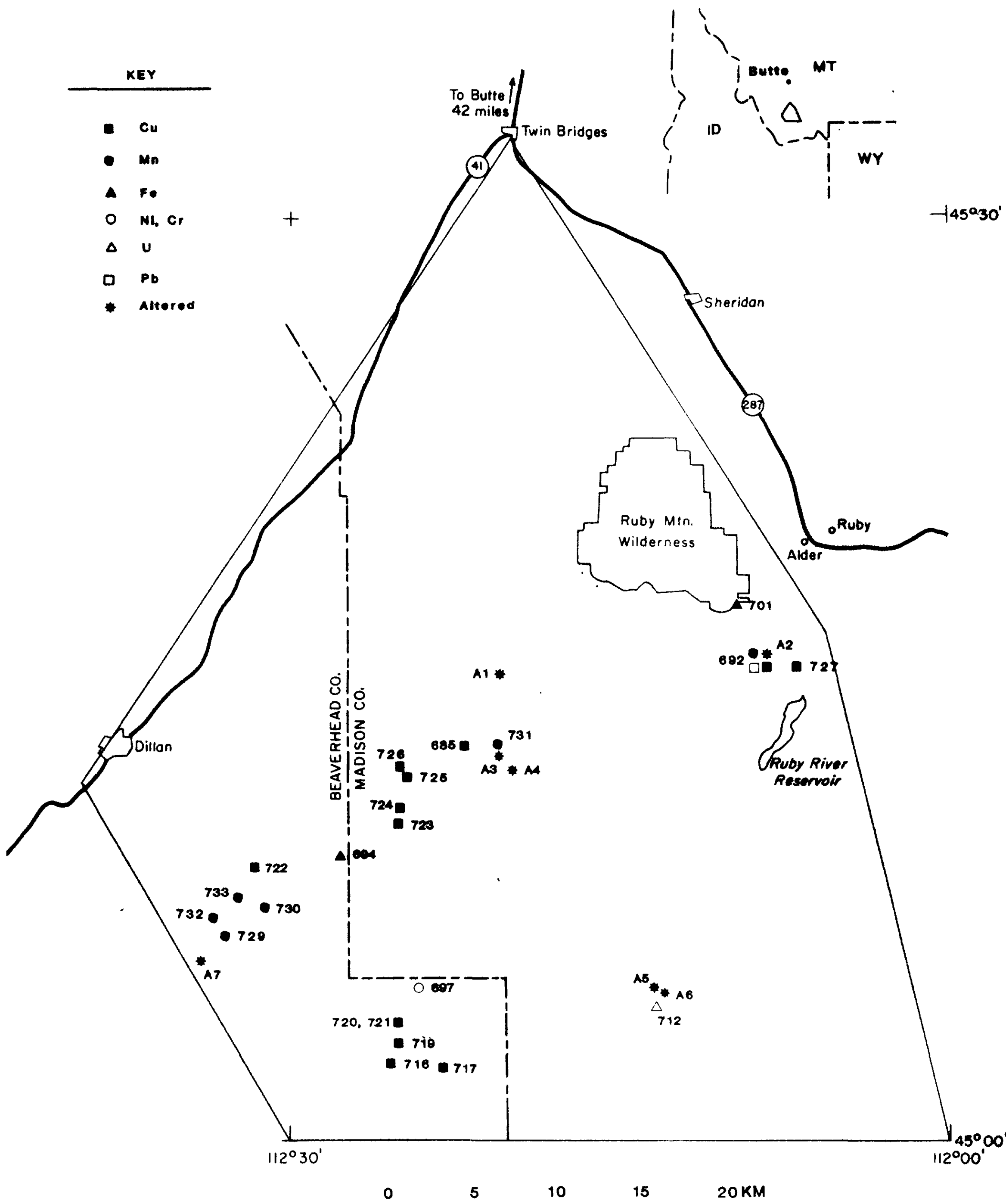

Figure 1. Boundaries of the Ruby Mountain area (large polygon), proposed Ruby Mountain Wilderness, known metal occurences, and altered areas.

Table 1. Metal deposits in the Ruby Mountain study area

Metal	Deposit #	Status	Formation	Occurrence
Cu	685	M	Aqf	Vein and replacement
	692	P	Am	Mn veins
	717	O	Aqf	Miscellaneous
	718	O	Aqf	Miscellaneous
	719	O	Aqf	Miscellaneous
	720	O	Aqf	Miscellaneous
	721	O	Aqf	Miscellaneous
	722	O	Aqf	Miscellaneous
	723	O	Aqf	Miscellaneous
	724	O	Aqf	Miscellaneous
	725	O	Aqf	Miscellaneous
	726	O	Aqf	Miscellaneous
	727	P	Aqf	Vein and replacement
Mn	692	P	Am	Mn veins
	729	O	Am	Mn veins
	730	O	Am	Mn veins
	731	O	Am	Mn veins
	732	P	Am	Mn veins
	733	O	Am	Mn veins
Fe	694	P	Ai	Bedded iron formation
	701	M	Ai	Bedded iron formation
Pb	692	P	Am	Mn veins
Ni, Cr	697	P	Apr	Miscellaneous
U	712	O	Tv	Unspecified

Modified from Loen and Pearson (1984). Status: M= mine with recorded production, P= prospect or mine, no production or production unknown, O= occurrence. Formation: Aqf= quartzo-feldspathic gneiss (Archean), Am= marble (Archean), Ai= iron formation (Archean), Apr= peridotite (Archean), Tv= volcanics (Tertiary).

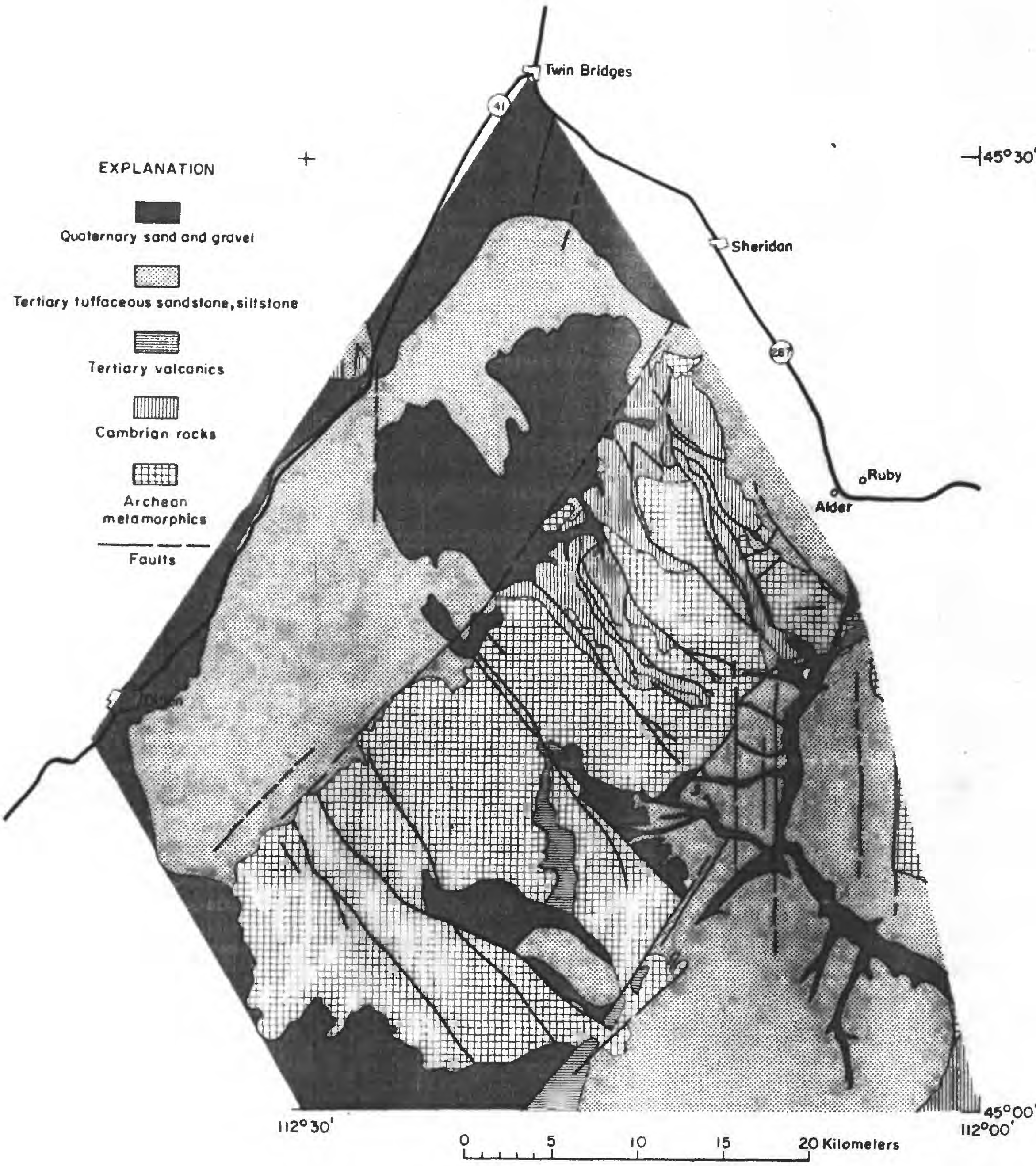

Figure 2. Generalized geology of the Ruby Mountain area (after Ruppel and others, 1983). Faulted Archean metamorphic rocks are surrounded by Tertiary and Quaternary sediments.

imaging. SAR data, although biased against east-west trending features due to its look direction, was included to help offset the directional bias in the Landsat data. Features that showed on both images were mapped only once.

Figure 3 shows the lineaments mapped by Purdy and Rowan (in press) that occur within the study area. Only a few lineaments correspond well to mapped faults (the northeast-trending lineament at latitude 45°, 22′N, longitude 112°, 29′W; the northwest-trending lineament at latitude 45°, 5′N, longitude 112°, 22′W). Four northeast-trending lineaments between 45°, 0′N, 112°, 30′W, and 45°, 30′N, 112°, 20′W parallel the major fault along the Tertiary-Archean boundary 13 km to the southeast. Known metal occurences and hydrothermally altered areas are also shown in Figure 3, some of which correspond closely to lineaments.

To test the hypothesis that lineaments of a particular trend may be associated with mineralization, the lineaments were digitized, and a statistical analysis was performed using the LINANL computer program developed by Sawatzky and Raines (1981). The first step is to identify statistically significant trends, by assuming that there is an equal probability for any trend to occur in a random situation. Following Raines (1978) and Sawatzky and Raines (1981), azimuth-frequency histograms for the lineaments were prepared using a 3.0 degree running average for smoothing (Figure 4). The non-length-weighted histogram depicts all 461 lineaments, each counted as one feature regardless of length. The length-weighted histogram counts each 0.5 km segment of a lineament as an observation, for a total population of 1433. The histograms show similar distributions, although length-weighting emphasizes several azimuths containing long lineaments. In each histogram, the mean frequency is the zero significance value, which is the number of lineaments expected in a random situation. In the non-length-weighted case the zero significance value is 7.7, for the length-weighted case it is 23.9. Deviations from these values represent non-random trends. As defined by Sawatzky and Raines (1981), "significant" trends are azimuthal intervals of frequency maxima bounded by minima (points below a -90% significance value). Accordingly, the three significant trends for the Ruby Mountain area are: NW (311°-332°), NNW (339°-343°), and NE (29°-64°). The lineaments in each of these intervals are plotted in Figures 5, 6, and 7, respectively, along with known metal deposits.

Visual inspection of these maps reveals that only 2 of 32 known deposits lie within 0.5 km of northwest-trending lineaments, and only 1 occurs near a north-northwest-trending lineament, but 17 are adjacent to northeast-trending lineaments. This association of northeast-trending lineaments to known metal deposits suggests a possible relationship between these lineaments and mineralization. Areas that contain a high concentration of northeast-trending lineaments could be good exploration targets. In order to depict these areas, a contour map was produced using an option in the LINANL software. To generate the contours, a 1.5 km by 1.5 km grid cell was used, based on a visual estimate of the average spacing between lineaments. A cell size of approximately half the average spacing was chosen, since larger grid cells masked detail and smaller grid cells isolated individual lineaments. A smoothing interval of 1.0 km was also applied.

The contour map of the northeast-trending lineaments is shown in Figure 8. The values on the contour plot are relative measures of concentration based on the number of lineaments intersected by each grid cell (Sawatzky and Raines, 1981). The range of concentration is 0-676, with contours drawn every 80 units. Note that almost all known occurrences plot within areas of high lineament concentration. The area enclosed by contour level 80 covers only

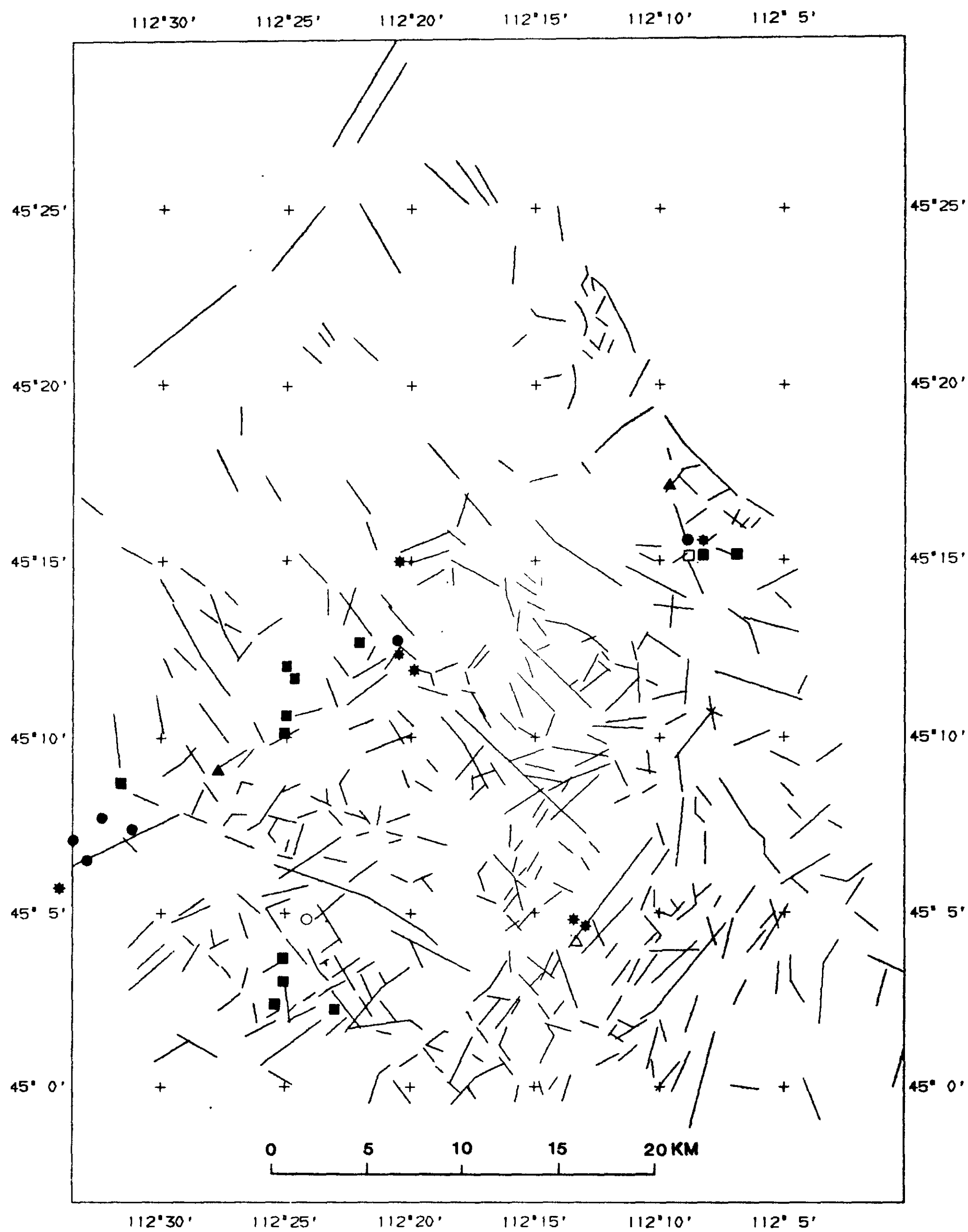

Figure 3. Lineaments mapped from Landsat and SAR images and the distribution of known metal occurrences (see Table 1).

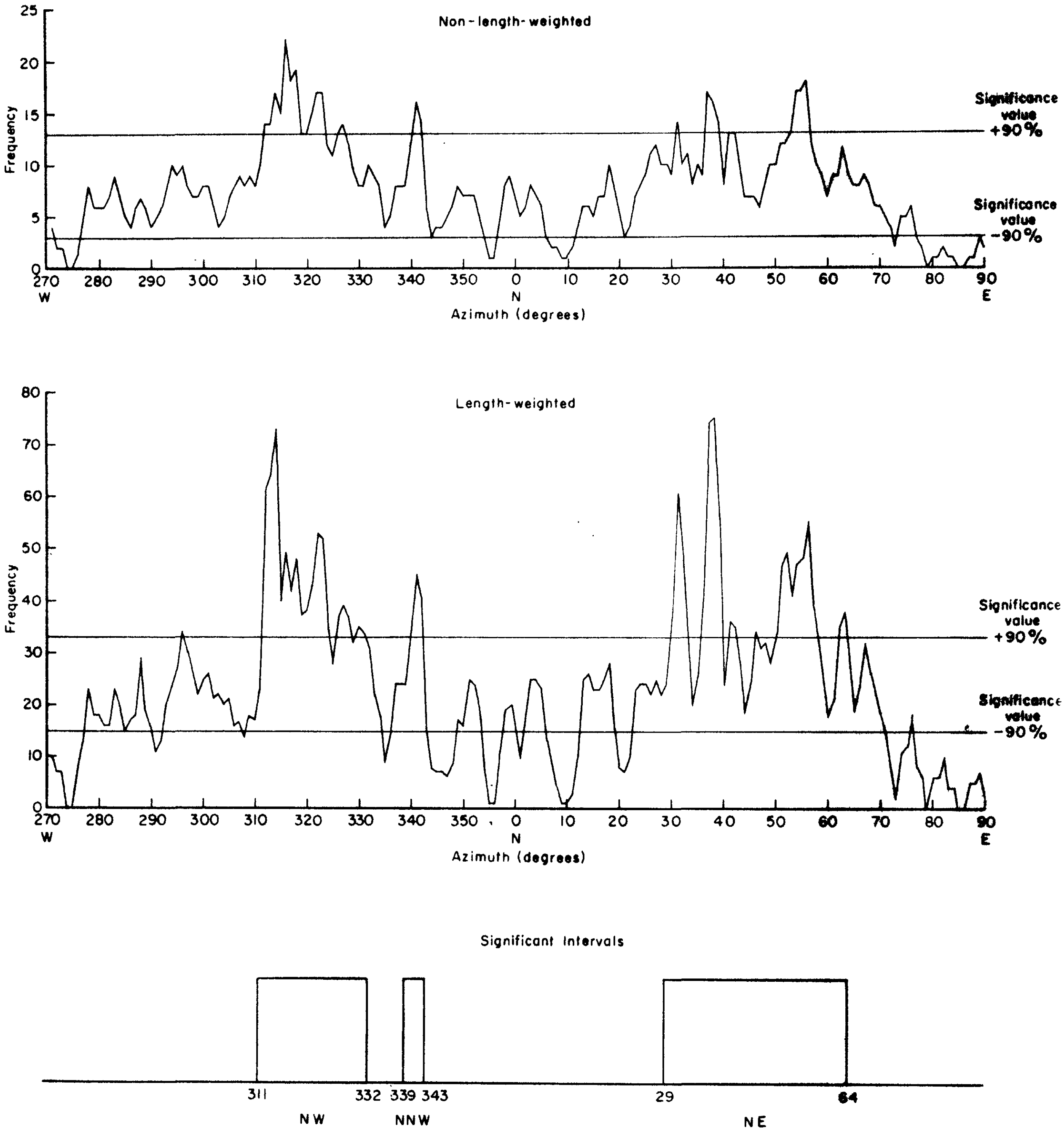

Figure 4. Azimuth-frequency histograms and statistically significant intervals of lineaments. Both histograms reveal similar trends, although length-weighting shows azimuths of several long linear features. Significant intervals determined according to Sawatzky and Raines (1981) (see text).

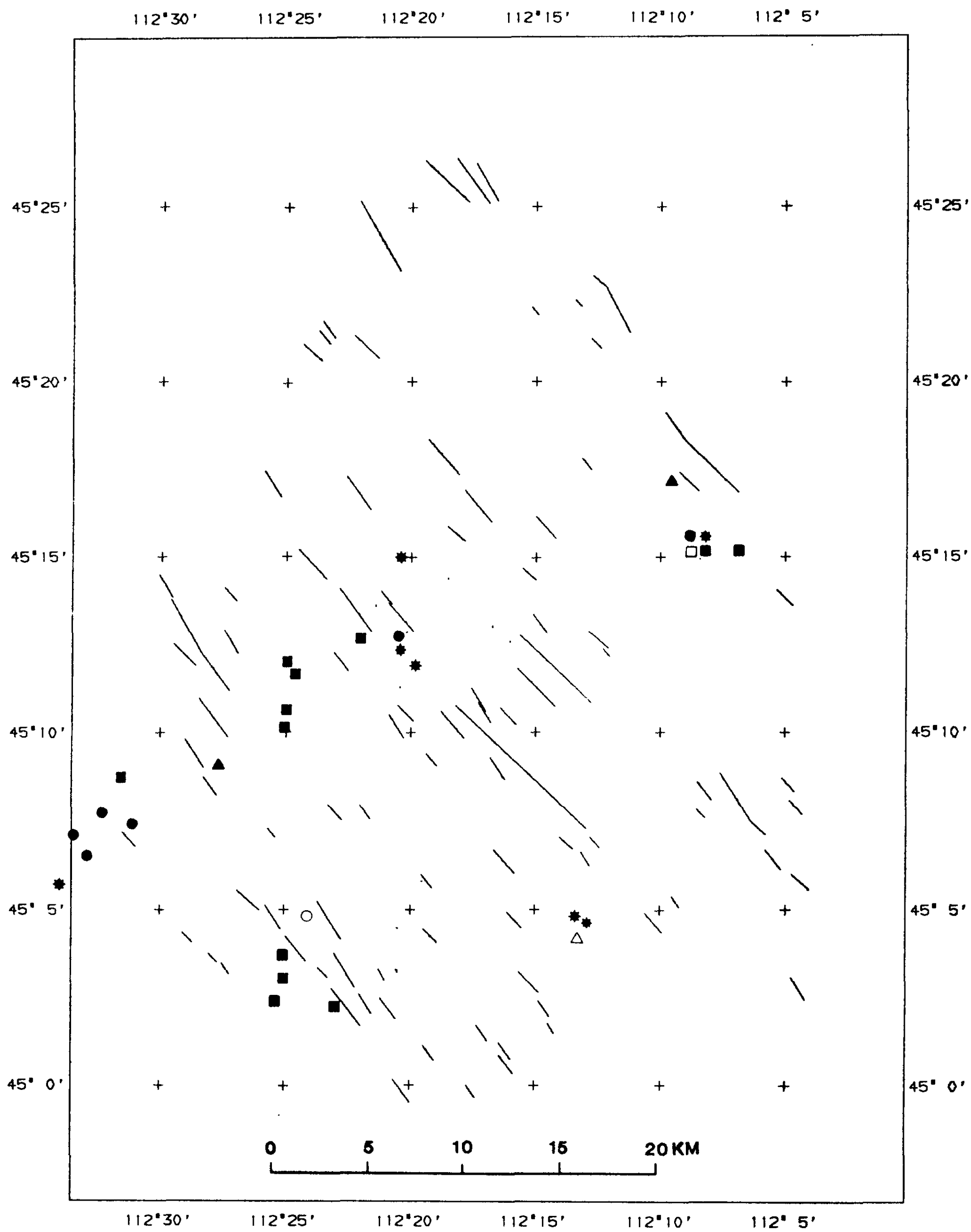

Figure 5. Statistically significant northwest-trending lineaments (311°-332°) and known deposits.

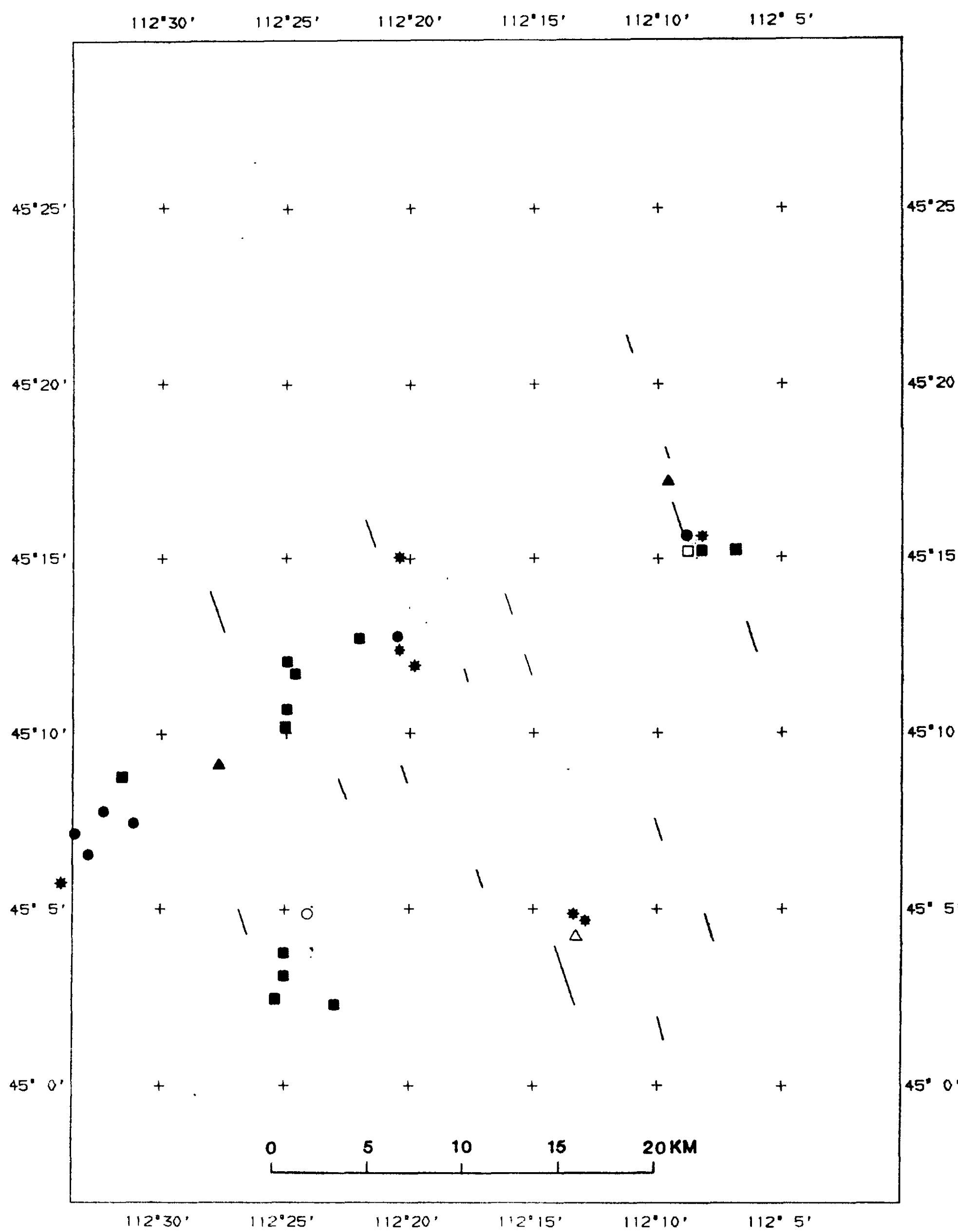

Figure 6. Statistically significant north-northwest-trending lineaments (339^{o}-343^{o}) and known deposits.

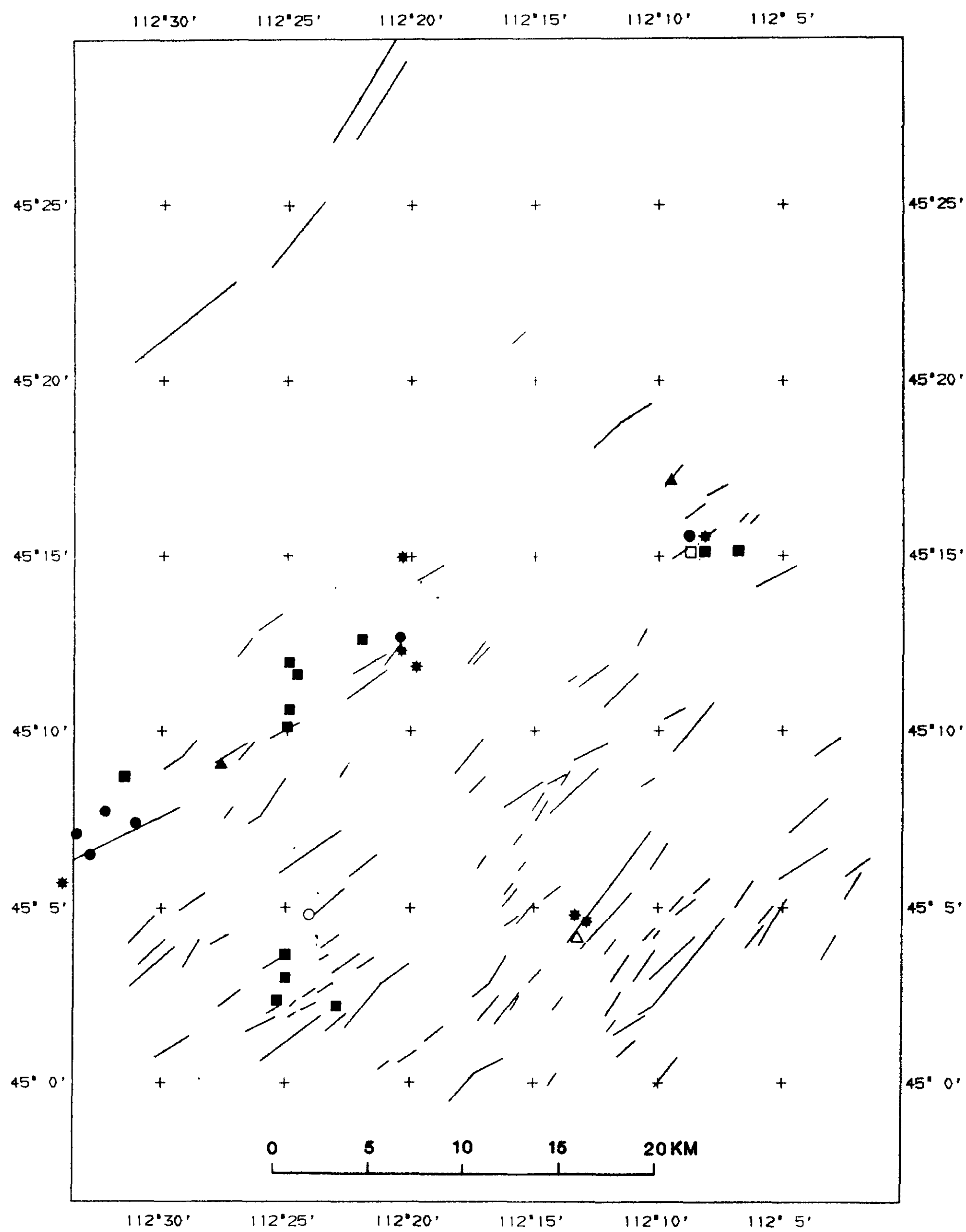

Figure 7. Statistically significant northeast-trending lineaments (29°-64°) and known deposits.

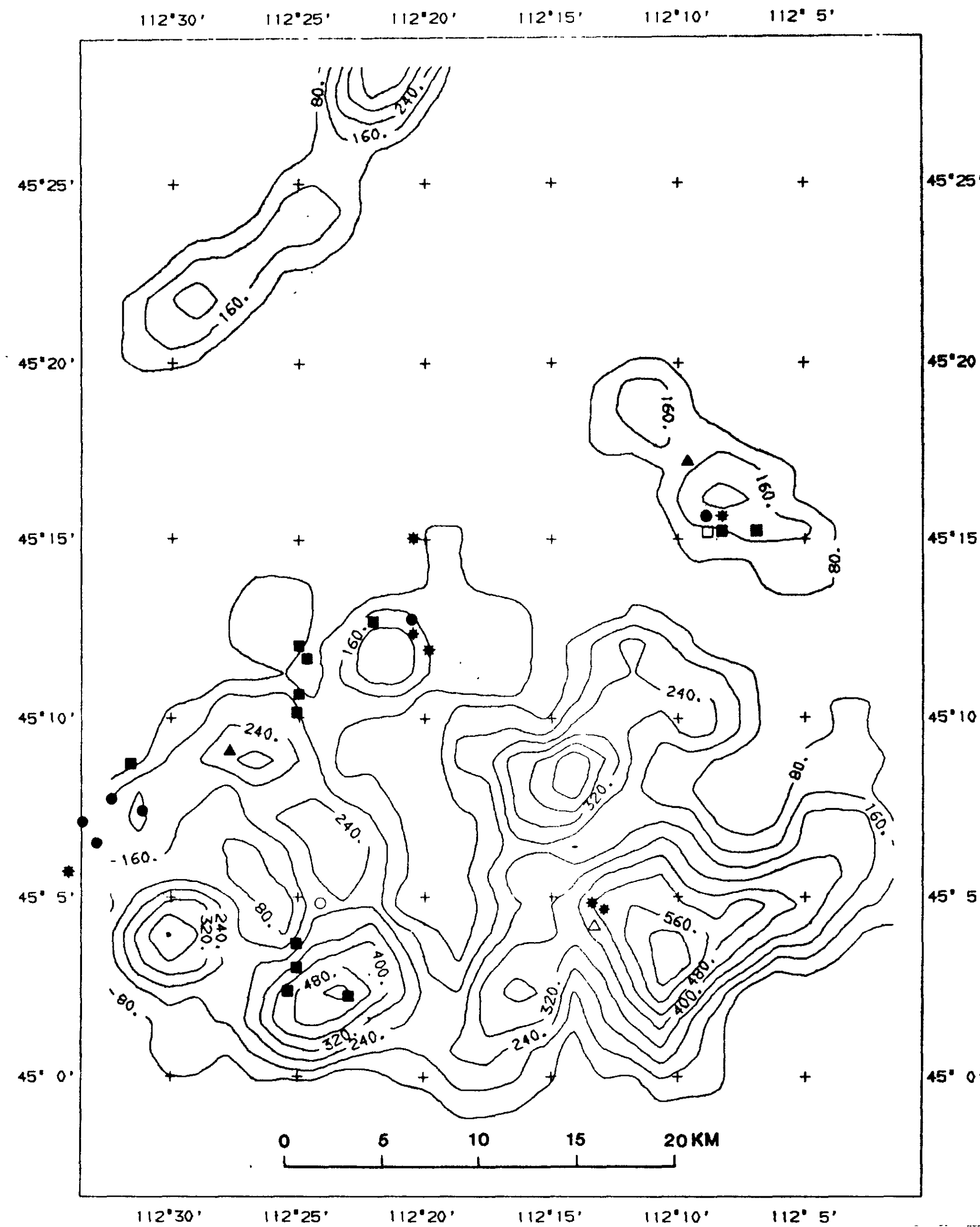

Figure 8. Contour map showing areal density of northeast-trending lineaments. The area within contour level 80 contains nearly all known occurrences, suggesting a relationship between northeast-trending lineaments and mineralization.

37% of the study area yet includes 96% of the metal deposits and 71% of the alteration (Table 2). These results suggest that the contour map of northeast-trending lineaments can be used to guide future exploration.

Table 1 shows that except for the uranium occurrence, all the metal deposits are within Archean rocks. A map of Archean rocks that also lie within contour level 80 is shown in Figure 9. These areas are exploration targets. Table 1 also shows that certain lithologies tend to host specific types of deposits. Note that 12 of the 13 Cu deposits occur within a quartzo-feldspathic gneiss (Aqf), all the Mn deposits occur within veins in a marble (Am), and both Fe deposits are in the bedded iron formation (Ai) (Loen and Pearson, 1984).

Conclusions

Within the Ruby Mountain study area, metallic mineral deposits are associated with high concentrations of northeast-trending lineaments. Presumably many of these lineaments are surface expressions of structural features that influenced mineralization. Consideration of lineament density and host rock can target areas for further investigation. Two of these areas lie in the southern part of the proposed Ruby Mountain Wilderness and should be evaluated for metal occurrences by other geologic, geochemical, and geophysical techniques.

Table 2. Known deposits in relation to high concentrations of northeast-trending lineaments

Deposit Type	Total # Known	# Lying Within Contour Level 80	%
Cu	13	12	92
Mn	6	6	100
Fe	2	2	100
Pb	1	1	100
Ni	1	1	100
Cr	1	1	100
U	1	1	100
All Metals	25	24	96
Alteration	7	5	71
All Deposits	32	29	91

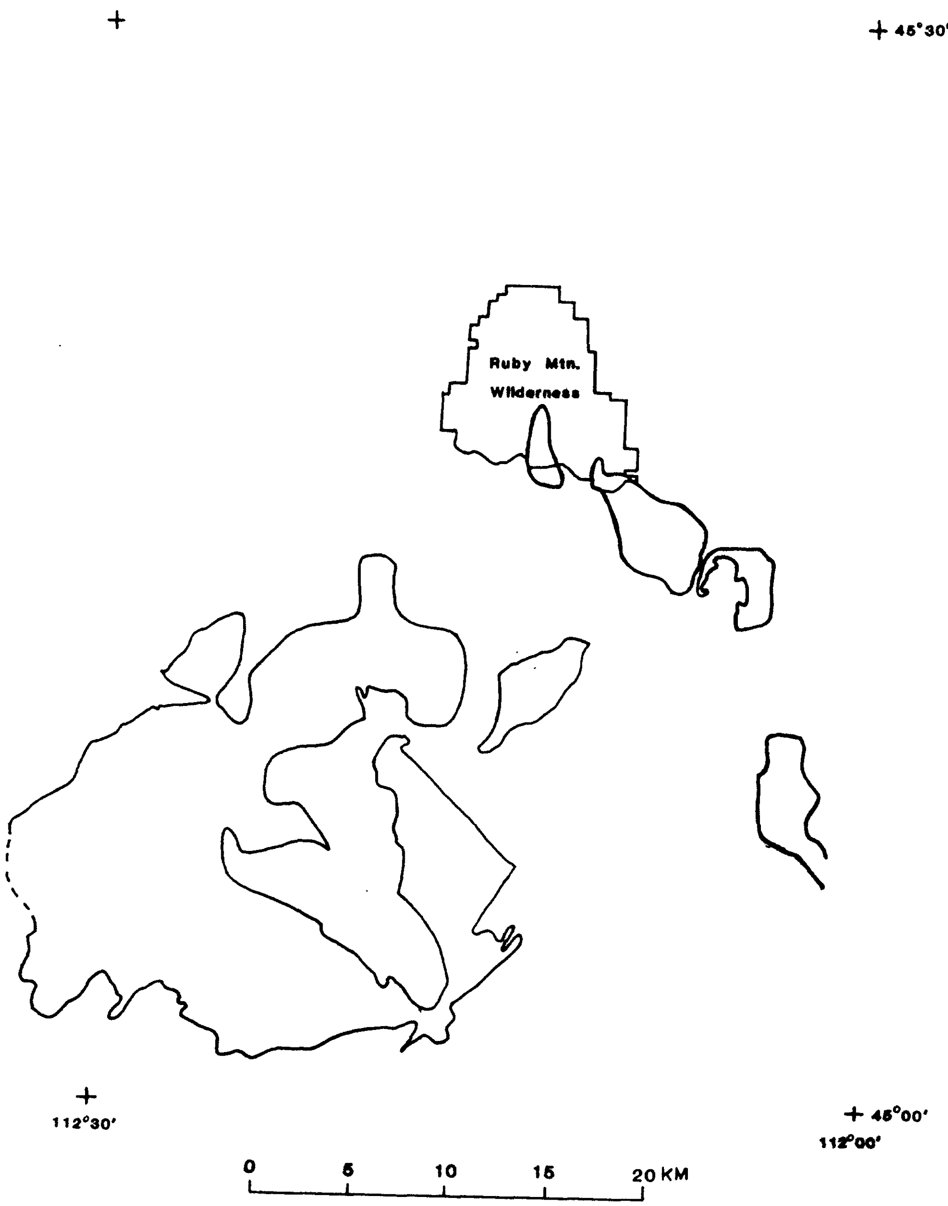

Figure 9. Areas lying within contour level 80 (from Figure 8) and in Archean terrain (from Figure 2). Analysis suggests that these areas have a higher potential for metallic mineral deposits than the remainder of the Ruby Mountain area.

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