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RELATION OF LINEAMENTS TO SULFIDE DEPOSITS: BALD EAGLE MOUNTAIN, CENTRE COUNTY, PENNSYLVANIA*

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M. Dennis Krohn and D. P. Gold

Office for Remote Sensing of Earth Resources, The Pennsylvania State University. Support for the work reported here was provided by NASA Contract NAS 5-23133 as part of the ERTS-1 Program.

The results of recent mineral exploration in central Pennsylvania suggest that the megascopic fracture pattern of the Appalachian Mountain system may have a controlling influence on the location of metallic sulfide occurrences. The Tyrone - Mount Union lineament (Gold, et al., 1973), a marked topographic linear feature over 160 kilometers long, is the locus of seven lead-zinc occurrences within three separate host lithologies, plus one copper occurrence and at least 3 known fault zones (Smith, et al., 1971; Rose, 1970). With the release of Landsat-1 (formerly ERTS-1) imagery for Pennsylvania in the autumn of 1972, many previously unknown lineaments were detected and offered potential new sites to search for lead-zinc mineralization. The objectives of this Landsat experiment was to attempt a ground verification for the newly-detected Landsat lineaments and to determine whether mineralized sites are significantly more numerous in the vicinity of lineaments than in areas characterized by the absence of lineaments.

Procedures

The test area encompasses a 60 kilometer section of Bald Eagle Mountain extending from two kilometers southwest of Tyrone, Pennsylvania (N40°39'/W78°15') to Lamb's Gap near Mount Eagle, Pennsylvania (N40°58'/W77°42'). The area includes one well-documented lead-zinc locality (Butts, 1939), plus four barite localities and several localities with anomalous heavy metal content which were discovered in an extensive geochemical survey of the stream network draining Bald Eagle Mountain (Hsu, 1973). Other advantages of the test site were that it was easily discernible on Landsat imagery and that it was one of the areas designated by ORSER for repetative underflight coverage by C130, U2, and RB57 aircraft.

A sampling and mapping traverse was made of the entire 60 kilometer length of the test area along the geologic contact of the Tuscarora Formation (an erosionally resistant white quartzose sandstone that is the principle ridge-forming lithology) and the Juniata Formation (a less erosionally resistant sequence of red siltstones and sandstones). In order to numerically estimate the mineralized population, integer counts of the sandstone float[1] were made at each sample locality along four cross-traverses,

[1]Float is defined as a general term for those rock fragments in the superficial cover material (soil) that are essentially in situ with respect to their original bedrock position (modified after Gray, et al., 1972, p. 266).

ABSTRACT

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RELATION OF LINEAMENTS TO SULFIDE DEPOSITS: BALD EAGLE MOUNTAIN, CENTRE COUNTY, PENNSYLVANIA
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The results of recent mineral exploration in central Pennsylvania suggest that the megascopic fracture pattern of the Appalachian Mountain system may have a controlling influence on the location of metallic sulfide occurrences. The Tyrone - Mount Union lineament, a marked topographic feature over 160 kilometers long, is the locus of seven lead-zinc occurrences within three separate host lithologies, plus one copper occurrence and at least three known fault zones.

The sixteen lineaments found to traverse a 60 kilometer length of Bald Eagle Mountain were plotted on a 25 x 30 centimeter enlargement of a Landsat-1 infrared image at a scale of 1:280,000. All lineament positions were verified on U2 and RB57 (aircraft) color infrared transparencies at a scale of 1:130,000 and 1:61,500, respectively. A 60 kilometer length of Bald Eagle Mountain was then traversed along the contact of the Tuscarora Formation (an erosionally resistant white sandstone) and the Juniata Formation (a less resistant sequence of siltstones and sandstones).

Discrete areas of finely-fractured and brecciated sandstone float along the crest of the mountain were found to be potential sites of sulfide mineralization, as evidenced by the presence of barite and limonite gossans. The negative binomial frequency distribution of the brecciated float supports the interpretation of a separate population of intensely fractured material. Such zones of concentrated brecciated float have an average width of one kilometer with a range from 0.4 to 1.6 kilometers and, where observed in outcrop, have subvertical dips. Direct spatial correlation of the Landsat-derived lineaments to the fractured areas on the ridge is low; however, the mineralized and fractured zones are commonly parallel to, but offset from, the lineament positions. This systematic dislocation might be a result of an inherent bias in the float population or might be the product of the relative erosional resistance of the silicified material in the mineralized areas.

60 meters long and 18 meters apart, perpendicular to the ridge axis. The presence and abundance of the following eight features that might indicate fracturing or mineralization were noted: sulfides (sphalerite, galena, and pyrite), barite, limonite gossans, druzy rocks, breccia, slickenslides, quartz-veins, and iron-staining. Sample localities were spaced at 0.4 kilometer intervals and ultimately came to a total of 148 for the entire test area.

Prior to the field work, lineaments were plotted on a 25 x 30 centimeter enlargment of the Landsat infrared (0.8-1.1 microns) image, 1045-15243-7 of 23 March 1973, at a scale of 1:280,000. Sixteen lineaments were found to pass through the test area (Figure 1) and all lineament positions were verified on U2 and RB57 color infrared transparencies at a scale of 1:130,000 and 1:61,500, respectively.

Results

Seventeen mineralized localities are found in this section of Bald Eagle Mountain; three localities have sphalerite and/or galena, seven localities have barite, and 12 localities have limonite gossans. Most of the barite is found near stream gaps on slickenslided fracture surfaces or as fracture fillings; whereas, the limonite gossans are usually found in a brecciated quartzite matrix near the crest of the ridge. Crushed rock geochemical analyses of the limonite gossans show that all but one of the gossans contain anomalous concentrations of trace elements, notably lead, zinc, and arsenic; one gossan sample contained 0.62% lead. The limonite gossan fragments frequently are found surrounded by a zone of brecciated or fractured float. Other such zones of brecciation are apparent along the ridge and have an average width of 1 kilometer with a range from 0.4 to 1.6 kilometers.

Continuous exposures in a 1.6 kilometer long silica brick quarry near Port Matilda, Pennsylvania, offer an opportunity to observe the subsurface nature of the zones of brecciated float. Five fracture zones -- thin ribbon-like structures of iron-stained, finely-fractured material, 0.15 to 1.0 meters in width -- are observed to vertically transgress bedding throughout the entire 20 meter quarry face. These five fracture zones in outcrop could all be linked to areas of brecciated float at the lip of the quarry face supporting the concept that the areas of brecciated float represent fracture-zones with subvertical dips.

The breccia data from the length of the test area were compiled into a frequency histogram to further test whether discrete populations of fracturing do exist on a scale comparable to the Landsat imagery (Figure 2). The observed discrete distribution was compared to three calculated distributions, the positive binomial, the Poisson, and the negative binomial distribution, using a chi-square goodness-of-fit test (Griffiths, 1967). Only the negative binomial distribution (Figure 3) was not significantly different from the observed frequency distribution, yielding a chi-square value of 18.755 with 18 degrees of freedom. A negative binomial result is

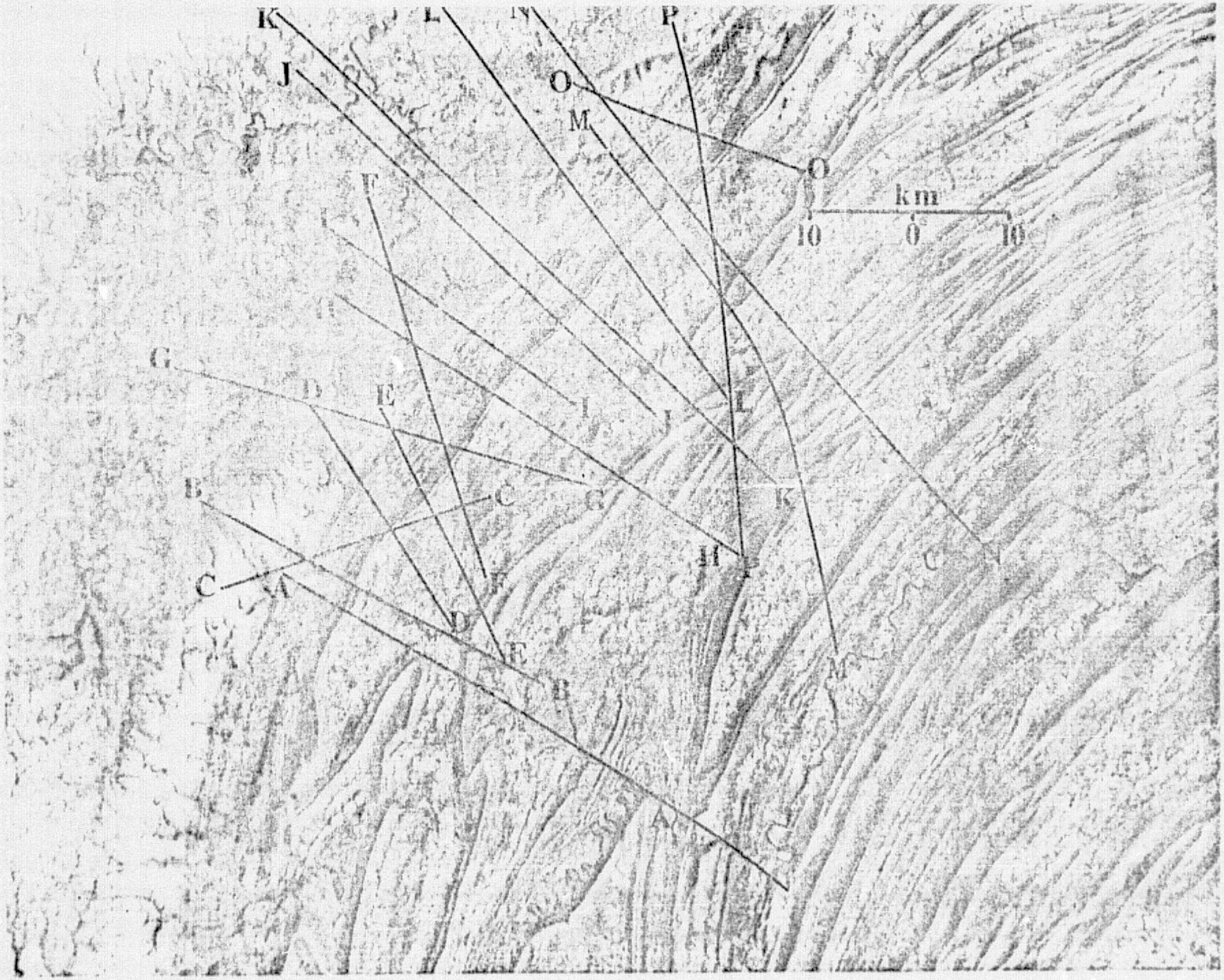

Figure 1: Enlargement of Landsat-1 image 1243-15253 of 23 March 1973 showing 16 lineaments found within the test area of Bald Eagle Mountain. Lineament B is the Tyrone-Mount Union Lineament; the silica brick quarry at Port Matilda lies between lineaments H and I.

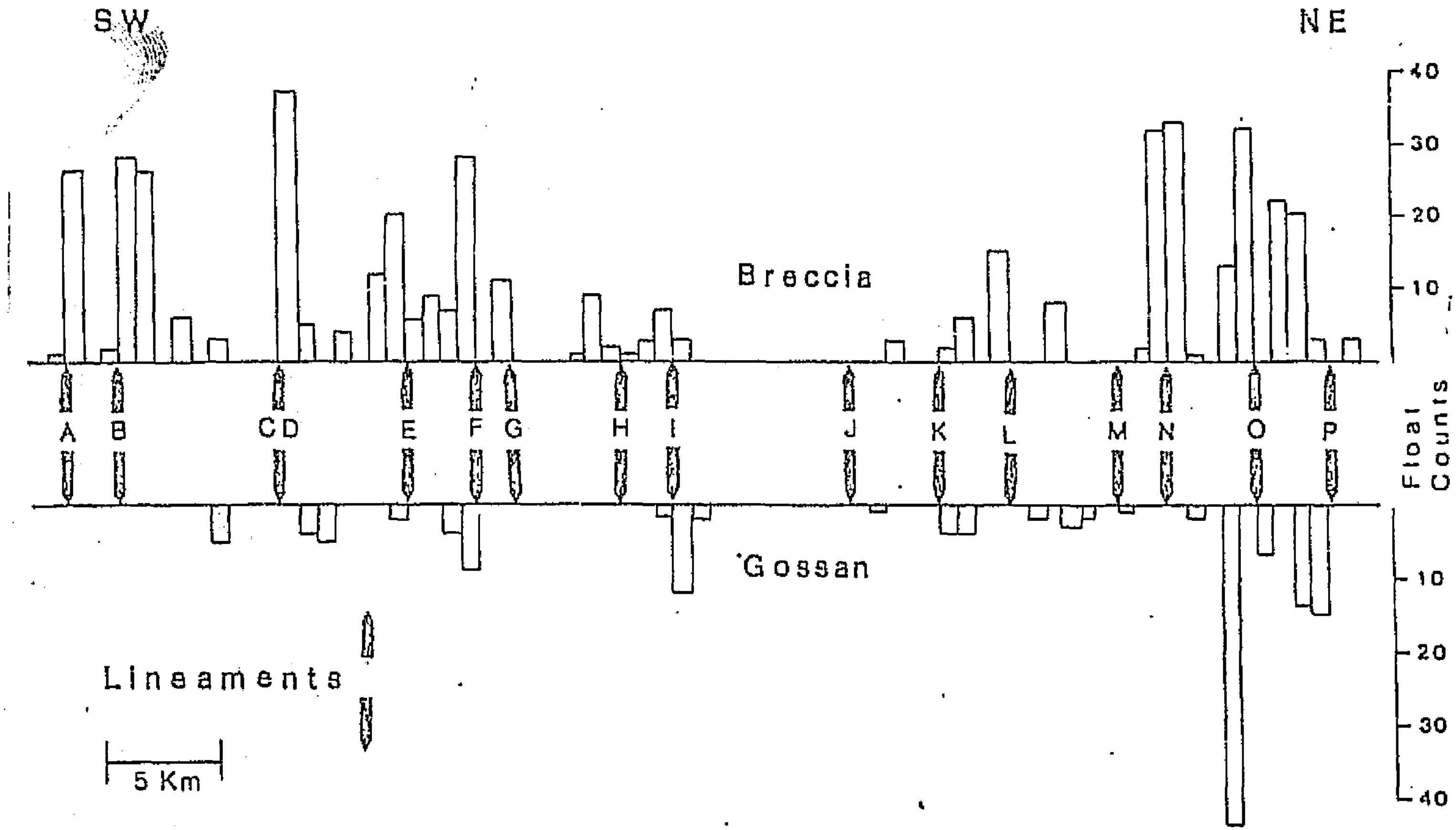

Figure 2: Histogram showing spatial relations of breccia and gossan float to the position of lineaments defined from Landsat imagery. Each bar represents the sum of two sample localities and is equivalent to 0.8 km along the ridge crest. Lineament C-D represents the intersection of two lineaments at the ridge crest.

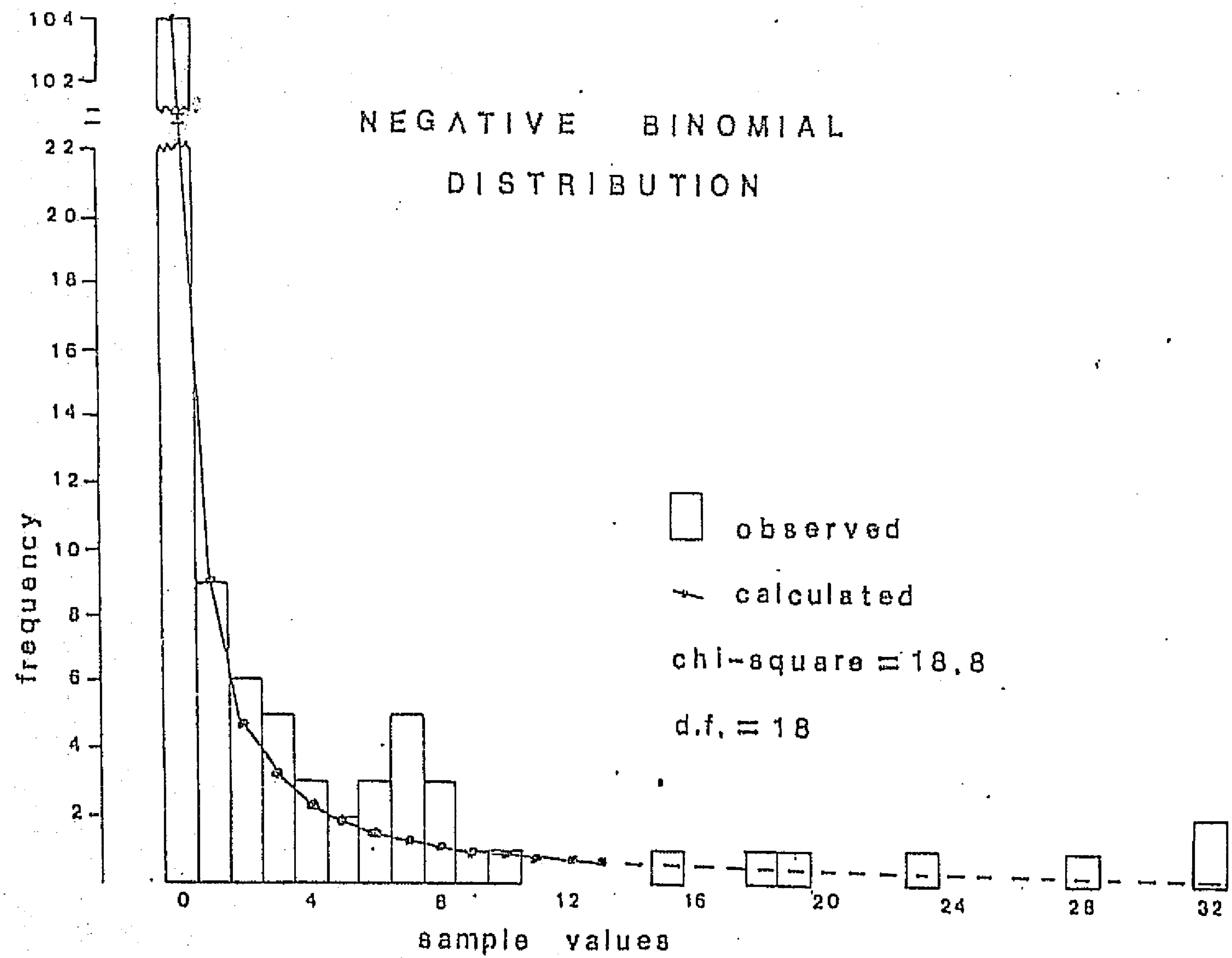

Figure 5: Frequency histogram comparing the observed distribution of integer sample counts for the breccia float to the expected distribution of the negative binomial. Note the break in scale along the ordinate. (d.f. = degrees of freedom.)

interpreted to signify that the trials are not independent, so that the presence of one event increases the chances that another event will occur, or that the probability does not remain constant from trial to trial (Griffiths, 1967). Hence the negative binomial supports the concept of discrete zones of intensified fracturing which are a separate population from the minor amounts of fracturing associated with the bulk of the ridge.

Lineament Correlations

Only four of the 17 fractured and mineralized float zones were symmetrically aligned with the lineament positions derived from the Landsat imagery. Inspection of Figure 2 indicates that many lineaments are marginal to the mineralized localities. To test whether the lineaments of Bald Eagle Mountain might be systematically offset from the mineralized zones, a 2 x 2 contigency table was constructed for three different lineament configurations (Siegal, 1956). The correlation index improved if lineaments were defined assymetrically to one side of their original Landsat-defined location.

Sampling bias is a possible explanation for this apparent systematic offset of the mineralized zones of the lineaments. Taking samples of float places an inherent bias on the data from the stream gaps because mass wasting has altered the float population in comparison to the other portions of the ridge. The common alignment of lineaments with stream gaps would lead to correlation with float minima, resulting in a net lower correlation.

Relative erosional resistance of the mineralized areas is a second possibility for the offset. The silicified material in a mineralized area would tend to remain topographically higher than the nonminerialized rocks, especially in fractured areas. This process should result in a resistant mineralized zone symmetrically bounded by a pair of lineaments. Lineaments A & B, J & K, and M & N, might be lineament pairs exemplifying such a process.

Conclusions

Discrete areas of finely-fractured and brecciated sandstone float are present along the crest of Bald Eagle Mountain and are commonly sites of sulfide mineralization, as evidenced by the presence of barite and limonite gossans. The frequency distributions of the brecciated float as the negative binomial distribution supports the interpretation of a separate population of intensely fractured material. Such zones of concentrated breccia float have an average width of one kilometer with a range from 0.4 to 1.6 kilometers and were observed in a quarry face to have subvertical dips. Direct spatial correlation of the Landsat-derived lineaments to the fractured areas on the ridge is low; however, the mineralized and fracture zones are commonly assymmetrical to the lineament positions. Such a systematic dislocation might result from an inherent bias in the float population or could be the product of the relative erosional resistance of the silicified material in the mineralized areas in relation to the erosionally weak material at the stream gaps. Hence lineaments, like other physical phenomena associated with basement rocks (e.g., magnetic intensity), need not always have a precise spatial correlative at the earth surface. Because of the subsequent erosional history, it might be necessary to interpret lineaments as broad, ill-defined features.

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