The analysis of angular atypicality of lineaments as an aid to mineral exploration

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SYNOPSIS

In an exploration project, data pertaining to 84 000 lineaments in an area of 25 000 km² were recorded. The total length of lineaments in intervals of one degree was determined. Angular intervals with low length densities were regarded as atypical. The proportion (by length) of lineaments with such atypical orientation was calculated for 5 km × 5 km grid squares. This index of angular atypicality was contoured and, used in conjunction with conventional photogeological techniques, contributed in a large measure to the success of the investigation.

SAMEVATTING

Gegewens met betrekking tot 84 000 lineamente uit 'n gebied van 25 000 km² is in 'n eksplorasieprojek opgeteken. Die totale lineament lengte in intervalle van een graad is bereken. Hoek intervalle met lae lengte digthede is as ontipies beskou. Die verhouding (volgens lengte) van lineamente wat ontipies gerig is, is bepaal vir 5 km × 5 km blokke. Kontoere van hierdie indeks van rigtings-afwyking is aangestip. Die gebruik van hierdie tegniek, saam met meer konvensionele fotogeologiese metodes, het baie tot die sukses van die ondersoek bygedra.

INTRODUCTION

During the initial exploration of a large area for minerals, screening procedures (e.g., photogeological surveys) are often employed to delineate subareas that might warrant further, more intensive investigation.

In a recent exploration project covering an area of 25 000 km², analysis of lineament data was used in conjunction with conventional photogeological techniques. A simple analysis, based on the proportion of lineaments with atypical orientation, contributed in a large measure to the success of the investigation. Although no information can be given of the area that was investigated and of the detailed results obtained, a brief description of the technique seems to be justified.

LINEAMENTS

The term *lineament* was initially used by Hobbs[1] for 'significant lines on the earth's face'. More recently it has been used by photogeologists (e.g. Mollard[2], and Kupsch and Wild[3]) to refer to narrow, approximately linear natural features visible on aerial photographs and mosaics. These features may be associated with linear patterns in vegetation, abrupt changes in type of vegetation, incised fractures, abrupt topographic changes, rectilinear stream courses, and differential weathering of fractures (Henderson[4]).

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RECORDING AND PRELIMINARY PROCESSING OF LINEAMENT DATA

In surveys where fewer than 5000 lineaments are annotated, it is feasible to transfer the data manually from aerial photographs to enlarged transparencies of existing 1:50 000 topographic maps. In view of the detail and quantity of annotation in the present study (some 84 000 lineaments), manual methods could not be considered. The method used was as follows.

The centre point of each aerial photograph was co-ordinated in terms of its position on the available 1:50 000 topographical maps. The principal points were transferred to adjacent photographs so that adjustments could be made for swing in the photographs. An A7 first-order stereo plotter was used to co-ordinate the principal points, fracture trace, and lithological boundary data, each annotated photograph being set up in relation to the co-ordinate data derived from the topographic maps. The data were transferred direct to cards by an on-line punch. Each lineament was coded according to its type (Dyke, Fault, Dyke filled fault, and Indeterminate). Where a lineament crossed a photo boundary, it was given a code number to ensure that its continuity on the neighbouring photograph was recognized and recorded. The data were used to plot the lineaments in a continuous field based on real ground co-ordinates, using a Calcomp 714, 80-inch flat bed plotter. The map of the total field of fractures was supplemented by one reproducing only the larger lineaments. This was used to obtain a better image of the gross structural components of the area, which tend to become obscured in the total field of fractures.

ANALYTICAL TECHNIQUES

A lineament is recorded as a straight line in a plane and is geometrically fully determined by its length, orientation, and location. Analysis must therefore be in terms of these properties. Henderson[4] recorded the total *length* of lineaments in 4 km² grid squares and contoured the resultant density values.

In an earlier project, the authors[5] used such length density data to obtain regional trend surfaces and residual contours. These densities were found to be markedly influenced by the lithology and by differences between the density of annotation of different geologists. Weights were calculated to compensate for these differences. This weighting was not entirely satisfactory, however, since important variations in fracturing may be masked by it.

An analysis of the *orientation* of lineaments was used by Blanchet[6] as an exploration method. He contended, on theoretical grounds, that lineament angular frequencies should occur in conjugate sets. His analysis of lineament data from western Canada yielded results conforming to a remarkably consistent conjugate grouping. When considering a particular locality, he classified each lineament into one of the conjugate groups and calculated local mean directions and deviations. These were used in empirical equations to obtain a measure of 'structural intensity'.

Permyakov[7] developed a number of empirical formulae to relate tectonic jointing in platform regions to the geometry of underlying structures. Gol'braykh[8] applied these formulae to lineament data and concluded, among other things, that the method cannot be used to *detect* local structures.

ANGULAR ATYPICALITY

In the project referred to in the Introduction, it was found that the angular frequency distribution of lineaments did not conform to the conjugate pattern described by Blanchet. The distribution was unimodal over approximately half of the area, and trimodal over the two other parts, each approximately a quarter of the area. Neither Blanchet's analysis nor the conjugate analysis developed by the authors in an earlier project[5] could therefore be used.

Areal data are commonly analysed by plotting contours, either directly or after regional trend values have been subtracted. This type of analysis is possible if single variables such as gravity observations, trace-element concentrations, or lineament densities are considered. In order to apply this method to angular data therefore, a single index characterizing the distribution had to be derived. The following method was used to obtain an index of angular atypicality. The sum of the lengths of lineaments in angular intervals of one degree was calculated for the whole area. These were plotted in a way similar to that shown in Fig. 1 (in an idealized form)

From the graph in Fig. 1 it can be seen that a high proportion of lineaments had orientations near to that of the two peaks (B and D). These could be regarded as having 'typical' orientations. In the same sense, those with orientations near the frequency lows at A and C could be regarded as being atypical. For a frequency level (L in Fig. 1) between the highest and lowest frequencies, angular intervals (u to v, w to x, and y to z) could be determined within which lineaments would be classified as being atypical. For the example depicted in Fig. 1, approximately 20 per cent (cross-hatched area) of lineaments would be so classified.

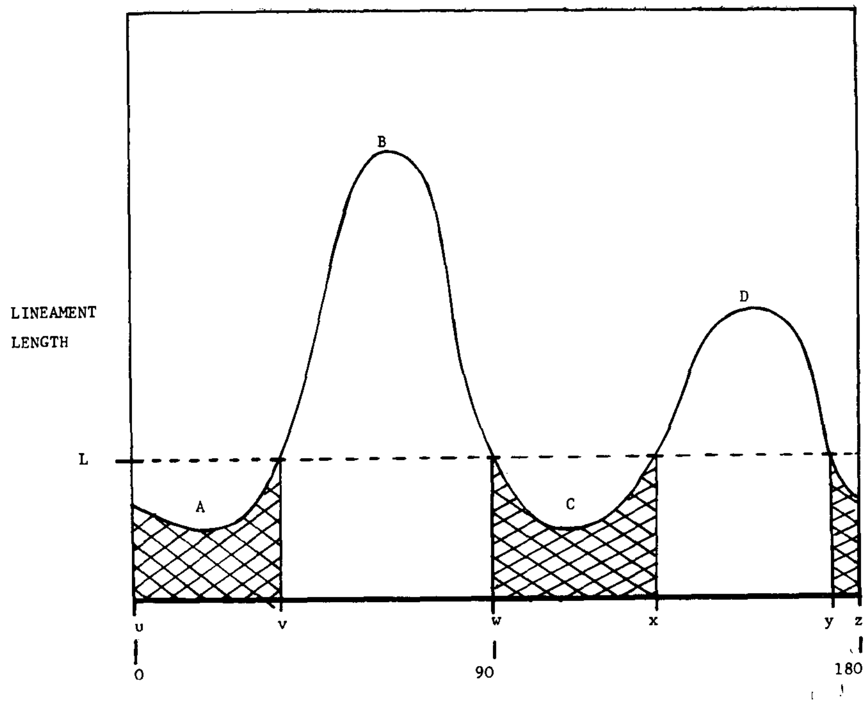

Fig. 1—Lineament orientation in degrees

The proportion of lineament lengths with atypical orientation in each grid square (5 km × 5 km) was calculated. This gave an index of atypicality ranging from 0 to 1. These values were contoured using a standard computer programme. The results obtained by classifying 10, 20, 30, or 40 per cent as atypical did not differ markedly, and the 40 per cent atypicality level was used for subsequent interpretation since it was more stable, from a sampling point of view, than the lower levels.

It will be noted that the index is not influenced by any preconceived notions about the angular frequency distribution. The changes in density due to lithological variations and different densities of annotation do not influence the index either, since it is expressed as a proportion of the total length in a given grid square.

INTERPRETATION

The contours of angular atypicality were used to delineate target areas in the following ways. Areas with high atypicality indices were noted. Approximately 20 per cent of the total area had indices of 0,5 or more, and 40 per cent of the 180 features were within this part of the area.

The pattern of angular atypicality anomalies was carefully studied in relation to (a) known mineral occurrences within the area and (b) photogeological anomalies. In this analysis, particular attention was devoted to identification of patterns and associations, and not merely to the areal coincidence of known features with angular atypicality anomalies.

Such associations as the occurrence of a series of contour peaks around a 'quiet' area, within which several known features were clustered, and the occurrence of isolated peaks within areas of very low background were accorded special significance. In this way, target areas were delineated in which 50 per cent of observed features could be incorporated within 10 per cent of the total area that coincided with clusterings or local occurrences of high atypicality peaks. Further detailed exploration could then be confined to small highly anomalous areas.

In a brief field examination of certain of these areas, the locations of ten features were visited. Of these, five proved to be of intrusive or extrusive origin, one was eliminated, and four were soil-covered. Of the five confirmed in the field, three were associated with mineralization that could be identified in the hand specimen.

DISCUSSION AND CONCLUSIONS

In both this and previous[5] projects, it was found that angular atypicality analysis provides an effective screening technique by means of which unbiased identification of anomalous areas can be achieved. In the case of intrusive or extrusive features, the technique is used most effectively in conjunction with the distribution of known features to determine patterns and associations in terms of which small target areas can be delineated.

Where deep-seated deformational structures, often without manifestation in surface dip or buried beneath an unconformity, must be identified (as in oil prospecting), angular atypicality analysis can be applied direct.

Deformational structures identified in this way have been found to accord well with the results of deep reflection seismics conducted over the anomalous areas[5]. The technique, which is a refined version of a method used in an earlier study, can be refined further. The use of a single background distribution is inadequate. In the present investigation it was found necessary to divide the area into three subareas, each with its own distribution. Clearly, the use of a background distribution trend would be better. Work on the development of a programme to determine such a trend is in progress.

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