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STRUCTURAL LINEAMENTS OF GASPE FROM ERTS IMAGERY*

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ABSTRACT

A test study was conducted to assess the value of ERTS images for mapping geologic features of the Gaspé Peninsula, Quebec.

The specific objectives of the study were: 1) to ascertain the best procedure to follow in order to obtain valuable geologic data as a result of interpretation; 2) to indicate in which way these data could relate to mineral exploration.

ERTS imagery differs from aerial photography because of the technical parameters of the imaging devices employed in the satellite and because of the Earth-viewing conditions that characterize the imaging process. Sound understanding of these factors is the prerequisite for achieving satisfactory results.

Of the four spectral bands of the MultiSpectralScanner the band from 700 to 800 nanometers, which seems to possess the best informational content for geologic study, was selected for analysis.

The original ERTS image at a scale of 1:3,700,000 was enlarged about 15 times and reproduced on film.

Geologically meaningful lines, called structural lineaments, were outlined and classified according to five categories: morpho-lithologic boundaries, morpho-lithologic lineaments, fault traces, fracture zones and undefined lineaments.

Comparison with the geologic map of Gaspé shows that morpho-lithologic boundaries correspond to contacts between regional stratigraphic units. Morpho-lithologic lineaments follow bedding trends, whereas fracture traces appear as sets of parallel lineaments, intersecting at high angles the previous category of lineaments. Fault traces mark more precisely the location of faults already mapped and spot the presence of presumable faults, not indicated on the geologic map.

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As a tool for mineral exploration the structural lineaments map of Gaspé can be used:

a) to improve the understanding of the tectonic framework of the Peninsula;

b) to direct exploration efforts over specific target areas;

c) to assist in deciphering the meaning of geophysical survey data;

d) to support the delineation of trends in the distribution of regional geochemical anomalies.

INTRODUCTION

This paper describes a test study appraising the value of ERTS images in providing data helpful to the understanding of regional geologic factors. The study consists of the analysis of imagery of the Gaspé Peninsula, Quebec, obtained with the multispectral scanning instrument mounted on ERTS. The study was conducted to seek answers to the questions: What type of geologic information can be extracted from ERTS imagery? How would this information relate to standard sources of geologic data? What is the significance of the interpreted data for mineral exploration activities?

LINEAMENTS ANALYSIS

Apart from the very small scale, which carries with it an inevitable loss of detail, geologic interpretation of space imagery can be undertaken by applying the same principles that are useful in the interpretation of standard aerial photographs (Van der Meer Mohr, 1968). Of course, the scale of observations will be considerably changed, thus one would not expect to obtain the same interpreted data, as a result of photogeologic work done on the two different materials. For a photogeologist, the particular interest in analyzing space imagery lies in the expectation that the reduction in scale would compress the pictorial information in such a way that large-scale picture elements normally not associated with geologic factors are filtered out. Consequently, regional geologic features would become more apparent.

Fundamental to photo-analysis for geologic purposes is the outlining of structural lineaments, a term attributed by Allum (1966, p. 31) to "any line on an aerial photograph that is structurally controlled". By this definition, the term structural lineament embraces any alineament of topographic, vegetative and lithologic features, or any boundary line between physiographic units, which is ascribed to the underlying geology and can be traced as a line on a photographic image. The use of the term lineament is here preferred to the term linear, also frequently used in the literature, because it refers to both straight and curved lines. This definition applies equally well to aerial photography and space imagery. However, the technique used to extract this information is not equivalent in the two cases.

Usually, with aerial photographs, the terrain is observed in stereoscopic vision, to facilitate the recognition of geomorphic features. Three-dimensional viewing of terrain considerably helps the interpreter in his endeavour to separate lines that are controlled by geologic factors from lines that are not.

The terrain stereomodel obtained by assembling two overlapping space images from adjacent orbits is characterized by reduced vertical exaggeration, because of its small base to height ratio. The diminished stereo-effect, combined with the small size of the observed landforms, limit the advantages of analyzing in stereo. The photogeologist engaged in the study of ERTS imagery will normally work without the aid of a stereoscope. The distinction between geologically controlled alineaments and alineaments resulting from natural or human causes, but unrelated to geology, becomes more difficult to him. The success in pin-pointing geologic lineaments will greatly depend on his ability and experience.

The procedure adopted for studying the ERTS imagery of Gaspé was first, to make a selection of the most appropriate spectral band and, subsequently, to enlarge the chosen original material to the format that would illustrate clearly the lineaments and at the same time provide the appropriate scale for correlation with geologic and geophysical maps.

The initial assessment of the relative informational value of the four MSS spectral bands would indicate that for Canadian terrain the band from 700 to 800 nanometers, possesses the best attributes for geologic study. On band number six, water bodies appear as very dark tones, the vegetation pattern is manifested by a wide range of photographic tones and there is a high contrast between lighted and shaded areas. The dense matrix of picture elements represented by 2,400 x 3,400 image data points per frame for the MSS system makes it possible to enlarge the original ERTS images up to about 15 times, without producing excessive visual image degradation, as would occur with standard aerial photography. It was felt that in order not to lose image quality, a film base reproducing the enlargement was required. The 1:250,000 scale of this type of enlargement matches the standard scale of compilation of regional geologic maps in Canada.

INTERPRETIVE RESULTS

The frame of orbit 793 imaged on Sept. 21, 1972, over Gaspé (Fig. 1) was the object of detailed visual analysis.

Some of the terrain on the west side of the picture is cloud-covered and consequently the resulting lineaments map of Gaspé (Fig. 2) covers mainly the eastern portion of the frame. The lineaments map shown on Figure 2 is an objective representation of imagery data, in which no attempt is made to specify the meaning of the lines in geologic terms.

This stage of interpretation can be reached with only a general knowledge of local geology. However, to classify the lines, that is, to assign lineaments to different categories, a further step is necessary, which requires a good understanding of the geology of the area, and also some inferential reasoning. The geologic setting of Gaspé is illustrated by the map prepared by McGerrigle and Skidmore (1967), and published by the Department of National Resources of Quebec. This map was the basis for the outline of the tectonic evolution of Gaspé by Béland (1969), and for the classification of mineral occurrences of Gaspé by Dugas, et. al., (1969).

The Gaspé Peninsula is a belt of Paleozoic sedimentary rocks which is a part of the Appalachian Geosyncline. It underwent successive phases of deformation with associated emplacements of igneous rocks. Greywackes and shales of Cambro-Ordovician age are predominant in a belt of slightly metamorphosed rocks, occupying Northern Gaspé, which was folded during the Taconian orogeny. Instead, in central and southern Gaspé, limestones, shales and sandstones of Ordovician, Silurian and Devonian age were folded during the later Acadian orogeny. In places, an undeformed and discordant unit of Carboniferous sediments covers the older rocks. The largest bodies of igneous rocks occur in Northern Gaspé. Mineralization in Gaspé appears to have occurred throughout a period of time, related to the successive orogenic events and normally associated with either basic or acid intrusions.

By taking into account the geologic background information, and giving consideration to the photographic appearance of the lineaments, their mutual relationship and their relation to surrounding features, a division of the structural lineaments into five categories was accomplished. The five categories are: morpho-lithologic boundaries, morpho-lithologic lineaments, fault traces, fracture traces and undefined lineaments. The corresponding map is shown in Figure 3.

Morpho-lithologic boundaries

These lineaments mark the separation of terrain units that have significantly different drainage patterns. These terrain units are sometimes enhanced by overall differences in tone. On the interpreted satellite image, the drainage pattern is expressed by its darker tone relative to the surrounding terrain. This is due both to the reduced reflectance of the water flowing in the stream channels and to the shadows associated with topographic depressions.

Comparison with the geologic map of Gaspe shows that there is correspondence between this category of lineaments and contacts of regional stratigraphic units.

The longest morpho-lithologic boundary appearing on Figure 3, coincides with the line of separation of the limestones and shales of the Matapedia group to the South from the slates and siltstones of the Fortin group to the North.

The elliptical morpho-lithologic boundary at the eastern edge of the same figure encloses the Maquerau group, an inlier of metasedimentary and metavolcanic rocks surrounded by younger Paleozoic sediments. The sharp change in terrain characteristics across a portion of Matapedia boundary and all across the Maquerau boundary suggests a fault contact.

Also distinctive is the separation of the Matapedia group from the limestones and siltstones of the Raudin group in southeastern Gaspé.

Morpho-lighologic lineaments

This category includes mainly the group of easterly trending lineaments that reflect the bedding of underlying sedimentary formations. Sills resistant to erosion might produce lineaments that would fall in this category. Some lineaments of this type originate from the influence of the strike of the strata on the drainage pattern, while others originate from differential erosion affecting the shape of terrain. At a few locations, the presence of folds is evinced by the curved outline of their closure.

Fracture zones

This category includes linear features attributable to terrain discontinuities generated by joints, minor faults and dykes. In view of the similarities in their photographic appearances, the distinction of this class from the morpho-lithologic group is not simple. Guidance in making the distinction is provided by their spatial distribution, since fracture zones are usually arranged in sets having a common orientation.

The set with orientation N 20 W, which means at right angle to the main bedding trend, seems to be the most prominent, particularly in the northwestern corner of the frame. South of the Grand Pabos fault, a set oriented N-S is well-pronounced. Also in southeastern Gaspé, it is interesting to notice a swarm of fracture lineaments, oriented N 20 E, cutting across various lithostratigraphic units.

Fault traces

In the interpreted area, there are a few lineaments that possess characteristics normally associated with large faults and were classified as such. The main fault trace corresponds to the Grand Pabos fault that on the satellite image appears as a terrain scar, which is easily recognizable over a distance of 60 miles. The continuity of the fault trace, especially at its western end, is surprising if compared with information previously acquired. On the geologic map of Gaspé (McGerrigle and Skidmore, 1967) the location of this fault is in part assumed, and shows a bend towards the south which on the basis of ERTS would be incorrect. The author undertook the photogeologic reconnaissance of the area in 1969 for the Quebec Mining Exploration Company (SOQUEM) on photographs at a scale of 1:35,000. He was not able to trace the Grand Pabos fault with the same accuracy as obtained with ERTS data.

Undefined lineaments

In this category were grouped lineaments of uncertain origin.

LINEAMENTS MAP AND MINERAL EXPLORATION

To provide a comprehensive discussion of the uses of the lineaments map in mineral exploration would exceed the scope of this publication. A few examples will be described illustrating the advantages to be derived from the application of lineaments data.

Regional tectonic framework

In recent years attention has been given to the possibility that ore deposits be related to circulation of magma and mineralized solutions along geo-crustal fractures.

Kutina and Fabbri (1972), and Kutina (1972) have compared regularities in the distribution of mineral occurrences with the presence of major morphological lineaments and major fault systems. Wertz (1972) has emphasized the role played by intersections of regional lineaments in the emplacement of intrusives, and consequently, in the regional distribution of ore deposits.

In Gaspé, where as previously noted mineralization is associated with igneous rocks, Dugas, et. al. (1969) suggested that transverse regional fractures might explain the N-S elongation of the McGerrigle batholith, and therefore, constitute the controlling factor for both the emplacement of the intrusives and the distribution of mineralized zones. He also assumed that a set of N-S aeromagnetic linears could identify such fractures. In this respect, the three sets of northerly trending fracture zones found through the study of E· TS data represent additional geologic evidence for the support of this theory. The precise significance of the fracture lineaments as to their relationship to mineralized areas warrants further investigation.

Target areas for exploration

Knowledge of the genetic type of mineralization existing in the region of interest, e.g. Gaspé, would indicate if a direct connection exists between a structural feature depicted on the lineaments map and a mineralized body. Otherwise, indications of the relationship between lineaments and mineralization can be produced by comparative analysis of the lineaments map and the regional distribution of mineral occurrences.

In Canada, data files inventories by Federa and Provincial Agencies give access to descriptive data sheets for each reported mineral occurrence, incl· ing the precise location. From these inventory data, it is an easy matter t compile a geographic map for the mineral occurrences.

The results of such a compilation for the region of Gaspé is shown on Fig. 4. In this figure, each point represents an occurrance, with the adjacent metal symbol indicating the primary mineralization. Correlations between lineaments and occurrences can be established empirically, by simply superimposing the two maps. The can also be sought by applying statistical techniques. For the region of Gaspé, the only obvious correlation between lineaments and mineralization is provided by the Grand Pabos fault, along which an alineament of occurrences is distributed. The converging evidence furnished by genetic factors, records of mineral occurrences, and structural lineaments, can direct the attention of the exploration geologist to a specific lineament, the intersection of two lineaments, or any peculiar feature appearing in the trend and pattern of the lineaments.

Interpretation of geophysical and geochemical reconnaissance data

Airborne geophysical and geochemical techniques are usually employed to localize favourable areas for follow-up field prospecting.

Positive aeromagnetic anomalies for the Gaspé region, that is, areas of the aeromagnetic contoured data where values of the magnetic field are greater than the local average, are sketched on the mineral occurrences map of Fig. 4. Data are from published aeromagnetic maps. These anomalies are originated either by various types of igneous rocks, intruded or deposited as volcanic tuffs and lavas within the sedimentary sequence, or by sedimentary rocks rich in magnetite. In Gaspé, they show close relationship to copper occurrences.

Correlation of the anomalies with the structural lineaments can be helpful in finding a satisfactory explanation for the anomalies.

The linear aeromagnetic anomaly designated by A on Figure 4 coincides with the strong lineament indicated by the same letter on Figure 3. One could assume that the anomaly is generated by a basic intrusion occurring along the lineament, which would therefore spot the location of a crustal fissure.

The letter B on Figure 4 points to two major anomalies, whose overall shape is in agreement with the curvature of the two lineaments enclosing the area indicated by Mi on Figure 3. Volcanic greywackes of the Mictaw group underlie this area.

On the New Brunswick side, the sharp rectilinear edges of a major anomaly designated by C on Figure 4 match two lineaments indicated by the same letter on Figure 3. In this case, there is no precise correspondence with the geologic map of New Brunswick, 1:500,000. (New Brunswick Dept. of Natural Resources, 1968.)

A similar procedure can be applied to interpret the regional distribution of metals, obtained as a result of geochemical stream-sediment surveys. To give an example, on Figure 5, the results of the geochemical survey for an area of southwestern Gaspé, bounded by Chaleur Bay to the south (Quebec Dept. Nat. Resources, 1971), are combined with the lineaments map. Three separate maps show the correspondence of the major lineament occurring within the area to the pattern of metal distribution for uranium, zinc and copper. Contour lines enclose areas with high concentration values. The geochemical maps were processed by computer and based on the moving average technique (rolling means), which is utilized to better outline regional trends (Gleeson and Martin, 1969).

It is evident from the figure that the major lineament marks a significant regional geochemical trend. To the north of the lineament there is, relatively speaking, a high concentration of uranium and low concentration of zinc and copper, the reverse is true for the area to the south of the lineament. If the two maps had not been combined, the trend would result much less obvious. A basic change in lithology across the lineament, that in fact represents the contact between the Fortin group and the Matapedia group, could explain the observed trend.

CONCLUSIONS

As set forth in the introduction, the primary objective of this study was to investigate the applicability of satellite imagery for the geologic study of Canadian terrain.

The achieved results are proof that, at least for the Appalachian physiographic region, significant geologic information can be extracted from ERTS data. This information is regional in nature, and correlates well with the geologic map of the area at the scale of four miles to the inch.

Structural lineaments obtained by interpretation show interesting correlations with aeromagnetic and geochemical stream-sediment survey data. In particular, sets of transverse fracture zones, of which no indication is given by the geologic map, were observed. In the Gaspé region, these fracture zones could be related to deep-seated weakness zones in the crust, and therefore could be valuable as indicators for possible preferential locations of intrusion and mineralization.

As a plan for future work, the investigation of satellite imagery data which has been collected at various times during the year is recommended. Seasonal factors will influence both illuminating conditions and type of ground cover, resulting in the opportunity to observe different terrain aspects.

Most of the terrain features identified in Gaspé seem to have geomorphic origin and, consequently, imagery gathered during the winter season should provide an increased amount of observable geologic elements.

By studying winter imagery, and comparing the results with those achieved in this study of end-summer imagery, it is expected that a more precise definition of the specific origin of each category of structural lineaments will be reached.

ACKNOWLEDGEMENTS

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Fig. 1- ERTS MultiSpectralScanner image of Gaspé. Orbit 793; Frame 1057-14473; Band No. 6: 700-800 nanometers.

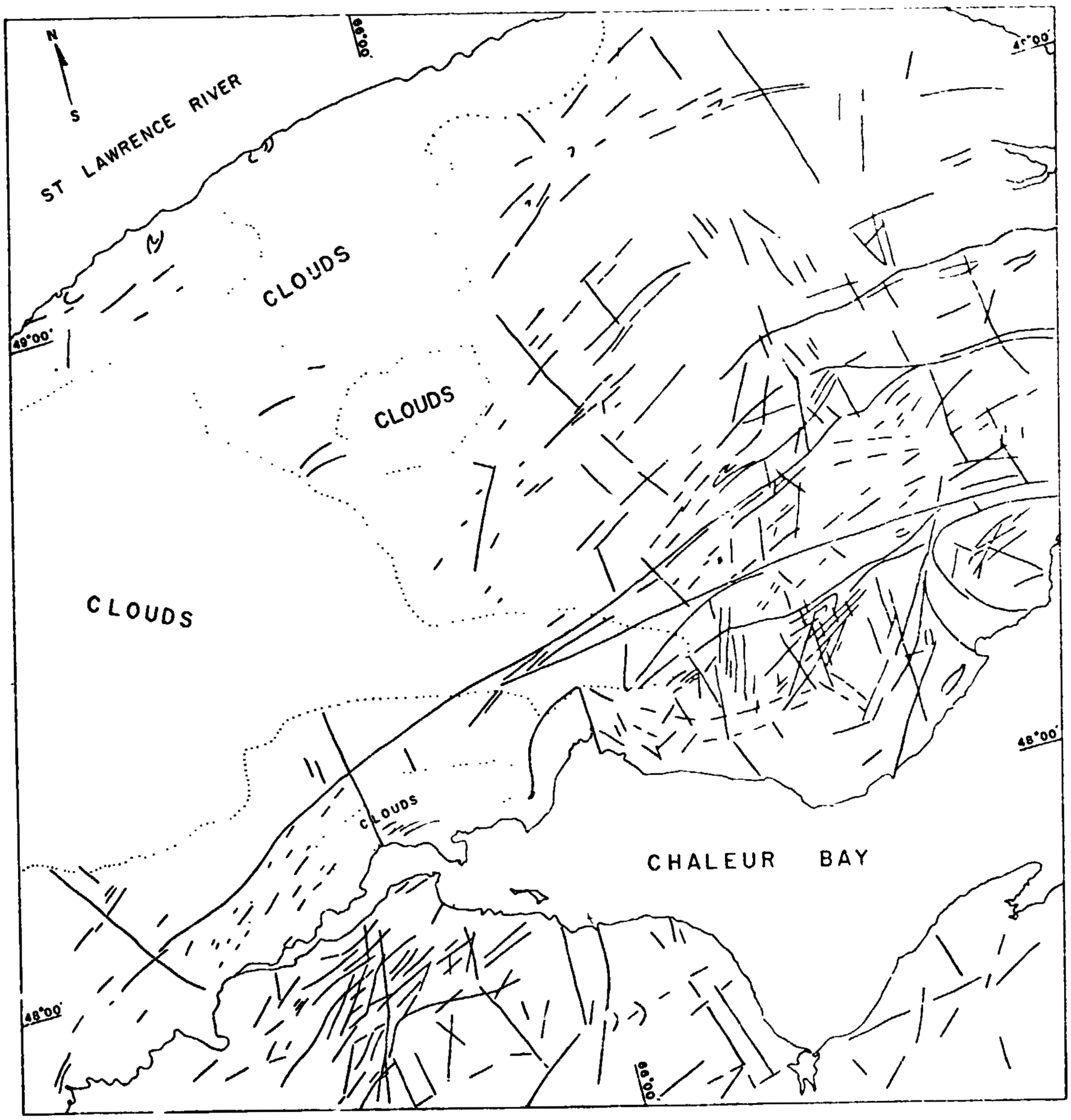

Fig. 2- Observed structural lineaments of Gaspé resulting from the interpretation of ERTS frame 1057-14473, Band No. 6.

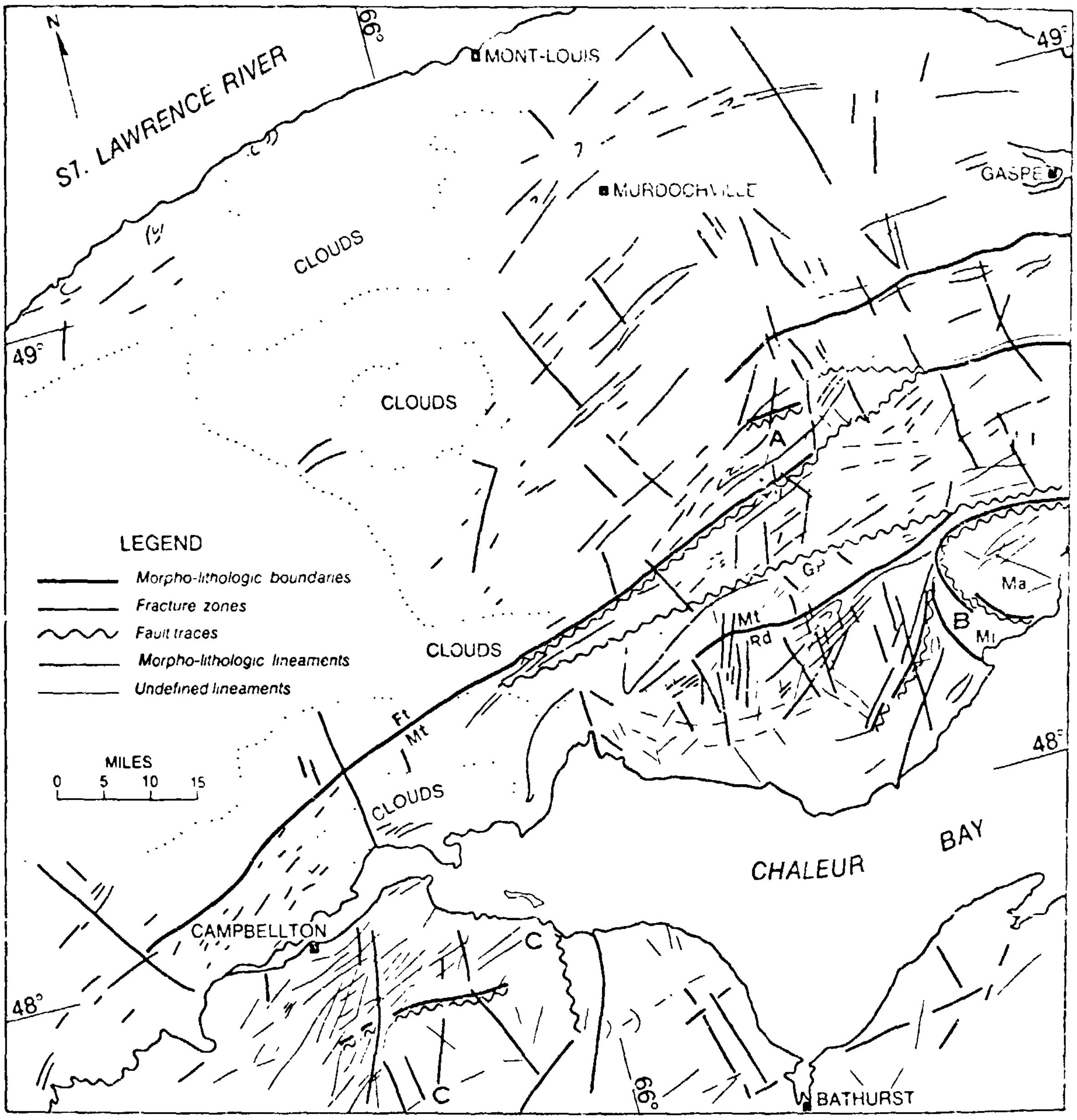

Fig. 3- Classified structural lineaments map of Gaspé

GP-Grand Pabos fault; Mi-Mictaw group; Mp-Matapedia group; Ft-Fortin group; Ma-Maquerau group; Rd-Raudin group.

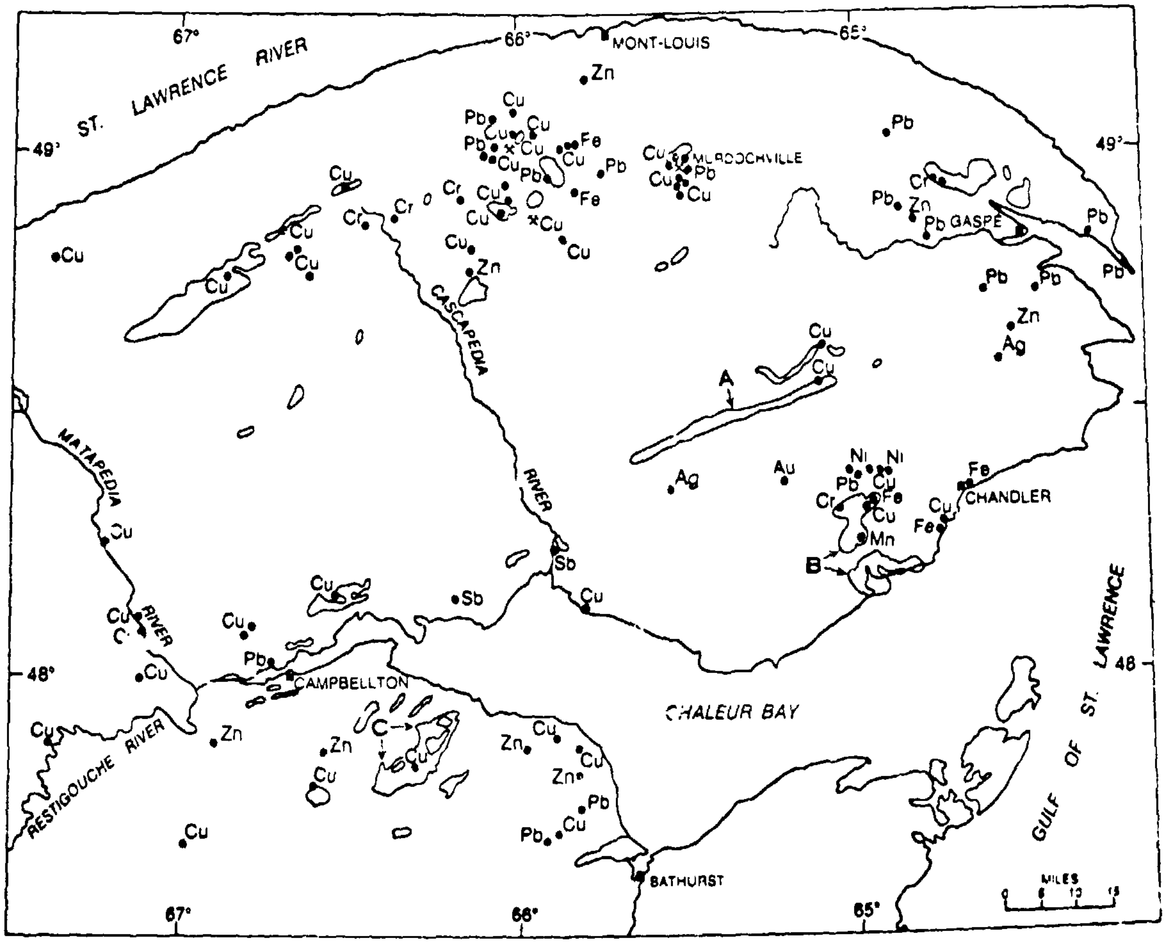

Fig. 4- Mineral occurences and contours of major aeromagnetic anomalies in Gaspé. Anomalies designated by A,B,C are correlated with lineaments of fig. 3.

Data Source: National Mineral Inventory, Mineral Resources Branch, Dept. E.M.R.; Aeromagnetic maps (1 inch to four miles series), Geological Survey of Canada, Dept. E.M.R.

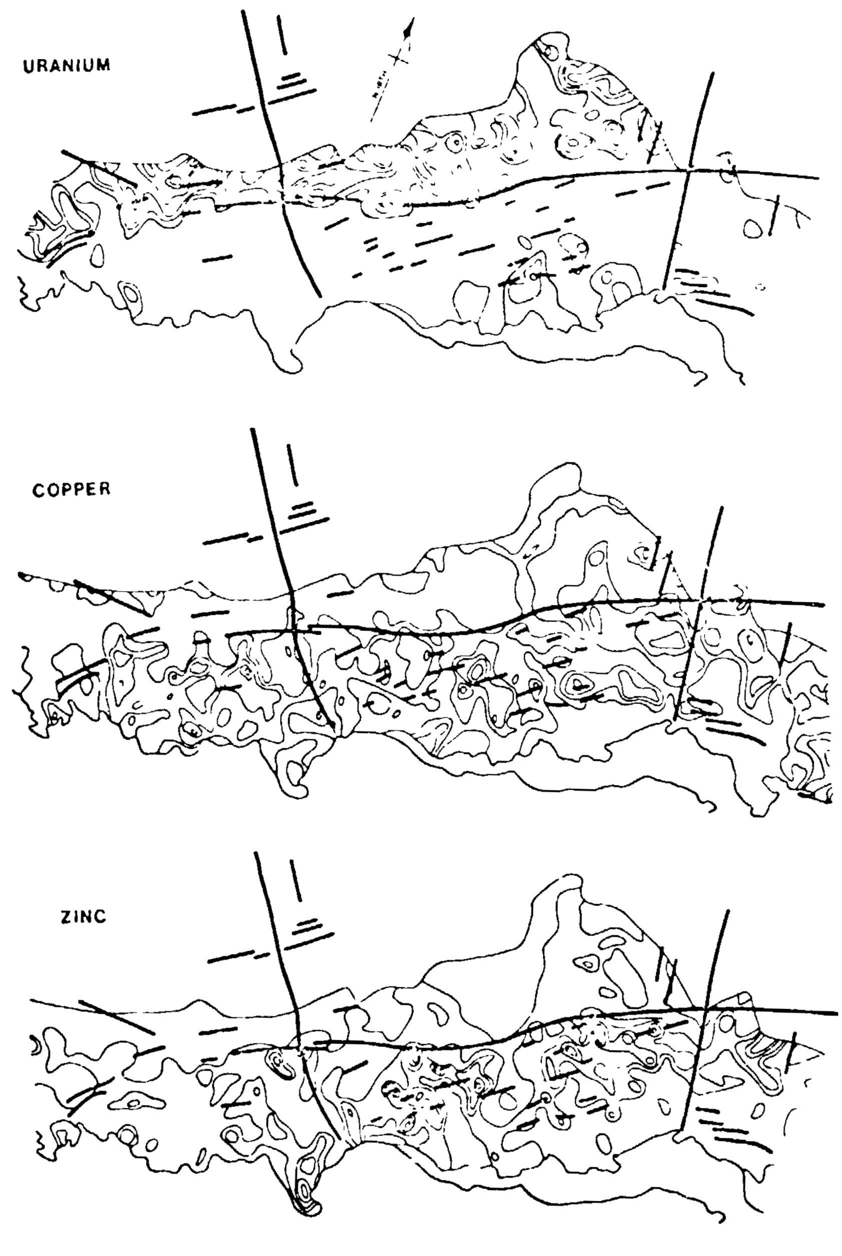

Fig. 5- Correlation of structural lineaments with geochemical stream-sediment metal distributions.