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Interpretation of Landsat imagery of the Tanacross quadrangle, Alaska

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In this study of Landsat[1/] imagery for the Tanacross quadrangle, Alaska, two fundamentally different types of images were used: (1) a black and white, single band, Landsat mosaic of Alaska, constructed with images that are not computer-enhanced; and (2) various types of computer-enhanced Landsat images.

The Landsat mosaic of Alaska was constructed in 1973 by the U.S. Department of Agriculture Soil Conservation Service, using band 7 images generated without computer enhancement. Study of this mosaic was conducted at a scale of 1:1,000,000, and the results transcribed to fit a standard 1:250,000-scale UTM projection map of the Tanacross quadrangle. Because of its synoptic perspective and low sun angle (most images were acquired during late summer or fall), the mosaic is most useful for identifying lineaments[2/], arcuate features, and circular features. Tonal variations signifying differences in ground color within the quadrangle are not detectable because the area is completely covered by snow on the Alaska mosaic.

Three Landsat 1 images with minimal snow and cloud cover (1029-20383, taken August 21, 1972; and 1692-20143 and 1692-20150, taken June 15, 1974) were selected for computer enhancement. In addition to identifying other lineaments, arcuate features, and circular features not detected on the Alaska Landsat mosaic, computer-enhanced imagery is generally most useful

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[1/] Landsat 1 (formerly ERTS-1) was launched by the U.S. National Aeronautics and Space Administration (NASA) on July 23, 1972, and Landsat 2 on January 22, 1975. Detailed information regarding the satellites' orbital characteristics and imaging systems can be found in NASA Document no. 71SD4249 (U.S. National Aeronautics and Space Administration, Goddard Space Flight Center, 1971) and U.S. Geological Survey Professional Paper 883 (Rowan and others, 1974).

[2/] The term "lineament," as used in this discussion, is based on O'Leary and others' (1976) definition.

for identifying subtle surficial reflectance variations caused by differences in vegetation, rock types, soil, and other variables. However, because of several factors discussed later in this report, reflectance variations in the Tanacross quadrangle yielded little information related to resource assessment.

Computer compatible tapes (CCT's) for the three Landsat scenes were processed by the image processing facility of the U.S. Geological Survey, Flagstaff, Arizona. Attempts to mosaic these three images together by computer were successful only for scenes 1692-20143 and 1692-20150, which make up the eastern 80 percent of the quadrangle. Because of previously unknown aberrations in either the Landsat 1 orbital path or the imaging system, scene 1029-20383 (in the western part of the quadrangle) could not be mosaicked by computer to the other two scenes. Therefore, corrections for atmospheric effects, sun elevation, noise, and geometric distortions and other computer enhancement techniques were applied separately to the two mosaicked images and to image 1029-20383.

CCT's for scene 1692-20150 were also processed independently by the image processing facility at the California Institute of Technology, Jet Propulsion Laboratory, Pasadena, California.[3/]

To derive maximum structural and surficial reflectance information, four types of computer-enhanced products were generated for study: (1)

[3/]Computer-enhanced color products generated by the U.S. Geological Survey, Flagstaff, Arizona, and by the California Institute of Technology, Jet Propulsion Laboratory, Pasadena, California are available at nominal cost from: EROS Data Center, Sioux Falls, South Dakota 57198. Orders should include P.A.O. (Public Affairs Office) numbers given elsewhere in this text.

false-color with various "stretches," (2) simulated natural color, (3) color ratio negative, and (4) "first derivative" single band black and white images.

Three false-color images were produced by various "stretches" and combinations of three of the four multispectral scanner (MSS) bands. After application of the standard corrections mentioned above, histograms of the different bands are analyzed to determine the ranges of DN values (the digital numbers on CCT's representing brightness levels) containing significant data. A different type of "stretch" is used in creating each of the three false-color images: (1) a linear stretch (Rowan and others, 1974); (2) a table stretch, which is simply a series of different linear stretches applied to various parts of the histogram; and (3) a sinusoidal stretch (Albert and Steele, 1976). Each of these stretches enhances different and commonly distinct spectral variations within the images. Each individually stretched band is then produced as a black and white film positive (transparency) at approximately 1:1,066,000 scale. These transparencies are then individually contact printed onto color film using a different colored light for each black and white transparency. The color combinations for each image are:

(1) linear stretch--band 4 in blue, band 5 in green, and band 6 in red (P.A.O. no. E-526-78-CT);

(2) table stretch--band 5 in blue, band 6 in green, and band 7 in red (P.A.O. no. E-531-77-CT); and

(3) sinusoidal stretch--band 5 in green, band 6 in blue, and band 7 in red (P.A.O. no. E-527-89-CT).

Finally, the false-color transparencies are photographically enlarged and printed at 1:250,000 scale.

The second type of computer-enhanced product is a simulated natural color image. Bands 4 and 5, respectively, measure reflected light in the yellow-green and red-orange regions of the visible spectrum and bands 6 and 7 measure in the invisible, near-infrared region. The blue part of the visible spectrum is not recorded. Photographically generated color Landsat images thus cannot show actual surficial color conditions. Simulated natural color images however, can be generated using computer enhancement techniques by predicting and creating a synthetic blue component from the data of the four MSS bands. A version of Landsat imagery is thus produced in which the colors approximate those which the human eye should see from orbital altitudes if atmospheric absorption and scattering were eliminated (Eliason and others, 1974). As in the false-color images, black and white transparencies are produced. The three black and white transparencies are subsequently contact printed onto color film using green for band 4, red for band 5, and blue for the synthetic blue band. The final product (P.A.O. no. E-533-56-CT and E-528-25-CT) simulates natural color and accentuates subtle color differences.

The third type of computer-enhanced product is a color ratio image negative (scene 1692-20150 only) produced by the California Institute of Technology, Jet Propulsion Laboratory in Pasadena, California. Details regarding their computer techniques are given in U.S. Geological Survey Professional Paper 883 (Rowan and others, 1974). For this study, the color ratio composite was constructed as follows: band 4/5 in blue, band 5/6 in green, and band 6/7 in red. The final color product (P.A.O. no. E-529-78-CT) is a negative print.

The fourth type of computer-enhanced product used in this study is a black and white "horizontal first derivative" of band 6 (P.A.O. no. E-532-78-CT and E-530-35-CT). This technique mainly involves recognizing differences between the DN values of adjacent individual pixels in a given direction (horizontal in this case). These differences are assigned gray level (DN) values and a histogram is generated. The data in the histogram are stretched to maximize the interpretability of the final print. First derivative images enhance lineaments and curvilineaments and are particularly useful in identifying the numerous shorter lineaments and the structural grain of an area.

RESULTS

Lineaments

For this study, the most useful application of the 1:1,000,000-scale black and white Alaska Landsat mosaic, prepared by the Soil Conservation Service, is the identification of lineaments and arcuate and circular features and their extensions beyond the Tanacross quadrangle boundaries. These features are traced onto a scale-stable plastic overlay, then enlarged to a scale of 1:250,000. Additional lineaments, arcuate features, and circular features observed on the computer-enhanced imagery are added to this overlay. The final locations of these features are accurate to within at least 1 km relative to the 1:250,000-scale topographic base map upon which they are superimposed. Most of the error is introduced by optical distortions during enlargement and by differences between projections (the mosaic is Albers Equal Area, the computer-enhanced images are nearly Lambert Conformal, and the map is Universal Transverse Mercator).

Also, many of these features occur in zones (wide valleys, for example) and are thus difficult to locate with precision.

Two approaches were used to map lineaments (figure 1) from Landsat images: (1) identification of the lineaments independent of any background geologic data, and (2) identification of mapped faults and of apparent extensions. To manipulate these complex lineament data, we have developed a computer program (Steele, 1976) to aid our analysis. The computer program determines: (1) the percentage of the quadrangle within 1 km of a lineament, (2) the directional trends of the lineaments, (3) the lengths of individual lineaments or segments thereof, (4) a histogram of directional trends versus cumulative lengths of the lineaments, and (5) the mean lineament length.

In our study of the McCarthy quadrangle, Alaska (Albert and Steele, 1976), we distinguished two types of lineaments. One type is related to the regmatic shear pattern (Sonder, 1947) which is thoroughly discussed in Hodgson and others (1976) and briefly reviewed in our report on the McCarthy quadrangle. The other type is related to faults, folds, and fractures that are probably the result of local and regional tectonics. Although both types of lineaments are present in the Tanacross quadrangle, the difference in trend between them is less well defined than it is in the McCarthy quadrangle.

Earlier researchers, notably Hobbs (1911), Vening Meinesz (1947), Sonder (1947), and Shul'ts (1971), for the most part, have found two orthogonal sets of planetary fracture or regmatic shear directions: (1) northwest and northeast, and (2) north and east. Other researchers, such as Katterfeld (1976), have found other, less distinct systematic directions (west-northwest, north-northwest, north-northeast, and east-northeast), the frequency of occurrence of which are of secondary importance.

In the Tanacross quadrangle, we found two nearly orthogonal sets of lineaments. The most prominent lineament set trends approximately N. 39° W. and N. 50° E., while the other set trends approximately N. 78° W. and N. 13° E. (figs. 2 and 3). The prominent northeast and northwest trends in several instances have been detected in the field and found to correspond to mapped faults, conjectured faults, or brecciated zones (Foster, 1970; Foster, oral commun., 1976). An additional approximately north- and east-trending set is suggested. The east-trending lineaments are weak, however, making it difficult to define these north- and east-trending lineaments as an orthogonal pair.

One major lineament trend, N. 45° W., seems to have no orthogonal pair in the Tanacross quadrangle. Although this trend could be part of the N. 39° W. and N. 50° E. lineament set, the difference in orientation seems to occur along an east-trending zone from approximately 63°10' to 63°15' north latitude (figure 1). Previous work in the Nabesna (Albert, 1975) and McCarthy quadrangles (Albert and Steele, 1976) indicates that the N. 39° W. trending lineaments do not occur south of this zone. On the other hand, N. 45° W. trending lineaments in the Tanacross quadrangle are nearly nonexistent north of this zone. Because of this lineament orientation change, we believe that this zone may be an east-trending tectonic or structural break, which is further evidenced by aeromagnetic, gravimetric, and geologic data.

Aeromagnetic data (Griscom, 1976) show an approximately east-trending aeromagnetic low near this proposed break in the eastern part of the

Tanacross quadrangle that, according to Griscom, largely corresponds to an east-trending row of plutons, most of which are probably connected at depth. In the southwestern part of the quadrangle, Griscom shows a series of inferred northeast-trending faults, several of which correspond to faults indicated on the geologic map (Foster, 1970), that seems to be terminated by the postulated tectonic or structural break. Aeromagnetically inferred northwest-trending faults near the break also seem to be terminated by it. Gravimetric data (Barnes, 1976a, b) show an east-trending boundary between a high and a low gravity anomaly just to the west that alines with a significant "saddle" across a north-trending gravity high in the Tanacross quadrangle. This gravity break corresponds well with the proposed tectonic or structural break. Geologic data (Foster, 1970) also suggest an east-trending structural break by: (1) the contact (approximate biotite isograd) between the Precambrian to Paleozoic biotite gneiss and schist unit and the Paleozoic phyllite and schist unit in the southwestern part of the quadrangle, which is sharply deflected eastward near the proposed structural break; and (2) the contacts between the Precambrian to Paleozoic biotite gneiss and schist unit, Paleozoic schist and quartzite unit, and Mesozoic granitic rocks in the southeastern part of the quadrangle, which are mostly east-trending near the proposed structural break. In the Tanacross quadrangle, northwest- and northeast-trending lineaments exhibit an imperfect spatial periodicity. Spacing between northeast-trending lineaments is the best developed and ranges from about 15 to 25 km, whereas the spacing of the northwest-trending lineaments is more poorly developed and ranges from about 15 to 30 km. Vogt (1974) suggests a method for estimating plate thickness from the regular spacing of volcanoes and major fractures. Applying his method to the Tanacross quadrangle, the spacing of lineaments indicate a thickness of 15 to 30 km, which is considerably less than the 40 km or so of crustal thickness gravimetrically derived by Barnes (1976a). Because Vogt's method is dependent upon crustal materials being homogeneous and because of the irregularity of the spacing of lineaments in the quadrangle, it is likely that the 15 to 30 km values reflect crustal heterogeneity rather than plate or total crustal thickness. This discrepancy, however, could also be caused by the lineament spacing in the Tanacross quadrangle reflecting the approximate depth of the Conrad discontinuity.

Correlations of lineaments observed on Landsat imagery of the Tanacross quadrangle and geophysical data are poor to good. Gravimetric data are sparse in this area (Barnes, 1976b), making associations with lineaments mostly ambiguous. Aeromagnetic data (Griscom, 1976), on the other hand, show a good correlation with lineaments, particularly in the postulated fracture zone between lineaments K and L. Generally the trends of lineaments correspond well with known structural data (Foster, oral commun., 1976).

Lineament A (fig. 4), with an approximate north trend, extends nearly 500 km from about lat. 65°30' N. to about lat. 61°31' N., crossing both the Tintina and Denali fault systems without any apparent offset. This lineament is by far the largest north-trending linear feature that we have observed in Alaska to date.

Lineament B, with an approximate N. 35° W. trend, extends more than 1,200 km from about lat. 62°30' N., long. 139°45' W. in Yukon Territory, Canada to at least Barrow, Alaska, crossing the Tintina fault system and the Porcupine Lineament without any apparent offset. Suggestions of lineament B show up in gravimetric data as a northwest-trending group of gravity highs approximately 150 km long and in magnetic data as the northeastern boundary of a northwest-trending magnetic high approximately 200 km long in the NPR-4 (Naval Petroleum Reserve) area (Woolson and others, 1962; Barnes, 1976a). Lineament B also corresponds to a northward deflection of the Barrow Arch (Grantz and others, 1975) and may extend into the Arctic Ocean.

Lineament C, with an approximate N. 60° W. trend, extends at least 1,300 km from lineament L in the northeastern part of the Tanacross quadrangle to Cape Lisburne, crossing the Kaltag fault-Porcupine Lineament without any apparent offset. Lineament C corresponds to northwest aeromagnetic trends, primarily the alinement of lows, in the Big Delta (Alaska Division of Geological and Geophysical Surveys, 1975a) and Ambler River (Alaska Division of Geological and Geophysical Surveys, 1975b) quadrangles. In northwestern Alaska, this lineament follows the approximate axis of the northward deflected belt of lower Paleozoic eugeosynclinal deposits, closely describing the northeastern boundary of the strongly metamorphosed rocks. The lineament seems to mark the southwestern extent of the numerous thrust faults in the Brooks Range and of the major folds in the late Jurassic and Cretaceous basin deposits in the Amatusuk Hills region (King, 1969). Lineament C also alines with the Herald fault zone (Grantz and others, 1975), indicating that it may extend into the Chukchi Sea for several hundred kilometers. For most of its length, this lineament seems to mark the northern limit of earthquake epicenters as shown by Gedney and others (1972).

Lineament D, with an approximate N. 45° W. trend, extends for more than 2,000 km from the east side of the Coast Ranges in British Columbia, Canada (the southern terminus of the lineament is beyond the coverage of the Alaska Landsat mosaic) to Point Hope, Alaska, crossing the Kaltag fault-Porcupine Lineament without any apparent offset. Aeromagnetic data in the Tanacross quadrangle (Alaska Division of Geological and Geophysical Surveys, 1973a) show a probable corresponding zone of northwest-trending contours that seems to demarcate areas of high and low magnetic regimes. Aeromagnetic data in the Big Delta quadrangle (Alaska Division of Geological and Geophysical Surveys, 1975a) show an apparent corresponding alinement of magnetic lows that seem to follow lineament D for about 100 km. Lineament D also corresponds to the southwestern termination of a gravity low in the Tanacross quadrangle and to the southwestern boundary of the principally east-trending gravity low associated with the Brooks Range (Barnes, 1976a). The lineament goes through a "pinched" area of merging synclinal axes and normal faults; seems to deflect the belt of metamorphosed lower Paleozoic eugeosynclinal deposits in the western part of the Brooks Range; tends to bound the northern limit of thick Late Tertiary and Quaternary deposits in structurally negative areas, except for those in the Yukon Basin; seems to mark, for the most part, the southwestern boundary of the Precambrian to Early Paleozoic metamorphosed synclinal deposits in the Yukon-Tanana

Uplands; and marks the northern boundary of early and middle Tertiary plutonic and intrusive rocks in western Alaska (King, 1969). Lineament D also alines with the axis of a major anticline in the Hope Basin of the Chukchi Sea (Grantz and others, 1975) and seems to correspond to major breaks in the gravimetric profiles of the Chukchi Sea (Ruppel and McHenrie, 1975), indicating that the lineament probably extends for some hundreds of kilometers northwestward. In addition, it can be traced through two seismically active areas, one near Fairbanks and the other near the town of Rampart on the Yukon River (Gedney and others, 1972).

Lineament E, with an approximate N. 50° W. trend, extends for at least 1,200 km from the central part of the western boundary of the Tanacross quadrangle to the east side of the Coast Ranges in British Columbia. (The southern terminus of the lineament is beyond the coverage of the Alaska Landsat mosaic.)

Lineament F, with an approximate N. 55° W. trend, is over 2,100 km long and corresponds in part to the Denali fault system. Close examination of the Alaska Landsat mosaic reveals that from the northernmost part of the Alaska Range, where the Denali fault forms an arc and curves southwestward, a subtle continuation of lineament F extends northwestward, approximately passing through the break between the Kaltag fault and the Porcupine lineament, to Kotzebue Sound where it appears to aline with the axis of a major syncline in the Hope Basin (Grantz and others, 1975). To the southeast, lineament F is coextensive with the Denali fault system for at least several hundred kilometers, and continues east of the Coast Range in British Columbia on strike with Campbell's (1972) northwestward extension of the Fraser-Yalakom fault system. This suggests that the Denali fault system may not be deflected southward to join the Chatham fault (Lathram and Albert, 1975).

Lineament G, with a N. 55° E. trend, extends for over 700 km from around 75 km southwest of the town of Willow, Alaska to at least central Yukon Territory. (The northern terminus of the lineament is beyond the coverage of the Alaska Landsat mosaic.) This lineament crosses both the Denali and Tintina fault systems without any apparent offset, corresponds to a mapped fault system in the Tanacross quadrangle (Foster, 1970) and to an aeromagnetically inferred northeastward extension of the fault system (Griscom, 1976). If extended further to the northeast, it would correspond to the major deflection of the belt of thrust faults, folds, and Cambrian to Jurassic miogeosynclinal deposits in Yukon Territory, marking the northern boundary of the Belt Series middle Proterozoic sedimentary and volcanic rocks and the southern boundary of the late Jurassic and Cretaceous deposits of successor basins (King, 1969).

Lineament H, with a N. 60° E. trend, extends for over 850 km from about 150 km east of Dillingham, Alaska to the central part of the Tanacross quadrangle. This lineament seems to delineate a gravity boundary along its southwestern half (Barnes, 1976a), partially corresponds to the Castle Mountain fault, crosses the Denali fault system without an apparent offset, and corresponds to a mapped fault in the Tanacross quadrangle (Foster, 1970).

Lineament I, with a N. 55° E. trend, is over 600 km long and extends from about 20 km south of Palmer, Alaska, to at least central Yukon Territory. (The northern terminus is beyond the coverage of the Alaska Landsat mosaic.) This lineament crosses both the Denali and Tintina fault systems without any apparent offset and corresponds to mapped faults in the Tanacross quadrangle (Foster, 1970).

Lineament J, with an approximate N. 55° E. trend, is over 850 km long and can be traced from the southwestern tip of Kenai Peninsula, across the Denali fault without any apparent offset, to the Tintina fault in Yukon Territory where it apparently terminates. To the southwest of Kenai Peninsula, the lineament alines with a sharp change in the bathymetry east of Kodiak Island (von Huene and Shor, 1969), indicating that it may extend at least a couple of hundred kilometers into the Pacific Ocean.

Lineament K, with an approximate N. 50° E. trend, is over 1,100 km long and extends from the southwestern side of Kodiak Island, across the Denali fault without any apparent offset, to the Tintina fault in Yukon Territory where it apparently terminates. This lineament is the northwestern boundary of what we interpret below as a probable major northeast-trending fracture or fault zone through the Tanacross quadrangle. On Kodiak Island, lineament K corresponds to a thrust fault mapped by McGee (1972), and on Kenai Peninsula, lineament K corresponds closely to the axis of maximum subsidence caused by the 1964 Alaska earthquake (Plafker, 1969). This lineament also parallels gravimetric contours throughout its length (Barnes, 1976a), corresponds to strong northeast-trending aeromagnetic contours in the Gulkana quadrangle (Alaska Division of Geological and Geophysical Surveys, 1973b), and closely corresponds to an aeromagnetically inferred fault in the Tanacross quadrangle (Griscom, 1976).

Lineament L, with an approximate N. 50° E. trend, is over 1,100 km long and extends from the southern part of Kodiak Island, across the Tintina and Denali fault systems without any apparent offset, to at least central Yukon Territory. (The northern terminus is beyond the coverage of the Alaska Landsat mosaic.) This lineament is parallel to gravimetric contours throughout most of its length (Barnes, 1976a) and corresponds in part to a fault near Prince William Sound inferred by Plafker and others (1975). It also passes through the epicenter of the 1964 Alaska earthquake, in part parallel to the boundary between areas of subsidence and uplift (Plafker, 1969).

Several lines of evidence suggest that the area between lineaments K and L may be a major tectonic break or fracture zone in the Tanacross quadrangle:

1. The zone corresponds well to major breaks in aeromagnetic contours in the Tanacross quadrangle (Griscom, 1976) and to a strong aeromagnetic trend in the Gulkana quadrangle (Alaska Division of Geological and Geophysical Surveys, 1973b).

2. The zone corresponds with major gravimetric contours for most of its length and with a minor gravimetric low in the Tanacross quadrangle inferred by Barnes (1976a, 1976b).

3. The zone is associated with the epicenter of the 1964 Alaska earthquake and with the boundary between areas of uplift and subsidence inferred by Plafker (1969).

4. The zone seems to terminate the Wrangell Mountains, which are located on the southeastern side of the zone as is the area of uplift described by Plafker (1969).

5. The zone parallels and coincides with several faults inferred from aeromagnetic data in the Tanacross quadrangle (Griscom, 1976).

6. The zone contains several faultlike features in the Tanacross quadrangle, visible on conventional aerial photographs, that are parallel to it.

7. The zone contains numerous shorter lineaments observed on Landsat imagery of the Tanacross quadrangle that parallel it.

8. The zone seems to cause the elongation of a nearby major circular feature (6, fig. 5).

9. The zone seems to just miss Prindle Volcano, which shows evidence of a deep connection because of peridotite and granulite inclusions (Foster, 1966; written commun., 1976).

This zone may not be terminated by the Tintina fault in Yukon Territory because lineament L seems to extend across the Tintina fault.

Because of the scarcity of known mineral deposits in the Tanacross quadrangle and the lack of data on those that are known, correlations with lineaments observed on Landsat imagery were not made.

The numerous short lineaments (less than 10 km), together with the relatively few long lineaments that are visible on the horizontal first derivative image, were analyzed as a group by using a diffraction grating (Ronchi ruling) which has a spacing of eight lines per millimeter. As the grating is rotated through 180 degrees, the trends of these lineaments are enhanced when they are normal to the lines of the grating (Offield, 1975). The various trends are plotted on a compass rose (fig. 6) and their intensities subjectively rated from weak to strong. In figure 3, the lineament trends are grouped in 5 degree intervals with the most significant 1 degree trend annotated. In figure 6 on the other hand, the trends are shown as 5 degree intervals (2.5° in each direction) merely for graphic convenience, with the measured trend annotated. Because the short lineaments far outnumber the long lineaments shown on main map, figure 1, the diffraction grating measurements reflect the parallelism of these shorter features without any significant effect from the longer lineaments. Unlike the McCarthy quadrangle where the shorter linear feature (type B) trends did not correlate with those of the longer (type A) linear features (Albert and Steele, 1976), the Tanacross quadrangle shows a strong similarity between both types (fig. 3, 6). Nearly all of the long lineament trends (fig. 3) have corresponding short lineament trends (fig. 6). There are only two major directions of short lineaments that do not correspond to those of the long lineaments: (1) approximately N. 11° W. to N. 21° W., and (2) N. 25° E. to N. 40° E. Short lineaments oriented in these directions may be related to local and regional tectonics in the Tanacross quadrangle or may be related to second order or subordinate lineament directions (Katterfeld, 1976; Thomas, 1976). We believe, therefore, that the structural and tectonic character of the Tanacross quadrangle is more closely related to the longer lineaments and to the regmatic shear pattern than are those of the Nabesna (Albert, 1975) and McCarthy (Albert and Steele, 1976) quadrangles to the south.

Circular features

Numerous circular and arcuate features observed on Landsat imagery of the Tanacross quadrangle are shown on figure 5 of this report. The largest circular feature is approximately 40 km in diameter, and the smallest single circular feature is approximately 4 km in diameter.

On the basis of geology, topography, and surface expression, we have subdivided these circular features into groups that are associated with (1) extensive extrusive features, (2) intrusive rocks, (3) small extrusive features, (4) metamorphic rocks, and (5) topographic depressions.

Circular features 7 and 10 are large (up to 35 km in diameter), nearly circular structures that are associated with the two major extrusive landforms within the quadrangle, Mt. Fairplay and Sixtymile Butte (Foster, 1970). These two circular features largely enclose extensive areas of felsic volcanic rocks, commonly delineating the contact between these rocks and the surrounding metamorphic and granitic rocks, and may represent calderas, which also are suggested by aeromagnetic data (Griscom, 1976).

Circular features 1, 8, 9, 13, and 15 are relatively small (up to 15 km in diameter), elliptical or circular structures, some of which are concentrically arranged. These features are associated with various intrusive bodies, and at least a few of the smaller features in area 1 may correspond to granitic plugs (Foster, oral commun., 1976). We believe that some of the other features in area 1 may also be related to separate episodes of intrusion. Circular features 8, 9, and 13 commonly delineate contacts with other rock types, whereas in area 1 the circular features are largely confined to the hornblende granodiorite phase of the Mesozoic granitic rocks and tend to delineate mineralogical changes within these rocks (Foster, 1976).

Circular features 5 and 6 are concentric, elliptical structures which appear to be associated with small, though mineralogically significant, outcrops of extrusive rocks. Both features are approximately centered on outcrops of felsic volcanic rocks which usually are associated with mineralization in the quadrangle (Singer and others, 1976). Circular feature 5 is an asymmetric structure with concentric arcs extending approximately 10 km to the east but only 2 km to the west. Circular feature 6 is more symmetrical than feature 5, except along the northwest side where it appears to be bounded by the postulated northeast-trending fracture zone formed by lineaments K and L. This boundary is also delineated by a fault inferred from aeromagnetic data (Griscom, 1976). East Taurus, the most geochemically anomalous region within the Tanacross quadrangle, is near the center of circular feature 6, as are several mapped sulfide occurrences (Foster, 1970). Griscom (1976) also describes several aeromagnetic trends and a fault which are subparallel to our conjectured structural axis for feature 6.

Circular features 2, 4, 11, and 14 are solitary, nearly circular features occurring in metamorphic terrane. Feature 2 is slightly elliptical and has two smaller concentric ellipses centered near the Canadian border. Some lithologic boundaries (Foster, 1970) associated with these features include: the contact between a quartz feldspar biotite gneiss, which is encompassed by features 2, and the surrounding granitic rocks; on feature 4 the contacts between a quartz-mica schist unit and a biotite gneiss and schist unit; ultramafic bodies enclosed by feature 14; and the contact between metamorphic and granitic rocks which may be described by the southern outline of feature 11.

Circular features 3 and 12 enclose topographic lows. Although in a mountainous area, feature 3 is lower than the surrounding terrane and does not appear to delineate lithologic contacts. Circular feature 12 generally coincides with the contacts between Cenozoic basalts and the Taylor Mountain batholith, and along its northwestern boundary, between metamorphic and granitic rocks.

Nearly all of the circular features observed in the Tanacross quadrangle, except for features 2, 4, 11, and 16, are associated with igneous intrusive or extrusive rocks. Circular features 2, 4, and 16, however, correspond to covered intrusive bodies inferred from aeromagnetic data (Griscom, 1976). Although circular feature 11 has no apparent association with mapped extrusive or intrusive rocks nor with any inferred covered intrusive bodies, we believe that it is nevertheless likely to be related to a hidden intrusive body because all other circular features in the quadrangle are.

Arcuate features 17, 18, and 19 are systematic sets of curved features which seem to have structural axes and do not seem to close as do circular features. The southern boundary of arcuate feature 17, which is within both metamorphic and granitic rocks, approximately coincides with the contact between granitic rocks and a Paleozoic schist and quartzite unit. The southeastern boundary approximately coincides with the contact between biotite hornblende granodiorite and undifferentiated granitic rocks. The axis of the structure is along the outcrop trend of a Paleozoic schist and quartzite unit. Arcuate feature 18 is a large, well-defined feature with a northeast- to east-northeast-trending structural axis. Most foliations (Foster, 1970) dip away from the axis. The feature is largely within metamorphic rocks, except along its southern boundary near Mt. Fairplay, where we feel it may reflect the structure of the metamorphic basement through the overlying volcanic rocks. To the northwest, feature 18 is abruptly terminated either by circular feature 12 or a fault zone (Foster, 1970; Griscom, 1976). Feature 18 seems to be terminated on the east by a series of north-trending lineaments possibly associated with lineament A. Arcuate feature 19 may be associated with the postulated major northeast-trending fracture zone between lineaments K and L. This association is suggested by our conjectured structural axis for the feature which nearly alines with an aeromagnetically inferred fault (Griscom, 1976) and coincides with lineaments we've observed on Landsat imagery.

Color anomalies

Variations in the spectral responses for rock and soil types are difficult to assess on the computer-enhanced Landsat imagery of the Tanacross quadrangle because the area has such a heavy vegetation cover. In the Nabesna quadrangle (Albert, 1975) and the McCarthy quadrangle (Albert and Steele, 1976) computer-enhanced simulated natural color imagery helped to identify areas of iron-oxide coloration. In the Tanacross quadrangle, however, a similar iron-oxide coloration is present virtually everywhere above the timberline, as well as in wet lowland areas. This coloration is apparently partially caused by vegetation beginning to grow in areas where the snow cover has just melted (Foster, oral commun., 1976) and, particularly in the Alaska Range, by actual iron-oxide colored areas. We are not able, however, to differentiate these two phenomena on the Landsat imagery and are thus unable to map mineralogically meaningful iron-oxide colored areas. Nevertheless, additional computer processing of CCT's could result in the differentiation of these two phenomena.

Vegetation stresses (extraordinary changes in growth characteristics which may be caused by anomalous concentrations of metals) are difficult to distinguish from variations in the vegetation cover caused by numerous forest fire scars, permafrost, and other factors within the quadrangle. Although other color variations are visible on the Landsat imagery, they are mostly related to vegetation changes caused by physiography and seem to have little or no relation to mineralogic changes.

No correlation is evident between color variations observed on Landsat imagery and geophysical data, geochemical data, or known mineral deposits.

CONCLUSIONS

Numerous lineaments recognized in the Tanacross quadrangle can be extended for many hundreds of kilometers, commonly corresponding to geologic, structural, tectonic, and geophysical breaks and trends. The structural and tectonic character of the quadrangle seems to be closely related to the longer lineaments and to the regmatic shear pattern. A major northeast-trending fracture zone and a major east-trending structural or tectonic break, both previously unrecognized, have been postulated. Most circular features are associated with igneous intrusive or extrusive rock types, and those that are not clearly associated with these rock types are probably related to covered intrusive bodies. The significance of arcuate features is unclear, although arcuate feature 18 seems to reflect the structure of the metamorphic basement through overlying volcanic rocks. Color anomalies and iron-oxide colored areas, similar to those described in the Nabesna (Albert, 1975) and McCarthy (Albert and Steele, 1976) quadrangles, are probably present in the Tanacross quadrangle. Because of the heavy vegetation cover and because spectral responses for certain vegetation phenomena are similar to those for iron-oxide areas, we could not specifically delineate any mineralogically significant iron-oxide areas.

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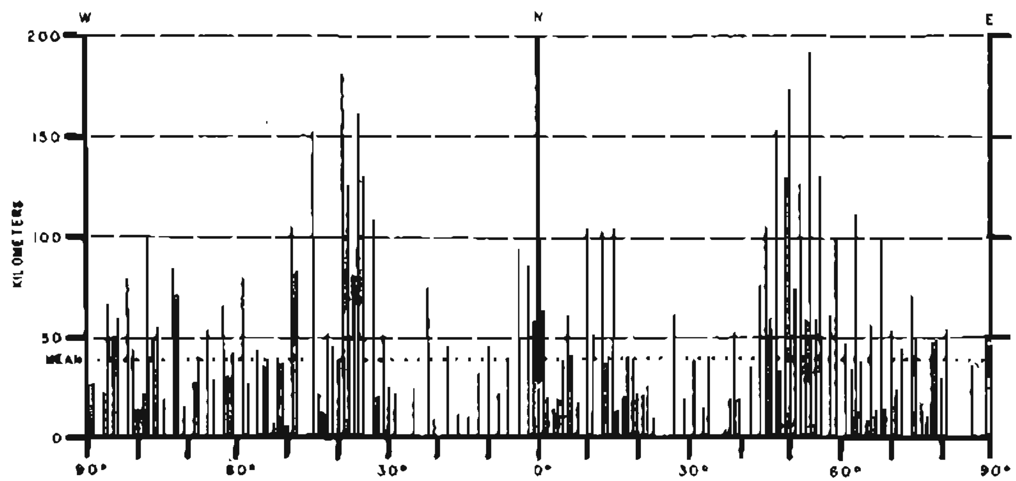

FIGURE 2. - HISTOGRAMS OF TRENDS AND CUMULATIVE LENGTHS OF LINEAMENTS OBSERVED ON LANDSAT IMAGERY OF THE TANACROSS QUADRANGLE.

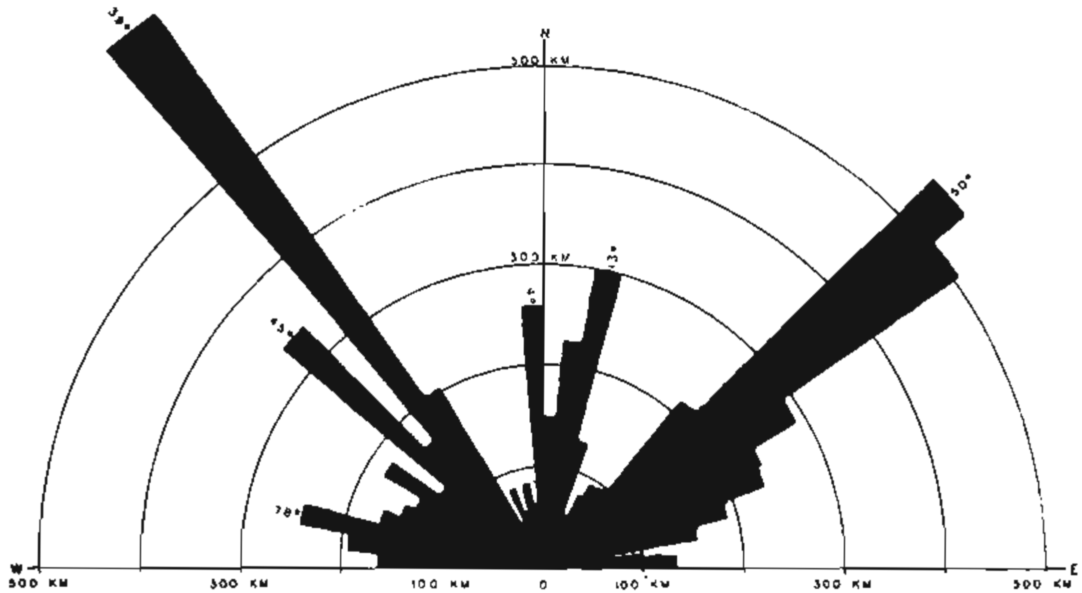

FIGURE 3. – COMPASS ROSE OF TRENDS AND CUMULATIVE LENGTHS OF LINEAMENTS OBSERVED ON LANDSAT IMAGERY OF THE TANACROSS QUADRANGLE.

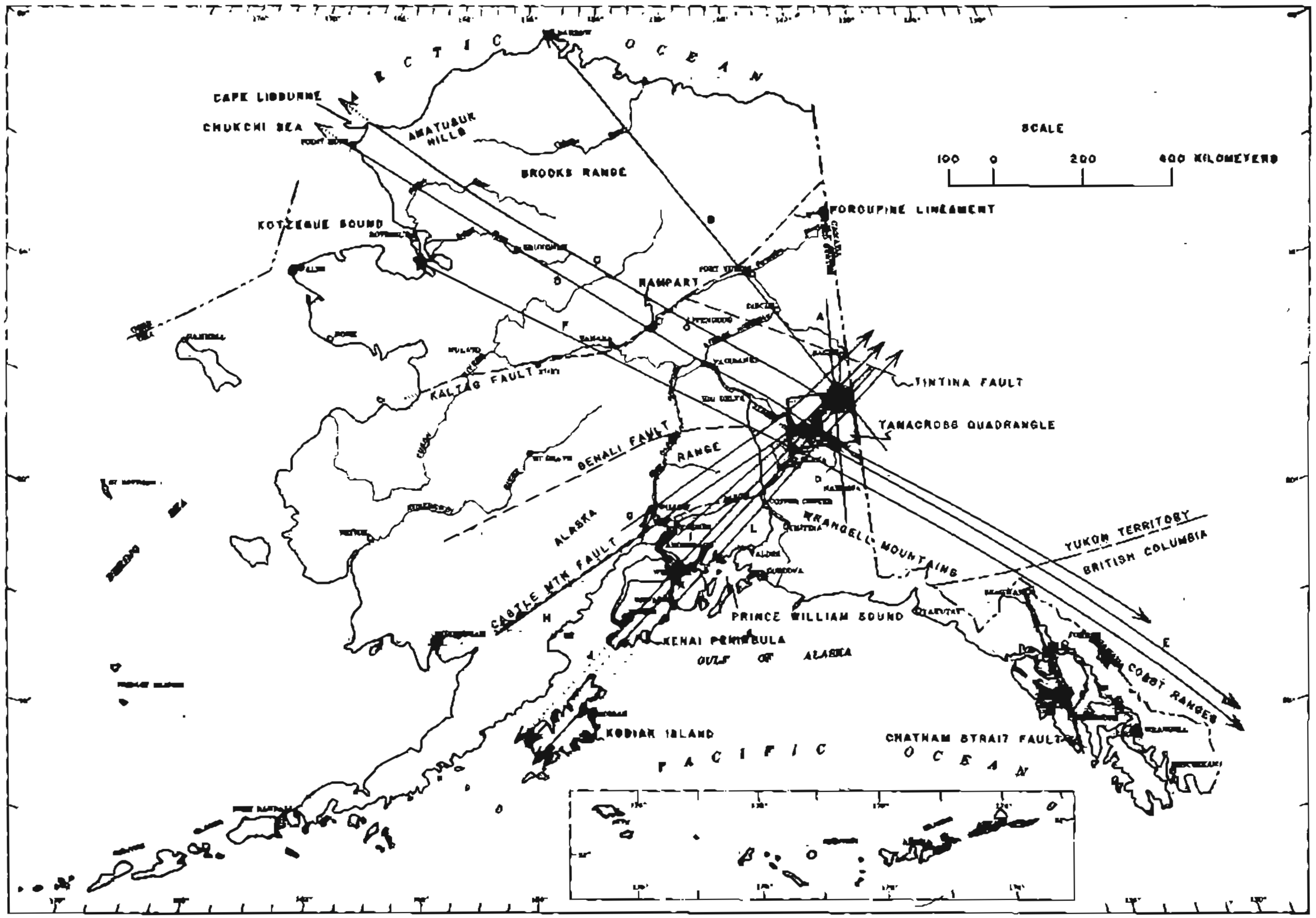

FIGURE 4. - INDEX MAP OF ALASKA SHOWING THE APPROXIMATE LOCATION OF THE TANACROSS QUADRANGLE, AND GEOLOGIC FEATURES, GEOGRAPHIC FEATURES, AND LINEAMENTS OUTSIDE THE QUADRANGLE THAT ARE DESCRIBED IN THE TEXT.

FIGURE 6. - COMPASS ROSE OF THE TRENDS OF LINEAMENTS LESS THAN 10 KILOMETERS LONG AS DETERMINED BY THE USE OF A DIFFRACTION GRATING ON LANDSAT IMAGERY OF THE TANACROSS QUADRANGLE. RELATIVE INTENSITIES ARE SUBJECTIVE.