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GEOLOGICAL SURVEY

Geomorphic domains and linear features on Landsat images, Circle quadrangle, Alaska

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ABSTRACT

A remote sensing study using Landsat images was undertaken as part of the Alaska Mineral Resource Assessment Program (AMRAP). Geomorphic domains A and B, identified on enhanced Landsat images, divide Circle quadrangle south of Tintina fault zone into two regional areas having major differences in surface characteristics. Domain A is a roughly rectangular, northeast-trending area of relatively low relief and simple, widely spaced drainages, except where igneous rocks are exposed. In contrast, domain B, which bounds two sides of domain A, is more intricately dissected showing abrupt changes in slope and relatively high relief. The northwestern part of geomorphic domain A includes a previously mapped tectonostratigraphic terrane. The southeastern boundary of domain A occurs entirely within the adjoining tectonostratigraphic terrane. The sharp geomorphic contrast along the southeastern boundary of domain A and the existence of known faults along this boundary suggest that the southeastern part of domain A may be a subdivision of the adjoining terrane. Detailed field studies would be necessary to determine the characteristics of the subdivision.

Domain B appears to be divisible into large areas of different geomorphic terrains by east-northeast-trending curvilinear lines drawn on Landsat images. Segments of two of these lines correlate with parts of boundaries of mapped tectonostratigraphic terranes. On Landsat images prominent north-trending lineaments together with the curvilinear lines form a large-scale regional pattern that is transected by mapped north-northeast-trending high-angle faults. The lineaments indicate possible lithlogic variations and/or structural boundaries.

A statistical strike-frequency analysis of the linear features data for Circle quadrangle shows that northeast-trending linear features predominate throughout, and that most northwest-trending linear features are found south of Tintina fault zone. A major trend interval of N.64-72E. in the linear feature data, corresponds to the strike of foliations in metamorphic rocks and magnetic anomalies reflecting compositional variations suggesting that most linear features in the southern part of the quadrangle probably are related to lithologic variations brought about by folding and foliation of metamorphic rocks. A second important trend interval, N.14-35E., may be related to thrusting south of the Tintina fault zone, as high concentrations of linear features within this interval are found in areas of mapped thrusts. Low concentrations of linear features are found in areas of most igneous intrusives. High concentrations of linear features do not correspond to areas of mineralization in any consistent or significant way that would allow concentration patterns to be easily used as an aid in locating areas of mineralization.

The results of this remote sensing study indicate that there are several possibly important areas where further detailed studies are warranted.

INTRODUCTION

Landsat images of the Circle quadrangle were studied to identify geomorphic characteristics of the region and to determine trends and patterns of concentrations of linear features as part of the Alaska Mineral Resource Assessment Program (AMRAP). The geologic map by Foster and others (1983), which is part of the Folio of the Circle quadrangle, is to be used in conjunction with this report.

The Circle quadrangle covers part of northeastern Yukon-Tanana Upland in east-central Alaska (fig. 1). North of the upland (pl. 1a) and the Tintina fault zone are the East and West Crazy Mountains; the Yukon River crosses the northeast corner of the quadrangle. The upland is a geologically complex area of Precambrian and Paleozoic metamorphic rocks intruded by granitic plutons of Late Cretaceous and early Tertiary age (Foster and others, 1983). In the northwestern part of the quadrangle are folded and slightly metamorphosed sedimentary rocks of Precambrian(?) and/or Paleozoic age.

Images for a Landsat scene were computer enhanced to aid image interpretation. On the enhanced band 7 image (pl. 1) south of the Tintina fault zone, the Yukon-Tanana Upland can be divided into two geomorphically different domains based on major differences in surface characteristics (pls. 1, 1a). The most southeastern domain is further subdivided by east-northeast-trending curvilinear lines that appear to separate different geomorphic terrains (pls. 1, 1b). North-trending lineaments together with the curvilinear lines form a regional pattern of large-scale east-northeast- and north-trending lines (pls. 1, 1a). As used in this report, the term lineament, adapted from O'Leary and others (1976), describes a linear alinement of geomorphic features that forms a regional break in the terrain, and is transverse to the structural grain of the region.

Linear features mapped from Landsat images were studied using strike-frequency analysis procedures to identify important trends of linear features; maps of spatial concentrations of linear features also were prepared. Linear features as viewed on a Landsat image are defined as straight-appearing topographic features, such as stream valleys, slope breaks, and cliffs; short, alined features are not connected by long interpretative lines. The procedures used in the study of linear features are based on methods summarized by Knepper (1983). Raines and others (1978), Offield and others (1982), and Turner and others (1982), using similar methods, showed correlations of trends and patterns of linear features with igneous rocks, mineralization, and regional geologic structures.

ACKNOWLEDGMENTS

The author is indebted to D. L. Sawatzky for the computer programs used in this study, to D. H. Knepper, Jr., for guidance in applications of computer programs and for many helpful discussions of various aspects of the study, and to J. W. Cady for relevant interpretations of aeromagnetic and gravity data.

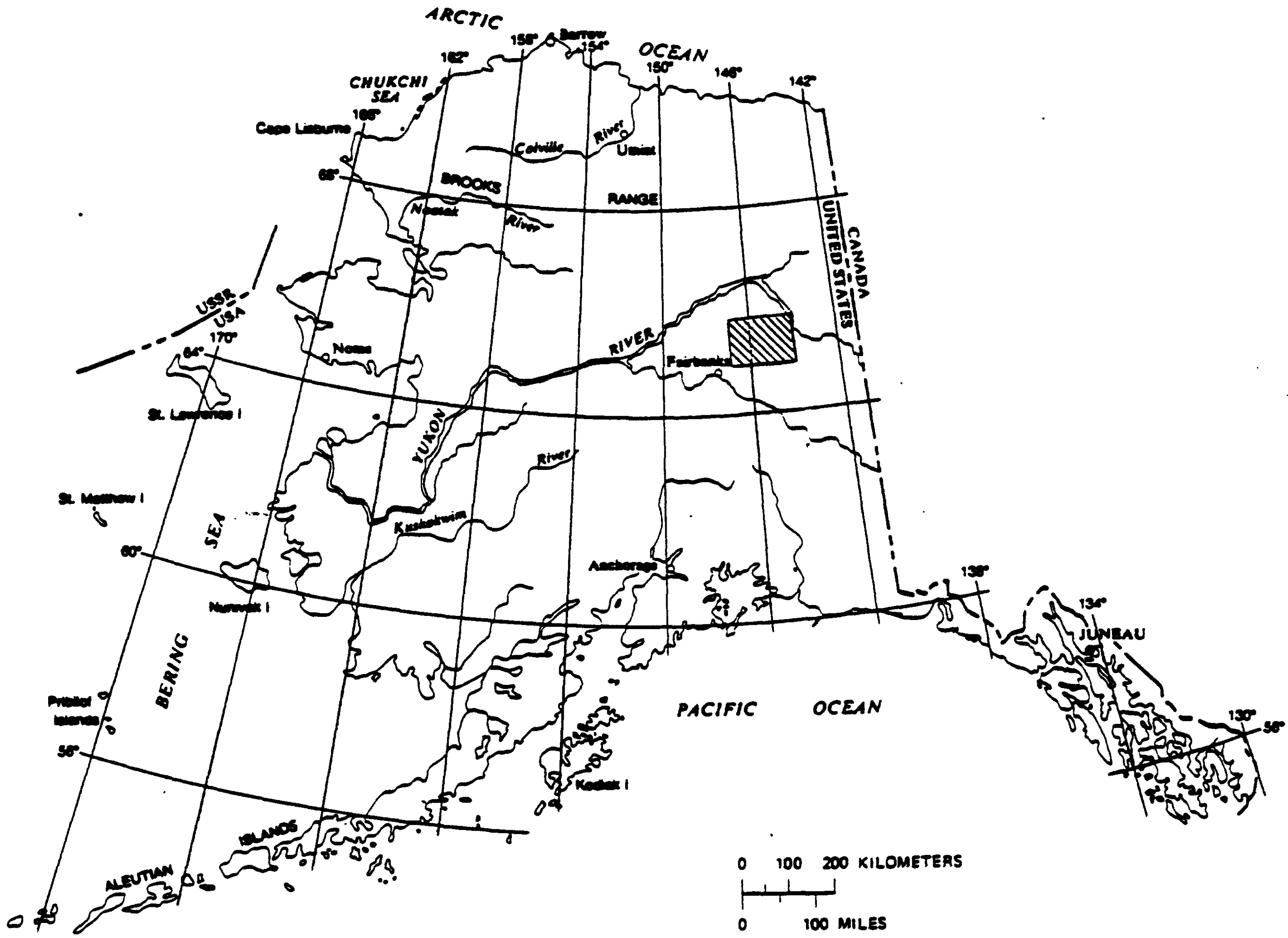

Figure 1. Index map showing location of Circle quadrangle, Alaska.

IMAGE PROCESSING

A computer-compatible tape of multispectral scanner (MSS) data for Landsat scene 2944-20083 (23 August 1977, sun elevation 33°, sun azimuth 151°) was processed by REMAPP procedures (Townsend and Sawatzky, 1976) to prepare enhanced images with optimal contrast for interpretation. The digital numbers for raw Landsat data occupy only from one-fourth to one-half of the dynamic range available from the MSS system; images made from these data have low contrast. Based on histograms of the digital numbers for bands 4, 5, and 7, a one-percent linear stretch was used to increase the contrast of the images. This procedure sets one percent of the digital numbers at each end of the dynamic range to 0 and 255, respectively, and linearly stretches the remaining 98 percent to fill the available range of 0-255 digital numbers. Plate 1 is a contrast-enhanced band 7 image.

Black-and-white positive film transparencies of bands 4, 5, and 7, edge enhanced bands 4, 5 and 7 (Knepper, 1982), and a color-infrared composite of bands 4, 5, and 7 (blue, green, and red, respectively) were prepared at a scale of 1:800,000 for interpretation. All these images were used for geomorphic interpretation and for mapping linear features.

GEOMORPHIC DOMAINS

South of the Tintina fault zone, the Yukon-Tanana Upland can be divided into two geomorphic domains that have major differences in surface characteristics. Domain A (pl. 1, 1a) is characterized by a relatively simple pattern of widely spaced drainages separated by low, rounded ridges; an area of relatively short, closely spaced streams occurs where intrusive rocks are exposed in domain A. In contrast, domain B is predominately characterized by an intricate network of closely spaced streams separated by narrow ridges.

Mt. Prindle and Quartz Creek plutons (fig. 2) separate headwaters of the major streams of domain A, Preacher Creek and Beaver Creek (pls. 1, 1a). Stream patterns formed by headwaters of the two creeks are strikingly different although both are eroding predominately Precambrian and Paleozoic quartzite and quartzitic schist (Foster and others, 1983). Preacher Creek, with a ladle shape, has headwaters in a large bowl-shaped area rimmed by igneous intrusives. Within the ladle are two mountains with elevations of 3,463 ft and 4,065 ft around which Preacher Creek and its tributaries curve.

North tributaries to Beaver Creek (fig. 3) exhibit modified dendritic patterns. West of the Circle-Livengood quadrangle border, starting with Ophir Creek, major tributaries on the south of Beaver and Nome Creeks trend northeast rather than northwest as would be expected in a dendritic stream pattern (fig. 3), suggesting structural control (Ollier, 1981, p. 161). Barbed drainage patterns develop when tributaries to a reversed stream flow in their original directions but turn back abruptly when joining the main stream (Ollier, 1981, p. 1760). South tributaries of Beaver and Nome Creeks in Livengood quadrangle exhibit barbed drainage, but north tributaries do not. Nome Creek and other tributaries of Beaver Creek in Circle quadrangle are dendritic so reversal of Beaver Creek is unlikely. In Livengood quadrangle, a short stretch of anomalous trending south valleys of Beaver Creek lies approximately along the mapped boundary (fig. 3) between Cambrian(?) grit, quartzite, slate, and argillite that form prominent ridges, hills, and ledges,

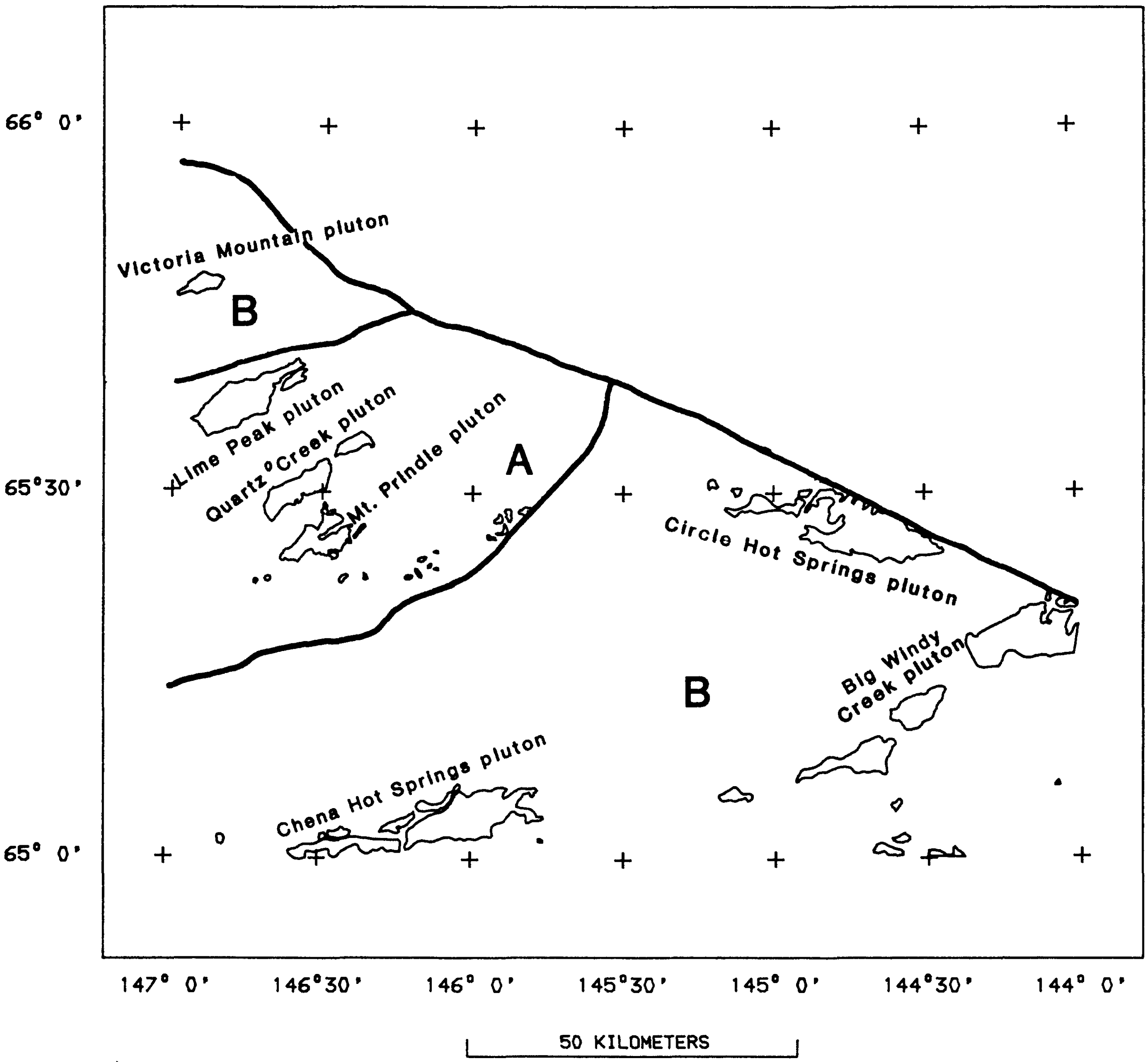

Figure 2. Map of igneous intrusives from Foster and others (1983). Heavy lines are geomorphic domain boundaries from plate 1a.

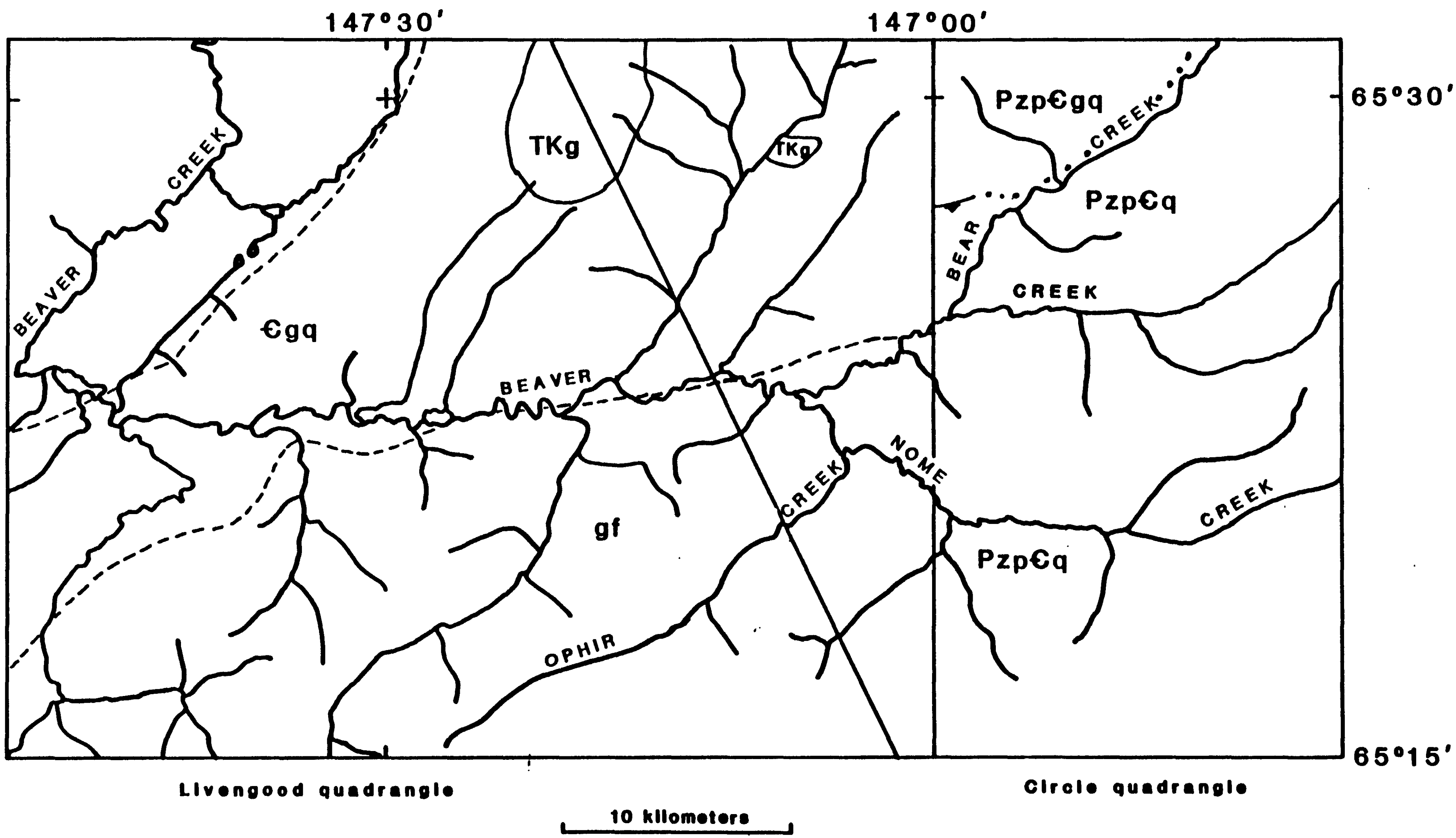

Figure 3. Map of Beaver Creek drainage system. Greenschist facies (gf), granitic rocks (TKg), and the approximate contact of grit and quartzite (€gq) are from Chapman and others (1971). Fault contact between quartzite (Pzp€q) and grit and quartzite (Pzp€gq) is from Foster and others (1983). Solid line is approximate location of part of a cross section from figure 2 from Churkin and others (1982).

and a pre-Silurian greenschist facies with the greenschist facies mapped as grading upward into the Cambrian(?) grit and quartzite (Chapman and others, 1971). An interpretation by Churkin and others (1982) postulates a major structural break separating Beaver and Yukon crystalline terranes (fig. 4). A northwest cross section (Churkin and others, 1982) crossing Beaver Creek in the area of the anomalous trending valleys (fig. 3) shows Yukon crystalline terrane thrust over Beaver terrane. This trust fault would explain the anomalous northeast-trending valleys south of Beaver Creek.

The headwaters of Beaver Creek in domain A appear to be eroding an erosional surface, the southern margin of which is receding northward because of headward erosion by north tributaries of Chatanika River that threaten the Beaver Creek drainage (pls. 1, 1a). The north tributaries form a distinctive erosional pattern (pl. 1), that follows the border of the surface and that can be traced into Livengood quadrangle; the erosional pattern of south tributaries of Chatanika River is characteristic of domain B. The area adjacent to Circle quadrangle on the west was viewed on an enhanced Landsat image not included in this report. The image showed that the characteristic terrain of domain A forms a northeast-trending zone that is bounded on both sides by the intricately dissected terrain of domain B and that can be traced northeast from south-central Livengood quadrangle to the Tintina fault zone. A linear alinement of igneous intrusives trends N.25W. across the anomalous zone of domain A (fig. 2).

Figure 4 shows boundary relationships between White Mountains and Beaver terranes (Churkin and others, 1982) and geomorphic domains A and B. Terranes are identified on the basis of lithology and structural style distinctive within each terrane, and boundaries between terranes are abrupt (Churkin and others, 1982). The boundaries between domains A and B are determined on the basis of major regional differences in surface characteristics seen on Landsat images as discussed above. Dash/dot lines within domain A (fig. 4) enclose a generalized area of igneous outcrops that was mapped on Landsat band 7 (pl. 1). As stated earlier the outcrops separate drainages of Preacher and Beaver Creeks in Circle quadrangle. The contrasting erosional style of Preacher and Beaver Creeks suggests a natural subdivision by the zone of igneous outcrops of geomorphic domain A into areas a1 and a1 (fig. 4). the border of a2 (fig. 4) approximates the northeast boundary of Churkin's (1982) Beaver terrane.

Domain A includes the area of Beaver terrane (fig. 4). Sections of the northwestern boundaries of the two differently defined areas, as far as domain A can be traced into Livengood quadrangle on the Landsat image, correlate well. Churkin and others (1982) state that the contact of Beaver with Yukon crystalline terrain (Y_2) is poorly exposed. Correspondingly, this boundary is not seen on Landsat images, (pl. 1), and both terranes are contained in domain A. The southeastern boundary of domain A (pls. 1, 1a) occurs entirely within the Yukon terrane. The southeastern boundary of domain A coincides in part with fault 1 (fig. 5), and correlates with mapped thrusts along Chatanika River (Foster and others, 1983). The sharp geomorphic contrast along the southeastern boundary of domain A and the existence of known faults along this boundary suggest that the Yukon terrane may be further subdivided. Detailed field studies would be necessary to determine the characteristics of the two subdivisions.

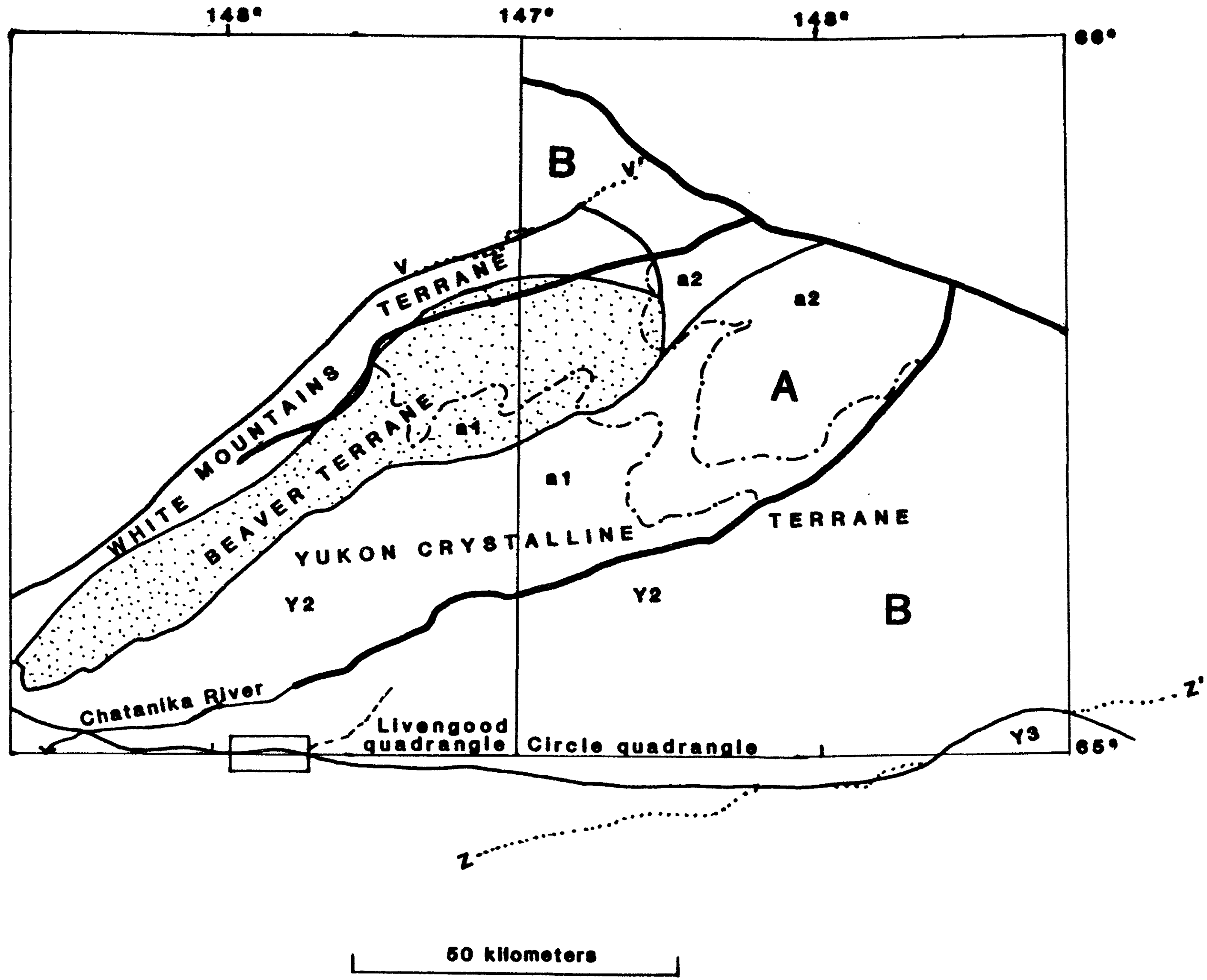

Figure 4. Map showing relationships of boundaries of tectonostratigraphic terranes (Churkin and others, 1982) and geomorphic domain A (heavy line). a1-a2 are subareas of domain A. Y_2-Y_3 are subterranes of Yukon crystalline terrane. Dash/dot lines enclose generalized areas of igneous outcrops mapped from Landsat. Dotted curved lines are from plate 1b. Dashed line is a structural contact from Landsat image (pls. 1,1a).

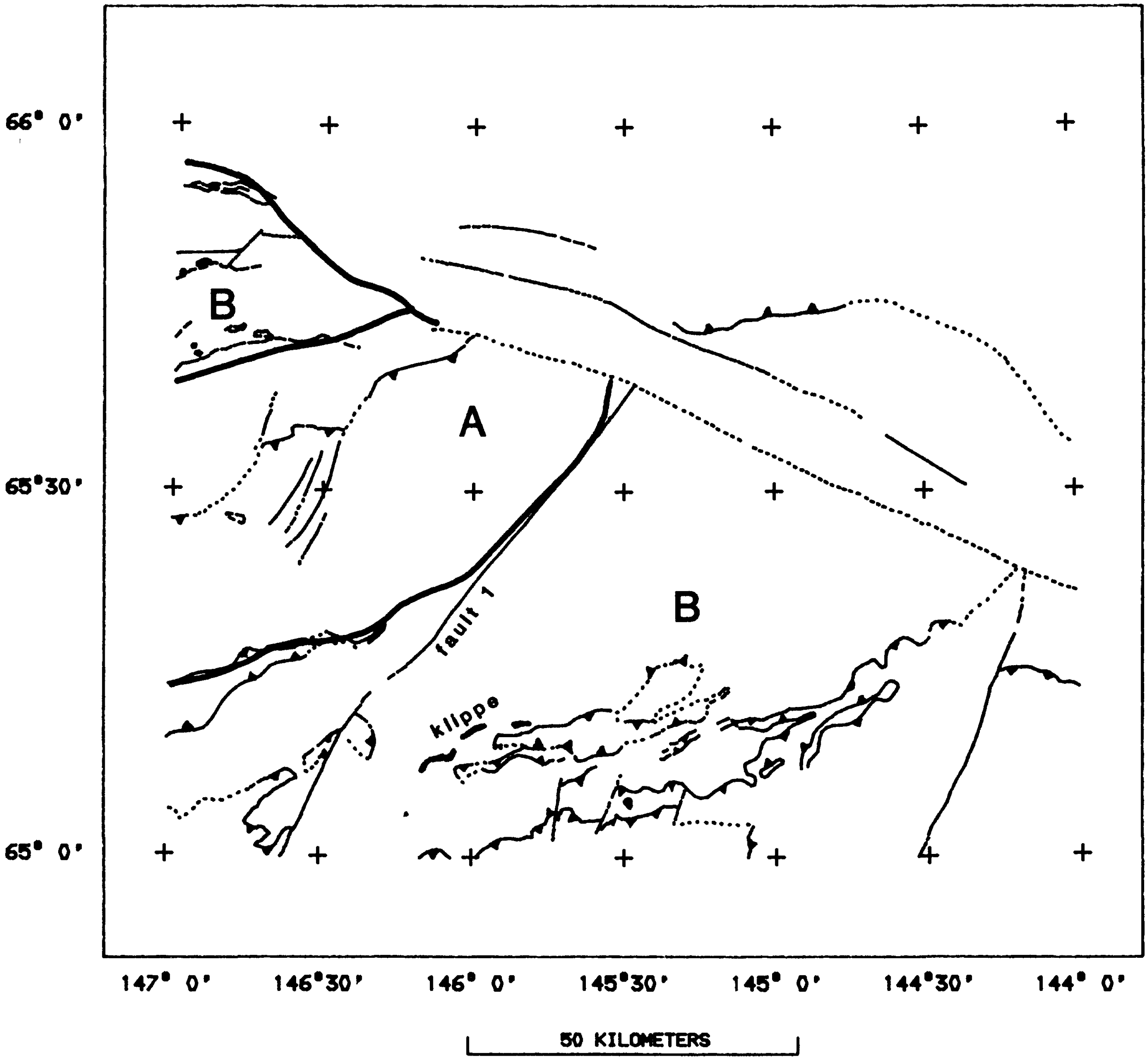

Figure 5. Map showing geomorphic domain boundaries and location of faults from Foster and others (1983).

East-northeast-trending curvilinear lines drawn along prominent valleys or connecting valleys appear to separate large areas of different geomorphic terrains in domain B in the southern part of the quadrangle (pls. 1, 1b). Line w-w′ (pl. 1a, 1b) coincides with the western boundary of geomorphic domain B (southeast) and has been discussed above. In domain B in the northwestern part of the quadrangle, line v-v′ (fig. 4) correlates with a segment of the northwest boundary of White Mountains terrane (Churkin and others, 1982). Line z-z′ correlates in part with the boundary between Yukon crystalline terrane Y_2 and Y_3 (fig. 4).

Several prominent north-trending lineaments are shown on plate 1b; some lineaments cut across the curvilinear lines and others do not. The term lineament, adapted from O'Leary and others (1976), is used here to describe a linear alinement of geomorphic features that forms a regional break in the terrain and is transverse to the structural grain of the region. The north-trending lineaments occur at high angles to the general east-northeast-trending curvilinear lines separating different geomorphic terrains. Although offset of ridges north of Birch Creek can be detected along lineament 3 on the Landsat images (pls. 1, 1b), detailed field studies would be necessary to evaluate the possible structural signficance of the lineaments.

LINEAR FEATURE ANALYSIS

A linear features map was made to study trends and patterns of concentrations of linear features that might contribute to understanding the geology of the region. To prepare a linear features map using all of the processed images, linear features were mapped by standard photogeologic methods on a transparent overlay that was transferred from image to image. Linear features were drawn on straight appearing topographic features, such as stream valleys, slope breaks, and cliffs; for consistency a straight valley rather than the adjacent parallel straight ridge was mapped. Short alined features were not connected by long interpretative lines.

The final digitized linear features map is suitable for statistical analysis. A statistical strike-frequency analysis procedure was used to determine important azimuthal trends in the linear features data (Sawatzky and Raines, 1981). The number, or frequency, of linear features trending in each of 180 1-degree classes was determined, and the frequencies were compared to the mean frequency of the 180 classes. Frequencies near the mean have low significance value, and as the frequency deviates from the mean, the significance value increases. The strike-frequency curve for the Circle data set is shown in figure 6. Only major azimuthal intervals with frequencies above the 90% significance value are listed in table 1. Generally, northeast-trending features predominate in Circle quadrangle, although north, east-west, and two northwest intervals occur with frequencies well above the mean (fig. 6).

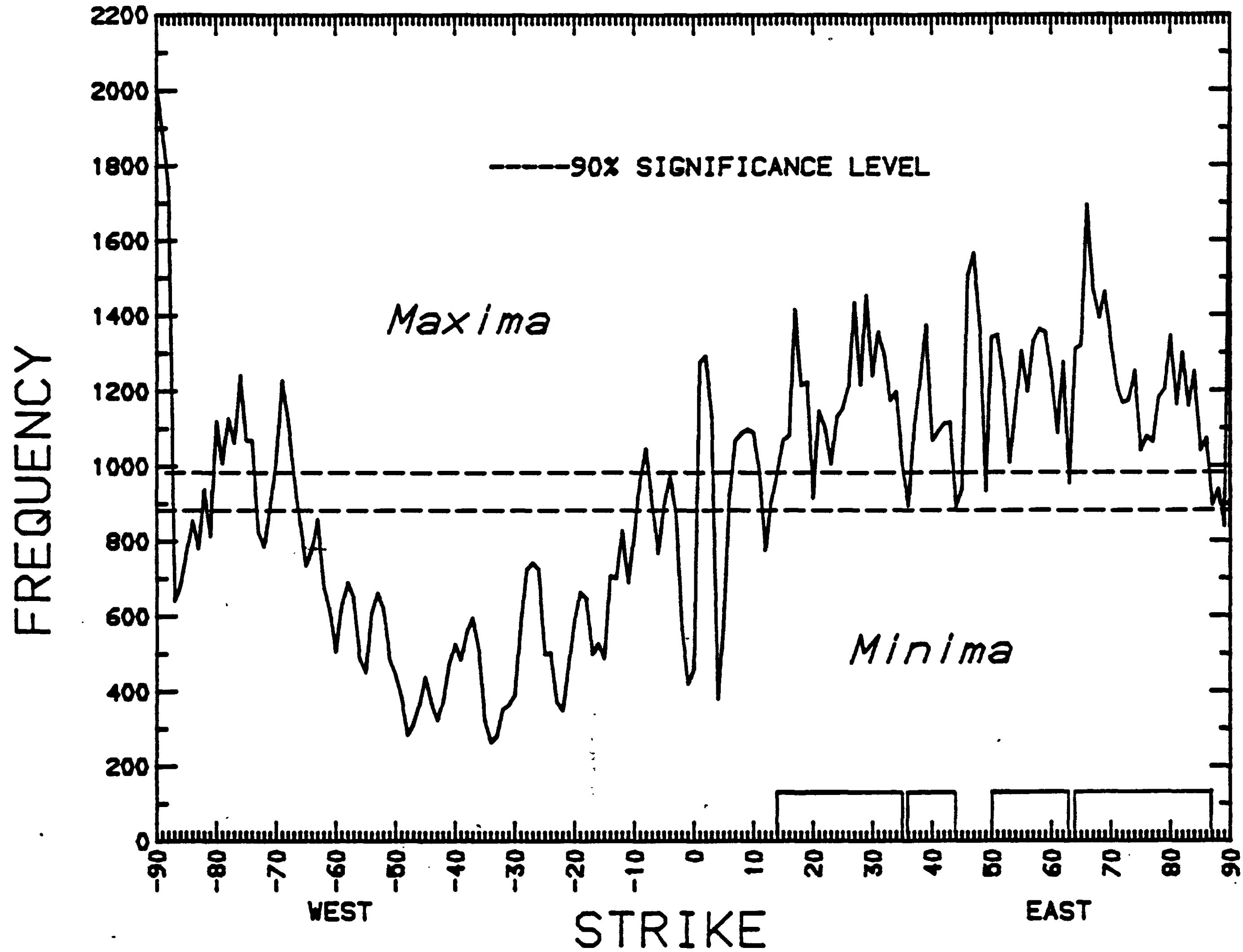

Figure 6. Strike-frequency histogram of linear features mapped on Landsat images.

Table 1.--Azimuthal intervals with frequencies above the 90% significance value determined by strike-frequency analysis

Major interval	Subdivision	Width(degrees)
N.0-3E.		3
N.6-11E.		5
* N.14-35E.		21
* N.36-44E.		8
N.45-49E.		4
* N.50-63E.		13
* N.64-87E.		23
	*N.64-75E., *N.76-87E.	
N.89-90E., N.87-90W.		4
N.7-9W.		2
N.67-70W.		3
N.74-81W.		7

* Discussed in report.

Maps of linear features within all azimuthal intervals with frequencies above the 90% maxima were plotted and compared with aeromagnetic and gravity maps (Cady and Weber, 1983) and with geologic maps (Foster and others, 1983; Menzie and others, 1983). Linear features maps included in the report are scaled at 1:1,000,000 to match the scale of the Landsat image in plate 1. Plate 2 is a composite of linear features on a generalized geologic base (see Foster and others (1983) for detailed geologic map) at the scale of 1:250,000.

Linear feature patterns and concentrations

Figure 7 is a linear features map showing a generalized interpretation of the various linear features density domains south of Tintina fault zone. Figure 8 is a contour map of the relative concentration of these linear features and shows the internal variations of concentration within each of the domains. Figure 9 shows the relationship between the density domains and the major faults of the quadrangle.

In figure 7, A1 and A2 approximately correspond to domain A on plate 1a, where A2 includes the upper drainage basin of Preacher Creek and A1 the upper drainage basin of Beaver Creek. B1 and B2 (fig. 7) approximately correspond to the southeast geomorphic domain B (pl. 1a), except along Chatanika River. Within B1 (fig. 8) elongate concentrations of linear features form subparallel linear zones that trend N.48-54E. and a zone trending N.45-50W. The northern outline of these intersecting zones forms the boundary between B1 and B2 (fig. 8).

On the northern part of the Landsat image (pls. 1, 1a) west of Yukon River, the terrain is divided by Beaver and Preacher Creeks into three, irregular-shaped areas with trends of drainage unique within each area. The Landsat image in north Circle quadrangle shows mostly northeast-trending streams, and generally northeast linear feaures were mapped on straight segments of these streams. Trends of northeast-trending linear features (fig. 10) within the three areas in Circle quadrangle were measured. Northeast-trending

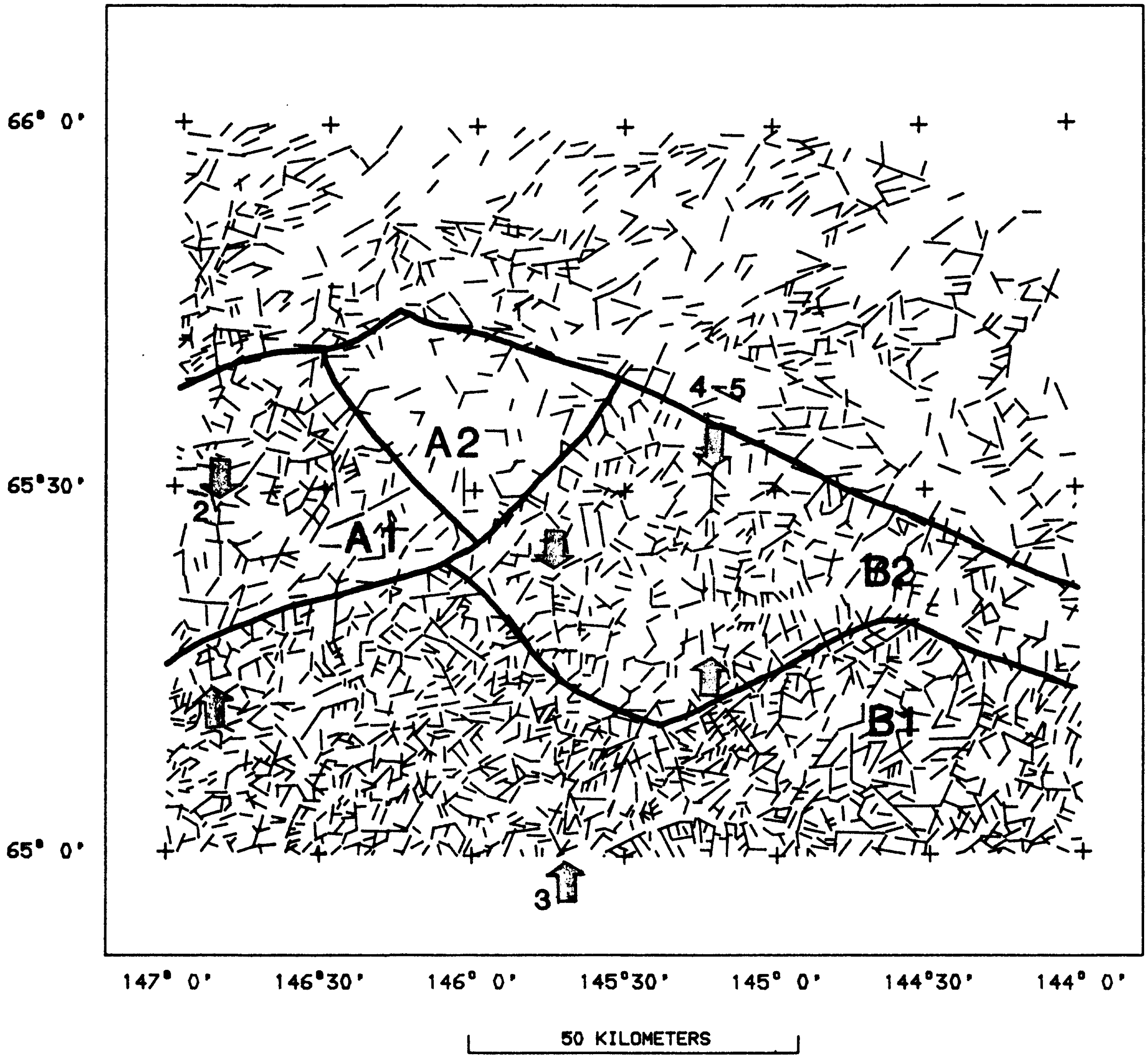

Figure 7. Map of interpreted relative density domains of linear features. Arrows mark alinements of linear features.

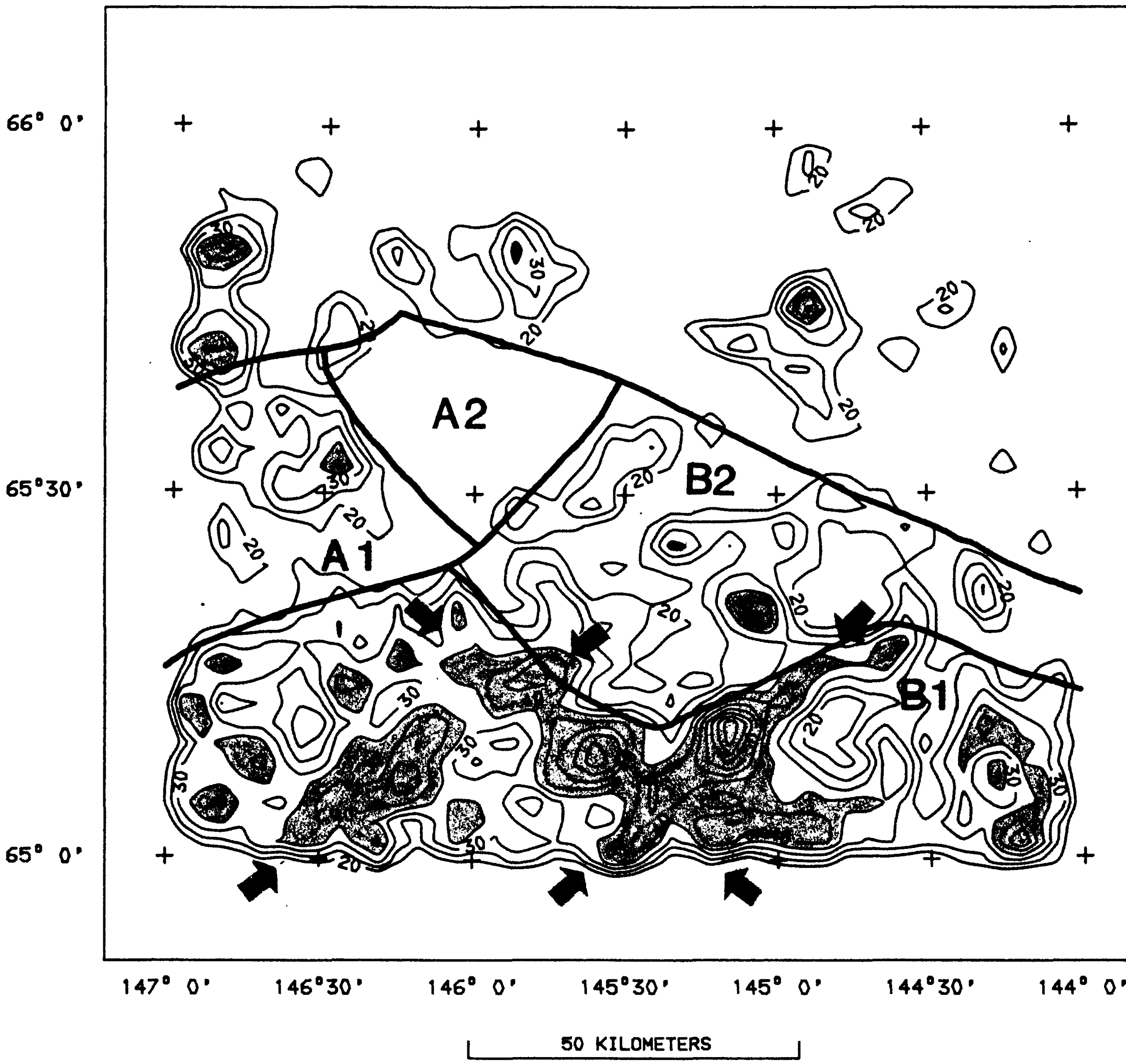

Figure 8. Contour map of concentrations of all linear features showing density domain boundaries from figure 7. Arrows mark linear trends of concentrations.

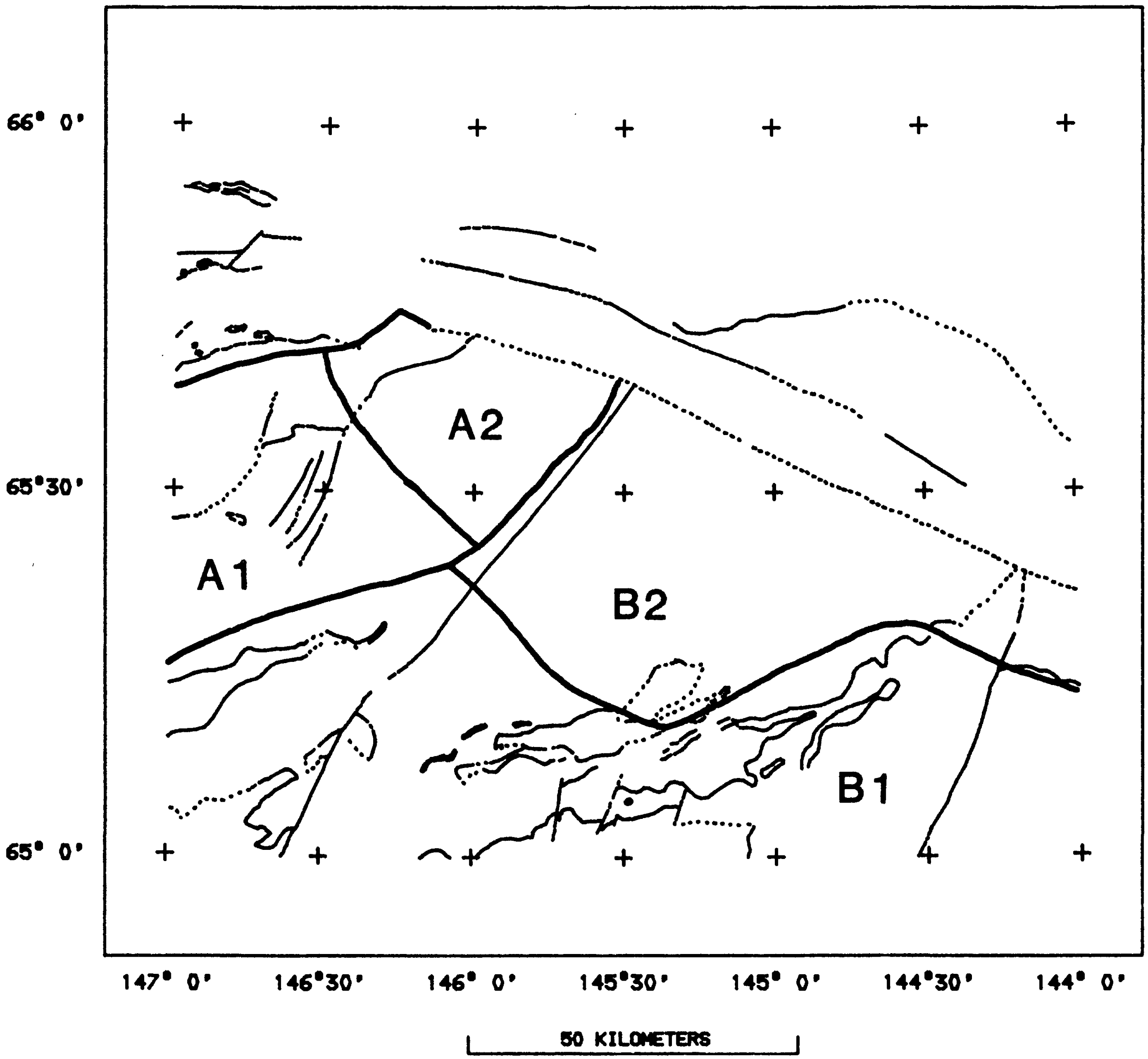

Figure 9. Map showing density domain boundaries from figure 7 and faults from Foster and others (1983).

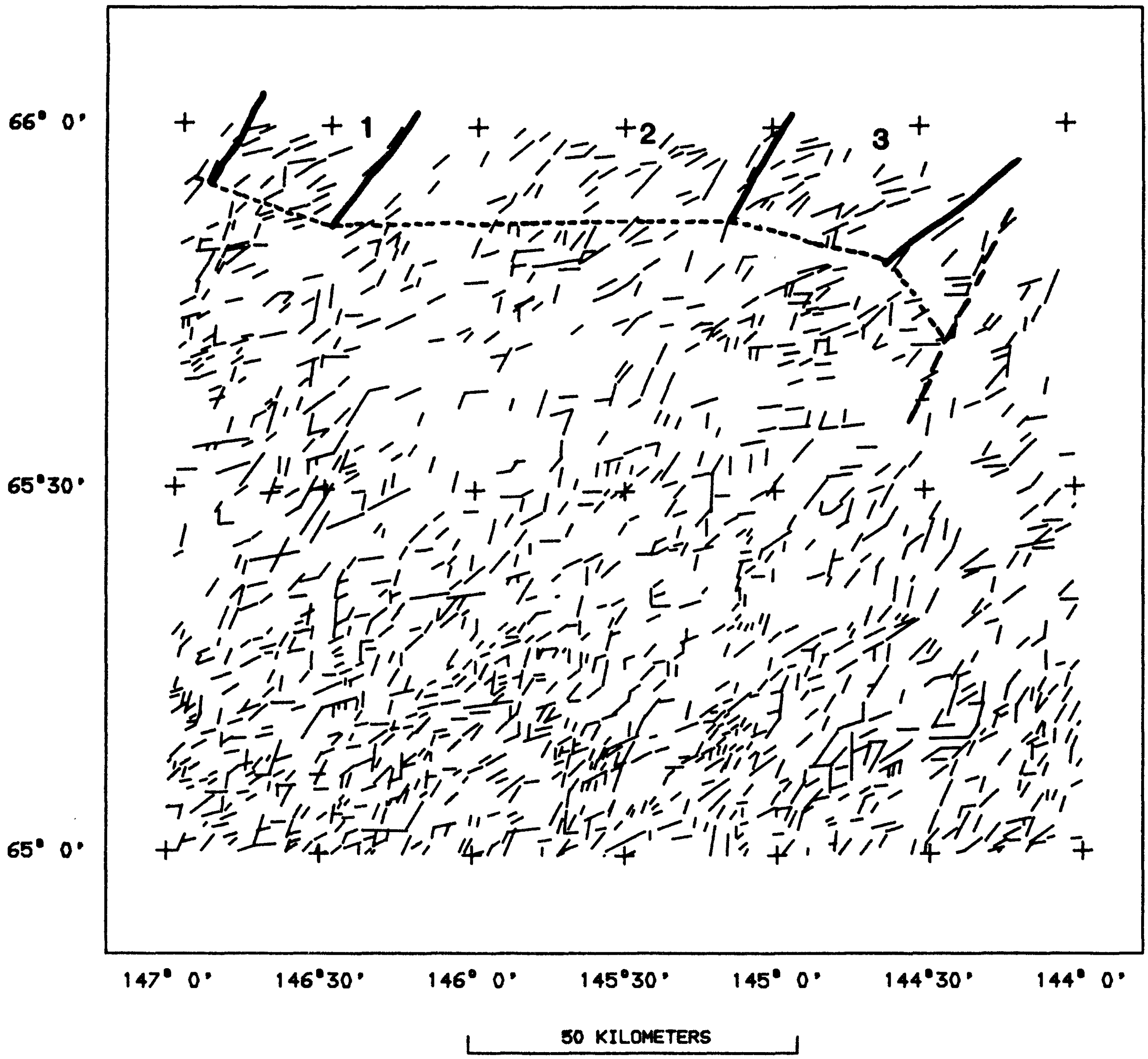

Figure 10. Map of northeast-trending linear features (N.0-90E.) showing three areas of trend domains in the northern part of Circle quadrangle. Dashed line is northern boundary of mountainous terrain. Heavy dashed line is mapped fault, from Davies (1972). Area 1-N.60E., area 2-N.49E. and minor N.77E., and area 3-N.71E. and minor N.52E. and N. 26E.

linear features that lie east of Big Creek in northwest Circle quadrangle (fig. 11) and north of mountainous terrain (fig. 10) have different average trends in the three areas defined by Big, Beaver, Preacher, and Birch Creeks (fig. 11).

Between Big and Beaver Creeks (area 1), the majority of linear features have an average trend of N.60E. (fig. 10). A lower density of linear features and a change in average trend to N.49E., with a minor trend of N.77E., characterizes the area between Beaver and Preacher Creeks (area 2). North of Big Creek (two creeks have the same name), between Preacher and Birch Creeks (area 3), the major trend is N.71E. with two minor trends of N.52E. and N.26E.

The pronounced northeast trends of streams north of mountainous areas in northern Circle quadrangle are markedly transverse to the north regional slope. Loess has been mapped throughout the northern part of the quadrangle (Foster and others, 1983), and the aeromagnetic map shows no evidence of northeast-trending lithologic discontinuities (Cady and Weber, 1983). Detailed structural mapping has not been done over the region, but in area 3 an inferred northwest fault (pl. 2) was mapped along the northwest-trending stream north of Big Creek (fig. 11). Davies (1972) mapped a northeast-trending fault trending partly along the valley of Birch Creek east of area 3 (fig. 10). There is no geologic mapping that supports the interpretation that there may be structural control of the northeast-trending streams, either regionally or locally; nevertheless, the strong northeast trends are anomalous in the region.

Although northwest-trending linear features make up a small portion of the total data set, the regional concentration pattern is of interest. Relatively few northwest-trending linear features are found north of Tintina fault zone (fig. 12); except in the vicinity of East and West Crazy Mountains (pl. 1a) where trends are north-northwest and west-northwest, respectively. The solar illumination of Landsat (N.29W. for the Circle scene) tends to subdue topographic features paralleling this direction, which results in fewer northwest linear features being mapped; but this does not account entirely for the low density of northwest-trending linear features in the north. A mosaic of south-looking radar, scale 1:250,000, shows a small-scale pattern of northwest linear tributary streams not visible on 1:800,000-scale Landsat images. A map of linear features made from the radar data north of Tintina fault zone confirms the results from Landsat that relatively fewer northwest-trending linear features occur north of Tintina fault zone. The geologic significance of this observation is not known.

GEOLOGIC RELATIONSHIPS

Structure and lithology

On plates 1 and 1a in domain A, an alinement (1) of north-south linear features paralleling the Circle-Livengood quadrangle border extends from north of Beaver Creek south to the Chatanika River. To the east a second alinement (2) parallels alinement 1 and also extends south to Chatanika River. The pronounced changes in topography across alinement 1 possibly may be due to a change in lithology; the straight stream segments of alinement 2 suggest control by faulting.

In the southeastern domain B an alinement of linear features (3 on pl. 1,

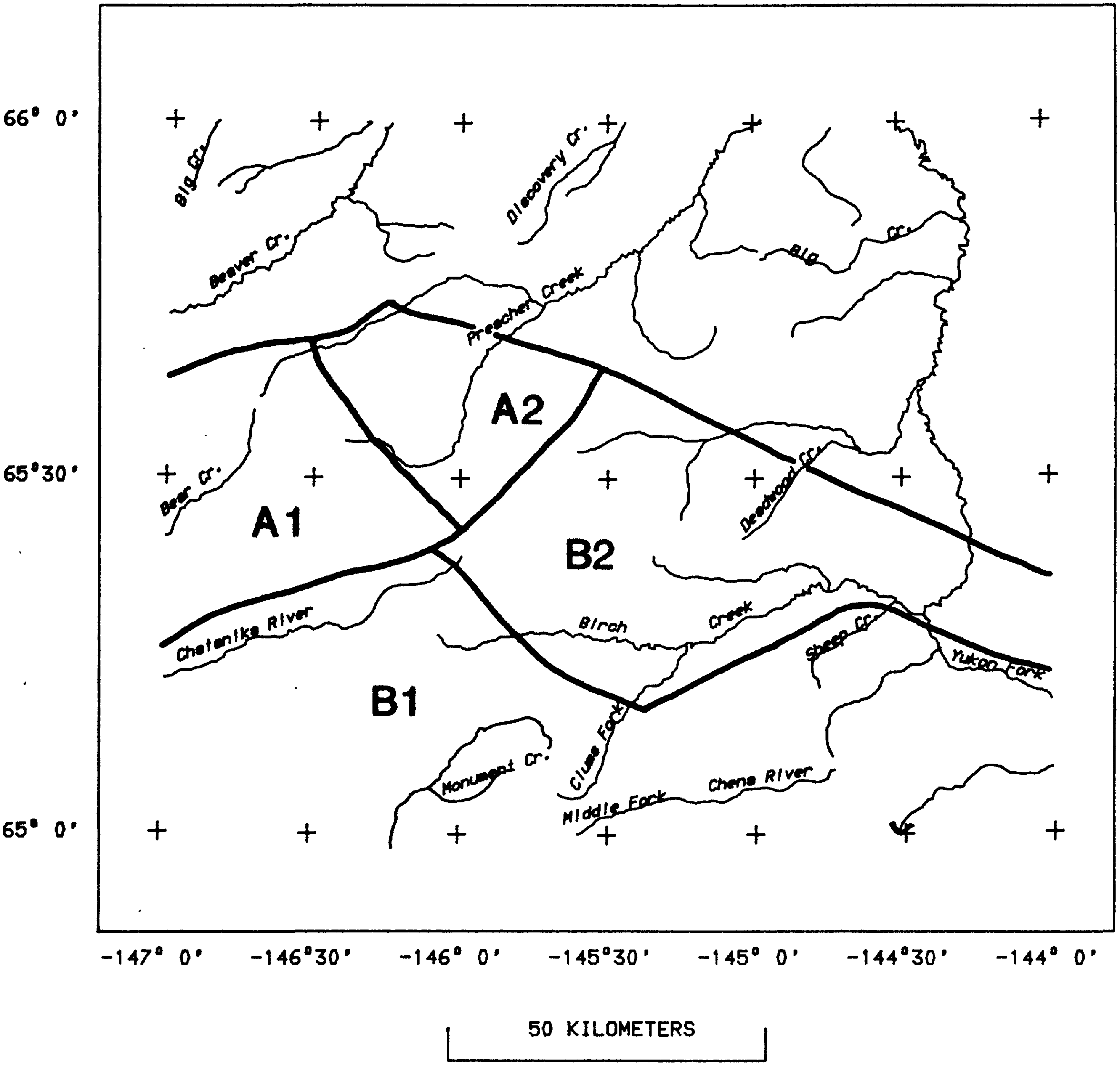

Figure 11. Map of selected streams and density domain boundaries from figure 7.

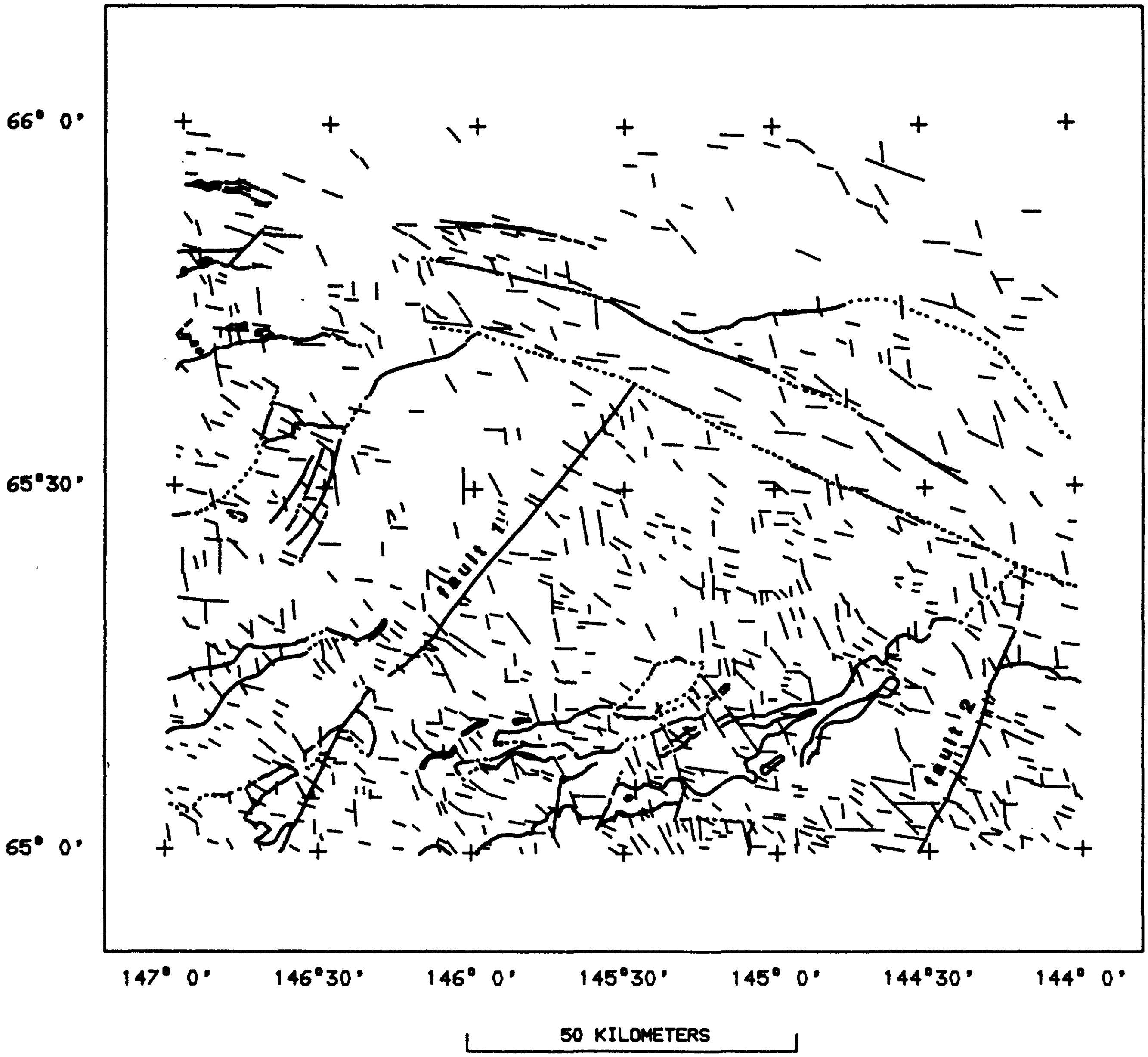

Figure 12. Map of northwest-trending (N.0-90W.) linear features and faults from Foster and others (1983).

1a) crosses Birch Creek at a change in trend of the valley, and extends as far south as the Middle Fork of the Chena River. The alinement marks a linear topographic discontinuity across which topographic patterns change. North of Birch Creek the discontinuity may be related to faulting as ridges on the west side of the discontinuity are offset from those on the east side. South of Birch Creek the discontinuity follows a metamorphic facies change in Paleozoic and Precambrian quartzite and quartzitic schists, and continues across two thrust traces that bound an area of Paleozoic quartzite (Foster and others, 1983). The discontinuity can be traced across a thrust front just north of the Middle Fork of the Chena River.

Two closely parallel alinements (4, 5 on pls. 1, 1a) of north-trending linear features bisects area B2 of domain B (fig. 6). Alinement 4 begins along a straight stream segment and ends at Birch Creek (pls. 1, 1a). North of Birch Creeks alinement 4 marks the abrupt terminous of two ridges (pls. 1, 1a) that trend east from the alinement; the middle part of the alinement is along straight stream segments. Alined straight stream segments make up alinement 5, the north half of which separates areas of different topography.

The southern end of alinement 4 forms part of the eastern boundary of an oval-shaped area of lower density of linear features (fig. 7) that is just north of the V-shaped boundary of B1-B2. Terrain within this oval-shaped area appears to differ from terrain in surrounding areas (pl. 1). Mapped thrusts correlate with part of the western leg of the V-shaped boundary (fig. 7), and a thrust fault along Clums Fork (fig. 11) forms the lower eastern margin of the oval-shaped area (fig. 7).

Northwest linear features (fig. 12, pl. 1a) intersect some thrust traces in domain B (southeast). Clusters of northwest linear features intersect regional faults 1 and 2 at high angles (fig. 12). Numerous northwest linear features parallel or coincide with the main faults bordering Tintina fault zone.

Detailed mapping needed to establish the hundreds of small high-angle faults that probably exist in the quadrangle (Foster and others, 1983) is yet to be done, so the extent, and therefore the significance, of relationships of all linear features to faulting cannot be determined, but possible correlations should not be ruled out.

Trends of the curvilinear lines shown on plate 1b approximate the northeast structural grain of the region, and are subparallel to trends of the mapped thrusts (fig. 5) that lie south of lines w-w′ and x-x′ (pl. 1b). Lines w-w′ and y-y′ are closely associated with mapped thrusts; lines x-x′ and z-z′ generally do not coincide with lithologic boundaries mapped by Foster and others (1983). As previously discussed, line z-z′ corresponds in part with the boundary between Yukon crystalline terranes Y_2 and Y_3 (Churkin and others, 1982). In the area of the box outlined on figure 4, the contact between Y_2-Y_3 lies along a structural break clearly visible on Landsat (pls. 1, 1b) The structural break can be traced to the northeast as shown by the dashed line on plate 1b and figure 4.

The area of highest concentrations of linear features, which is found in density domain B1 (fig. 8) corresponds to a broad gravity low that is caused by low density crust of the Yukon crystalline terrane (Cady and Weber, 1983). The low concentration of linear features at long 144°30′-145°W., lat 65°-65°15′N. coincides with an area of lowest gravity, which contains exposed (fig. 13) and inferred granitic intrusives (Cady, and Weber, 1983).

In the southern part of the quadrangle, the area of high concentration bounded on the north by number 20 contour in figure 13 corresponds to a region of aeromagnetic highs (Cady and Weber, 1983) that have trends of approximately N.65-75E. Strike frequency analysis of only northeast-trending linear features located in this same area showed the major trend to be N.64-72E., which is within the range of trends for aeromagnetic highs. This trend interval of N.64-72E. approximates a subdivision of the broad, major trend interval of N.64-87E. (table 1), which is based on all linear features for Circle quadrangle. Cady and Weber (1983) interpret northeast- to east-northeast-trending magnetic highs and lows as reflecting compositional variations in Paleozoic to Precambrian metamorphic rocks and syntectonic granitic rocks. Linear features reflect structures and/or erosional enhancement of lithologic contacts. Generally, linear features were mapped on drainages possibly channeled by foliation. Linear features within the trend interval of N.64-72E. closely parallel trends of mapped foliations in metamorphic rocks (Foster and others, 1983) in the southern part of the quadrangle. Generally there is correspondence of trends of foliation, magnetic anomalies indicating compositional variations, and linear features throughout the area. Therefore, most of the northeast-trending linear features, especially in the interval of N.64-75E., in the southern part of the quadrangle probably are related to lithologic variation brought about by folding and foliation of the metamorphic rocks.

Concentrations of linear features in the second, broad trend interval N.14-35E. (table 1) appear to correlate with some mapped thrust faults (Foster and others, 1983) in domain B in the southern quadrangle (fig. 14). Five high concentrations of linear features are just north of lat 65°N. Four concentrations (1, 2, 3, 5) correspond to areas of mapped thrust faults, but concentration 4 is in an area of unresolved geology (Foster and others, 1983). Anomalous drainage patterns along the southern end of linement 6 (pls. 1, 1b) coincide with concentration 4 (fig. 14). Of all the other northeast intervals, spatially coincident high concentrations are found only for interval N.50-63E. (highs 2 and 3) and interval N.36-44E. (high 2). Linear features trending N.14-35E. may be somehow related to mapped thrust faults in the region of high concentrations 1, 2, 3, and 5, and thrusting may exist in the area of the fourth.

Igneous rocks

Throughout the region south of the Tintina fault zone, the granitic plutons are multi-phase and dominately peraluminous biotite granite (Menzie and others, 1983). Relatively low concentrations of all trends of linear features are found in the areas of most mapped plutons (fig. 13). Low concentrations (fig. 13) of all linear features are found where igneous rocks are exposed over large areas, as well as over small areas that are associated with inferred buried intrusives (Cady and Weber, 1983). The few exceptions are small-area concentrations in the vicinities of Chena Hot Springs pluton (fig. 2), a small pluton at long 145°10′W., lat 65°05′N., and Quartz Creek pluton where high concentrations are located. Major north-northeast-trending faults (fig. 5) were mapped in both Quartz Creek and Mount Prindle plutons

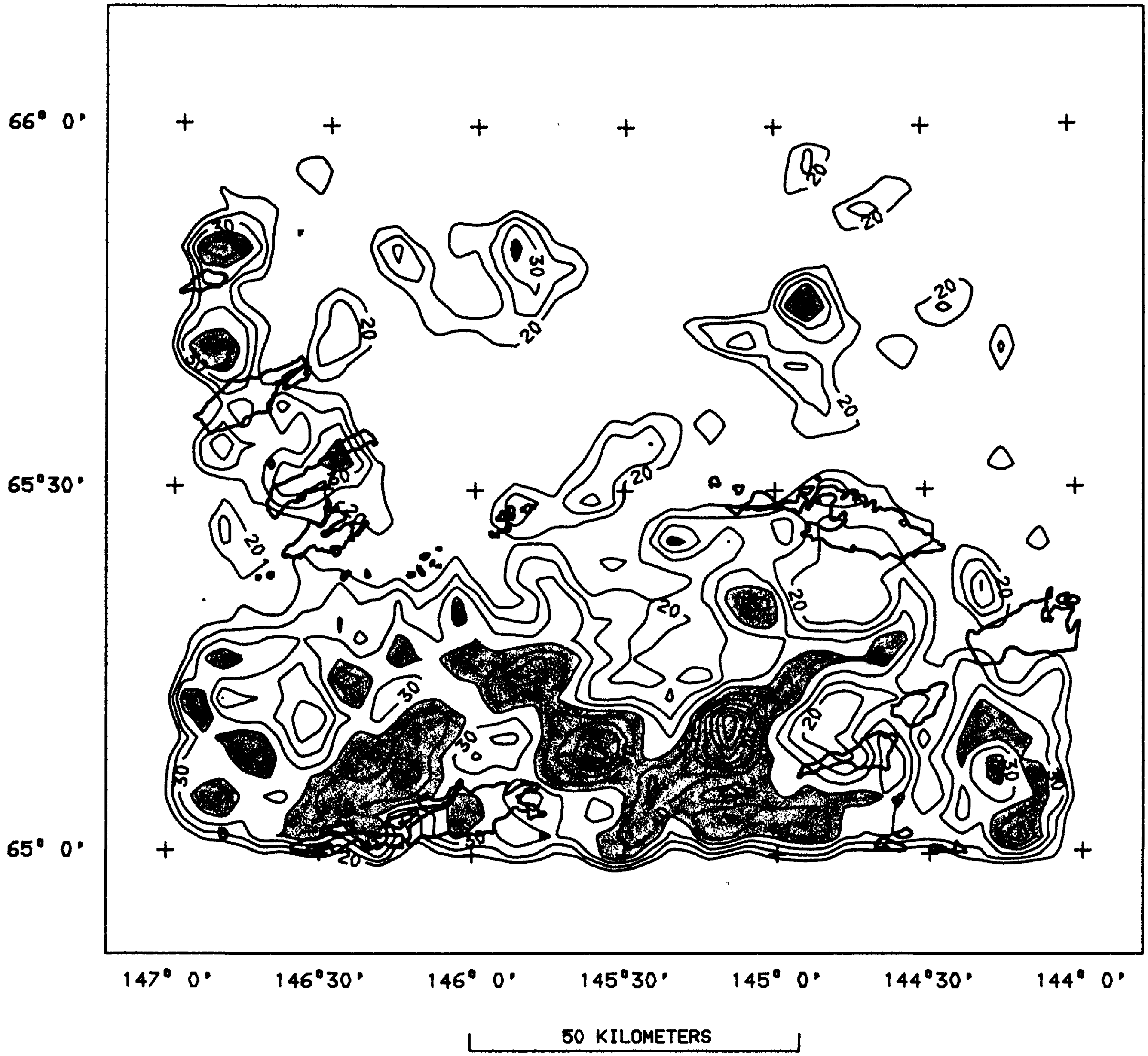

Figure 13. Contour map of concentrations of all linear features and igneous intrusives from Foster and others (1983).

(Foster and others, 1983), and numerous dikes cut both the granites and adjacent quartzites (Menzie and others, 1983). The contrasting appearance on the Landsat image (pl. 1) of Quartz Creek pluton and Mount Prindle pluton suggests differences that may account for a concentration of linear features being associated only with Quartz Creek pluton.

Examination of concentration maps of specific trend intervals show correlations of high and moderately- high concentrations with parts of some mapped plutons. Moderate concentrations of linear features trending N.14-35E. are associated with the area of Victoria Mountain pluton, and with sections of Lime Peak, and Circle Hot Springs plutons (figs. 2, 14). The high concentration of all linear features (fig. 13) on Quartz Creek pluton is due mostly to linear features trending N.14-35E (fig. 14). High concentrations of northwest-trending linear features occur in the area of Big Windy Creek pluton, and linear features trending northeast predominate on the northeast half of the unnamed pluton southwest of Big Windy Creek pluton. No hypothesis can be offered for these correlations.

Mineral and placer deposits

In Circle quadrangle, Menzie and others (1983) delineate tracts I-VIII (fig. 15) that are permissive for occurrence of mineral deposits, areas A-D that show localities where placer mining has been concentrated, and area E that may contain buried placer deposits. Within domain A, tracts I-III encompass areas of igneous outcrops and, therefore, correlate with low concentrations of linear features (figs. 15, 16), except for a high concentration on Quartz Creek pluton as discussed earlier. Mineral deposits that may be found in tracts I-III are: 1) tin vein/greisen deposits in tracts I-III, 2) uranium deposits hosted by peraluminous granites in tract II, 3) tungsten tactite/skarn deposits in tract III, and 4) lode gold deposits in metasedimentary terranes in tracts II and III (Menzie and others, 1983). Placers have been mined for gold on most streams in area A (fig. 15).

Tract IV, which also may include tin vein/greisen, uranium, and lode gold deposits (Menzie and others, 1983), is located in subarea B2 of domain B, where the area of the second lowest concentrations of linear features is found (figs. 15, 16). Throughout area D (fig. 15) placers have been mined (Menzie and others, 1983); the most productive streams are in the area of a small high concentration of linear features at long 145°20'W., lat 65°25'N. (fig. 16) that coincides with Mastedon Dome (pl. 2).

The highest concentrations of linear features in the quadrangle are found in domain B/B1 (figs. 15, 16) that includes tracts V-VII. Uranium deposits hosted by peraluminous granites may be found in tract V (Menzie and others, 1983), which encompasses Chena Hot Springs pluton (figs. 2, 15). The concentration of linear features at long 146°W., lat 65°N. is primarily due to a concentration of northwest-trending linear features and the concentration at long 146°20'W., lat 65°N. is due to northeast-trending linear features. Correlation between the small-area high concentration of linear features at long 146°W., lat 65°N. (fig. 16) and the locations of active placer claims (Menzie and others, 1983) on Monument Creek (fig. 11) cannot be explained with available data.

Within tract VI the area of low concentration of linear features (fig.

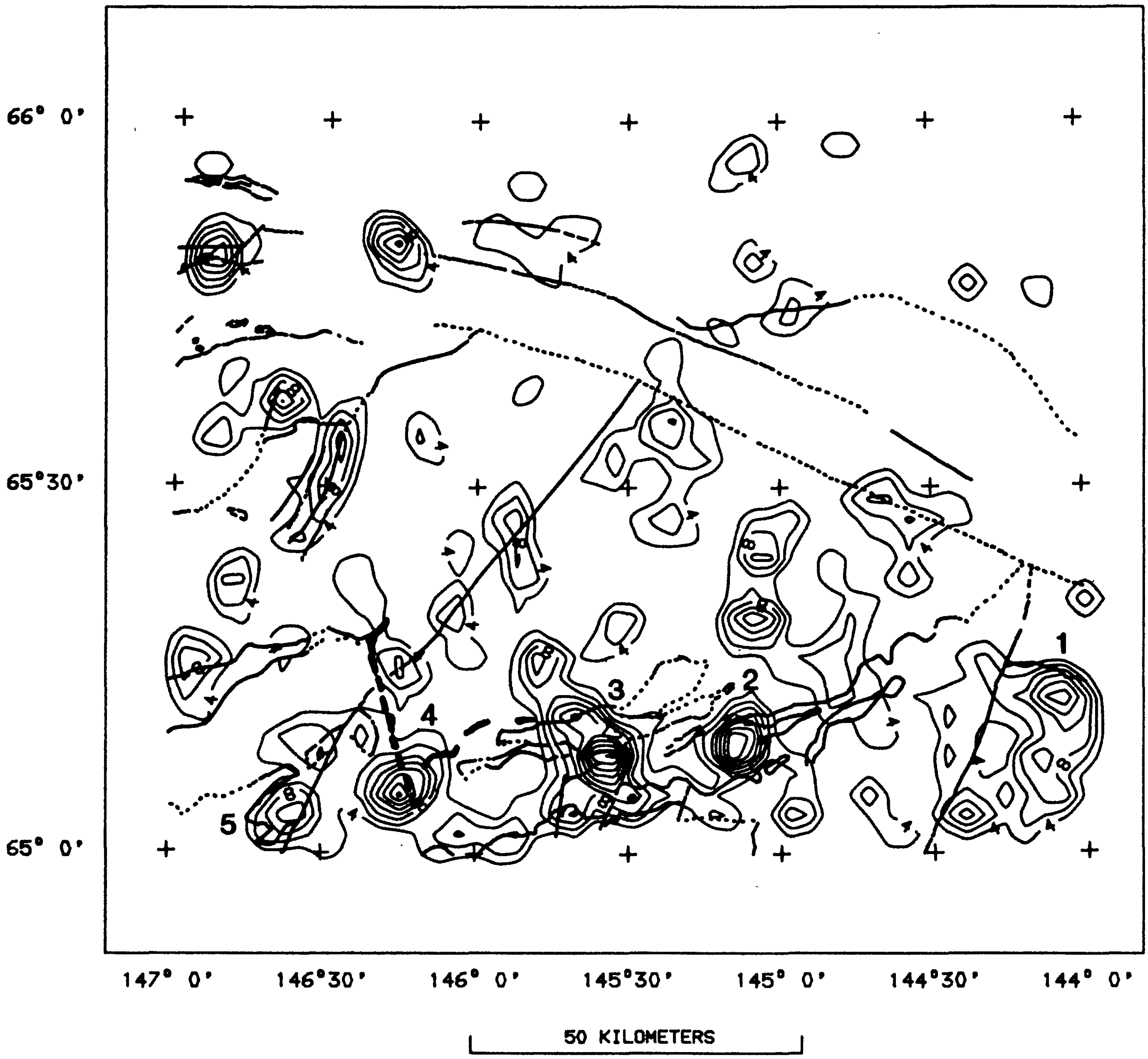

Figure 14. Contour map of concentrations of linear features trending N.14-34E. and faults from Foster and others (1983). Heavy dashed line is lineament 6 from plate 1b.

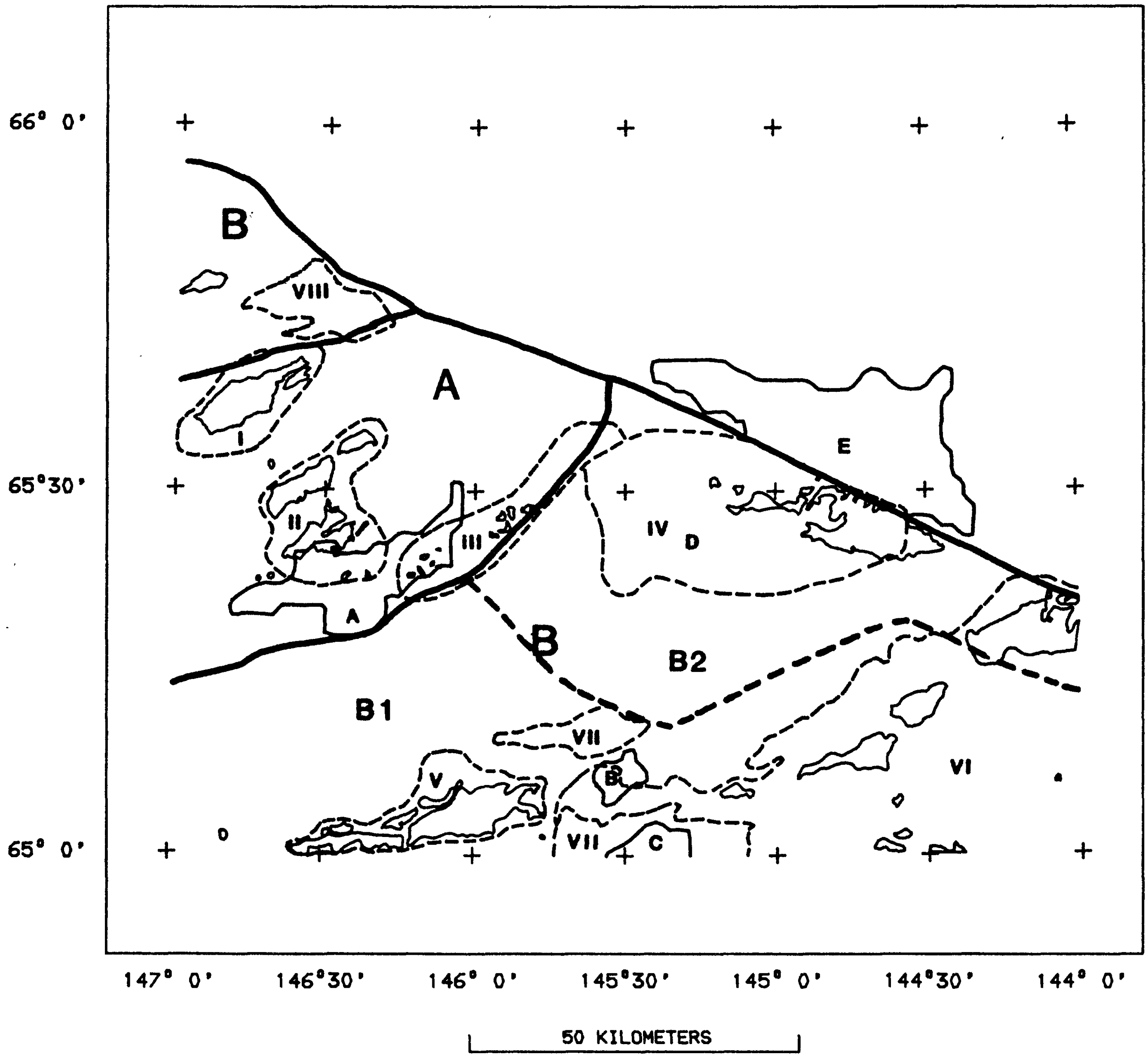

Figure 15. Tracts (I-VIII) and areas (A-E) permissive of mineral and placer deposits from Menzie and others (1983), igneous intrusives from Foster and others (1983), and domain boundaries from plate 1a and figure 7.

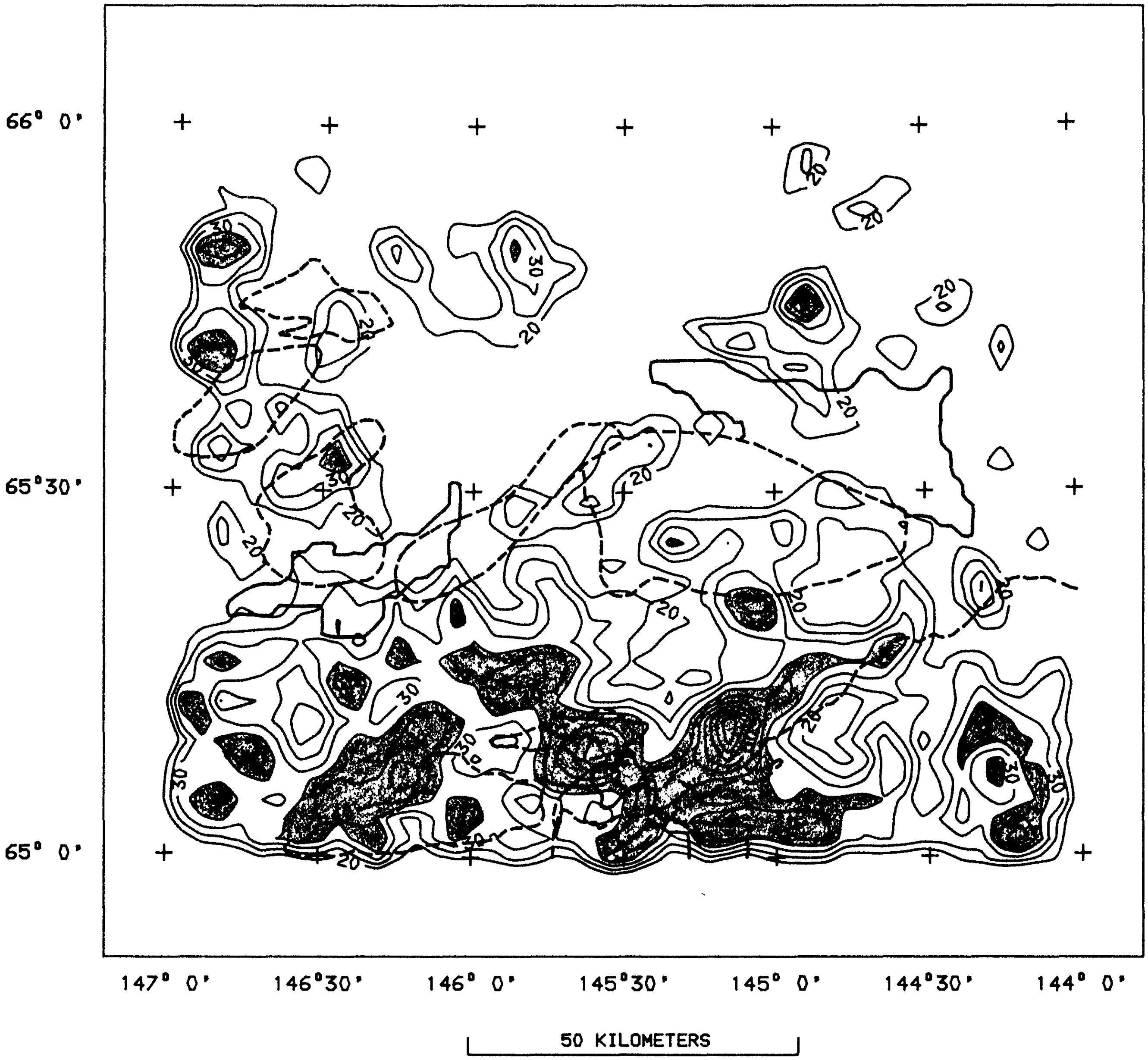

Figure 16. Contour map of concentrations of all linear features, and tracts and areas permissive of mineral and placer deposits from Menzie and others (1983). See figure 15 for labels of areas.

16) at long 144°30′-145°W., lat 65°-65°15′N. coincides with an area of exposed (fig. 15) and inferred granitic intrusives (Cady and Weber, 1983) as discussed earlier. Menzie and others (1983) report that the mapped intrusives probably are largely unfractured, and that tungsten skarn/tactite deposits may be found within tract VI. Concentrations of linear features are located east of long 144°25′W, and west of long 145°W. (fig. 16).

Tracts VII and VIII (fig. 15) in domain B/B1 and northwest domain B, respectively, may include shale-hosted lead-zinc deposits (Menzie and others, 1983). One of the two areas of highest concentrations of linear features (fig. 16) in the quadrangle is centered on tract VII (north), which consists of quartzite and meta-argillite bounded by thrust traces (Foster and others, 1983). Linear features that trend northwest, N.14-35E., and N.64-87E. comprise most of the high concentration in tract VII (north). High concentrations are also found in much of tract VII (south)(fig. 16). In tract VII (south), mostly northwest-trending linear features were mapped on predominately northwest-trending tributaries of the Middle Fork Chena River (pls. 1, 1a) which suggests lithologic control of linear features due to erosion of phyllites and marbles mapped in the area by Foster and others (1983).

A relatively low concentration of linear features is associated with tract VIII (fig. 16), which includes argillite, conglomerate, and associated tuffaceous rocks (Foster and others, 1983). The difference in lithologies, as well as thrusts bounding tract VII (north), may account in part for the contrast in concentrations of linear features in tracts VII and VIII.

Gold has been mined from gravels along creeks and the Middle Fork of the Chena River in areas B and C (Menzie and others, 1983) of domain B/B1 (fig. 15). Though few placer claims have been staked in area E, creeks draining tract IV (area D) may have eroded gold-bearing rock from above the granite and deposited the sediments at favorable sites within the small sedimentary basin underlying area E (Menzie and others, 1983). There is an increased density of linear features in the central part of area E within Tintina fault zone.

Linear feature concentrations do not correspond to areas of igneous intrusives (fig. 13) in any significant or consistent way. Igneous intrusives are found in tracts I-IV and, therefore, the tracts are in areas of low concentrations of linear features. The highest concentrations are centered on tract VII (north) and are in an area just to the east (fig. 16). High concentrations are also found in tract VII (south). Shale-hosted lead-zinc deposits may be found in tract VII (Menzie and others, 1983), which suggests a possible correlation between high concentrations of linear features and shale host rocks. This possible correlation must be discounted as tract VIII, also containing shale host rocks, has a low-moderate concentration of linear features. This minor concentration is due to northwest-trending linear features. Northwest linear features are concentrated in tract VII (north) but not in the area to the east. The boundaries of tract VII (north and south) coincide with thrust faults. Linear features somehow related to thrusting may provide an additional component to form the high concentrations in tracts VII that is not found in tract VIII.

CONCLUSIONS

Geomorphic domains A and B are identified on enhanced Landsat images on the basis of major regional differences in surface characteristics. Domain A is a northeast-trending, roughly rectangular area of widely-spaced drainages separated by low, rounded ridges, which is transected by a northwest-trending zone of igneous intrusives. Domain A is bordered on the northeast end by Tintina fault zone, and on both sides by terrain characterized by an intricate network of closely-spaced streams separated by narrow ridges.

The northwest boundary of geomorphic domain A generally corresponds with the northwest boundary of Beaver terrane, which is identified on the basis of lithology and structural style that differs markedly from surrounding terranes (Churkin and others, 1982). Structural control is suggested for anomalous-trending south tributaries of Beaver Creek located on Landsat just west of the Livengood-Circle quadrangle border. The southeast boundary of Beaver terrane borders this stretch of Beaver Creek, and a thrust fault was mapped along the terrane boundary (Churkin and others, 1982).

The northwestern part of geomorphic domain A includes Beaver terrane, and on Landsat images the southeastern part of domain A shows sharp contrast with the adjoining Yukon crystalline terrane of Churkin and others (1982). Most of the southeastern boundary of domain A correlates with mapped faults (Foster and others, 1983). The contrast in geomorphic characteristics of the adjacent areas and the parallel trends of Beaver terrane and geomorphic domain A suggest that the southeastern part of domain A be investigated for possible lithologic and structural differences that might identify the area as being a subdivison of Yukon crystalline terrane.

East-northeast-trending curvilinear lines drawn on Landsat images along prominent valleys, or connecting valleys, appear to separate large areas of different geomorphic terrains. Two lines, z-z′ and v-v′, correlate with segments of boundaries of tectonostratigraphic terranes (Churkin and others, 1982). Prominent north-trending lineaments and the east-northeast-trending lines form a large scale regional pattern that is transected by mapped north-northeast high-angle faults.

Statistical strike-frequency analysis of linear feature data indicates that northeast-trending linear features predominate throughout Circle quadrangle and that northwest-trending linear features are found mostly south of Tintina fault zone. Average trends of northeast-trending linear features found in the northernmost part of the quadrangle were measured within areas that, on Landsat images, appear to be defined by northeast-trending Beaver and Preacher Creeks. Different major average trends are found between Big and Beaver Creeks (N.60E.), between Beaver and Preacher Creeks (N.49E.), and between Preacher and Birch Creeks (N.71E.). Reconnaissance mapping (Foster and others, 1983) and aeromagnetic data (Cady and Weber, 1983) rule out northeast lithologic variations as a controlling factor of the anomalous northeast trends. Anomalous trends and differences in average trends among the three areas studied appear to reflect influence of structural controls.

Computer maps of spatial concentrations of linear features show the highest concentrations of linear features to be in the southern one third of the quadrangle. This area of highest concentrations corresponds to a broad gravity low that is caused by low density crust of Yukon crystalline terrane (Cady and Weber, 1983). The high concentrations correspond to a region of aeromagnetic highs (Cady and Weber, 1983). Cady interprets northeast- to east-northeast-trending magnetic highs and lows as reflecting compositional variations in metamorphic and syntectonic granitic rocks. Trends of the aeromagnetic highs are approximately N.65-75E. In this region a major trend of only northeast linear features, N.64-72E., closely parallels trends of mapped foliations in metamorphic rocks (Foster and others, 1983). The correspondence of trends of foliation, magnetic anomalies, and linear features throughout the area suggests that most northeast-trending linear features, especially those in the broad trend interval of N.64-87E. for all linear features, are probably related to lithologic variations brought about by folding and foliation of the metamorphic rocks.

A second important trend interval, N.14-35E., may be related to thrusting as high concentrations of linear features within this interval are found in areas of some mapped thrust faults (Foster and others, 1983). Thrusting is suggested for an area of high concentration lacking known thrust faults.

Prominent north-trending lineaments mapped on Landsat images indicate areas of varying surface characteristics that suggest possible influence of lithologic variations and/or structural controls.

Low concentrations of linear features are found in areas of most mapped (Foster and others, 1983) and inferred (Cady, 1983) igneous intrusives. Tracts I-VI, identified by Menzie and others (1983) as being permissive for occurrence of mineral deposits, either enclose mapped intrusives or outline regions where intrusives are located. There is no consistency in correlations of concentrations of linear features with mineralized areas; therefore, linear feature concentrations are not of value as an aid to locating areas of mineralization.

The results of this study indicate that there are several possibly important areas where further detailed studies are warranted.

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Plate 1. Enhanced Landsat band 7 image (2944-20083), scale 1:1,000,000.

Plate 1a. Geomorphic domain boundaries (heavy line) and alinements of linear features (dashed line); overlay to plate 1.

Plate 1b. Major lineaments (dashed line), curvilinear lines (dotted line possibly separating different terrains), and major, high-angle faults (heavy line-solid, dashed, dotted); overlay to plate 1. Faults from Foster and others (1983), Weber and others (1978), and Brabb and Churkin (1969). Rectangle with dashed line is structural contact and a segment of terrane boundary shown on figure 4.

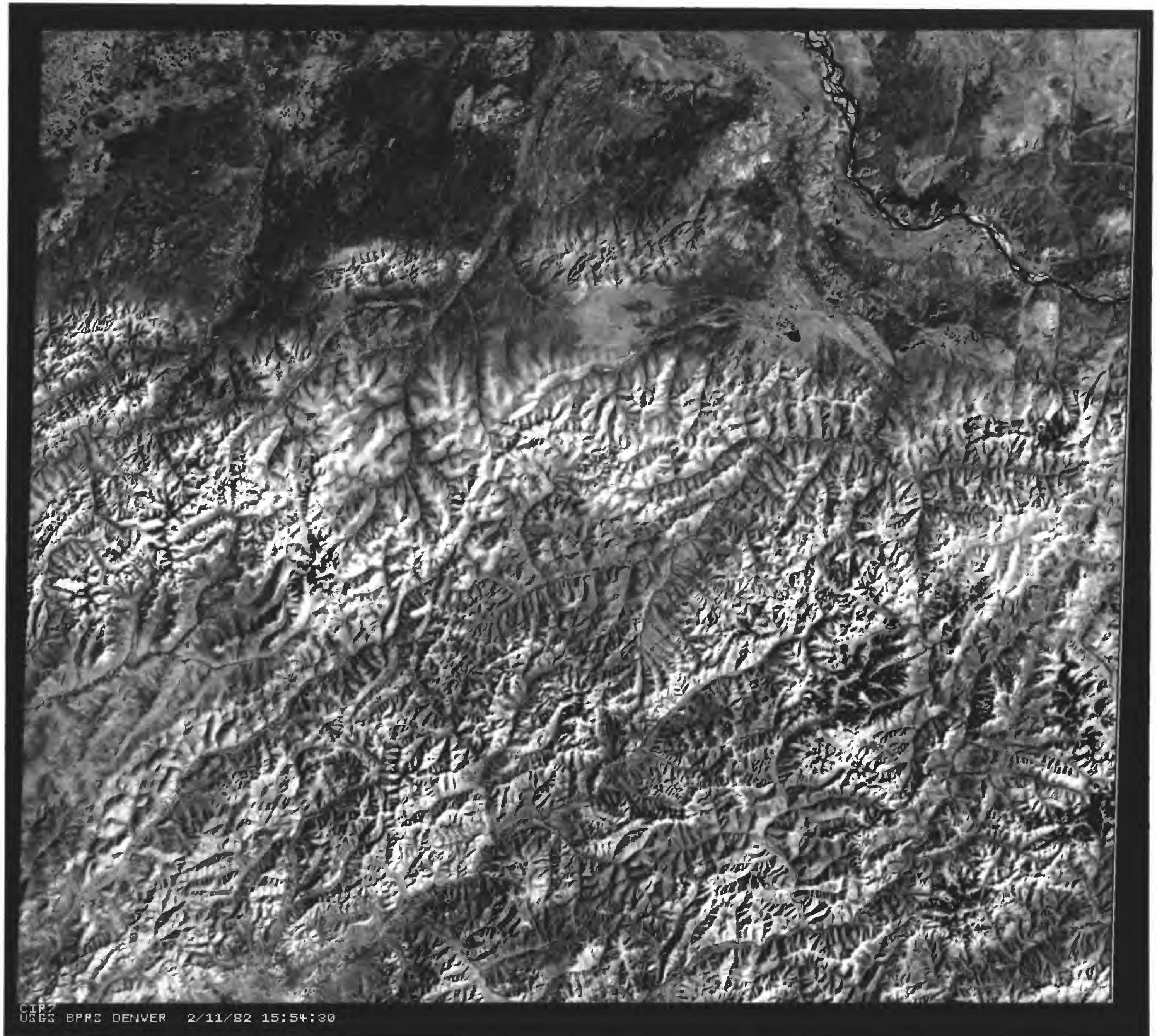

Plate 1

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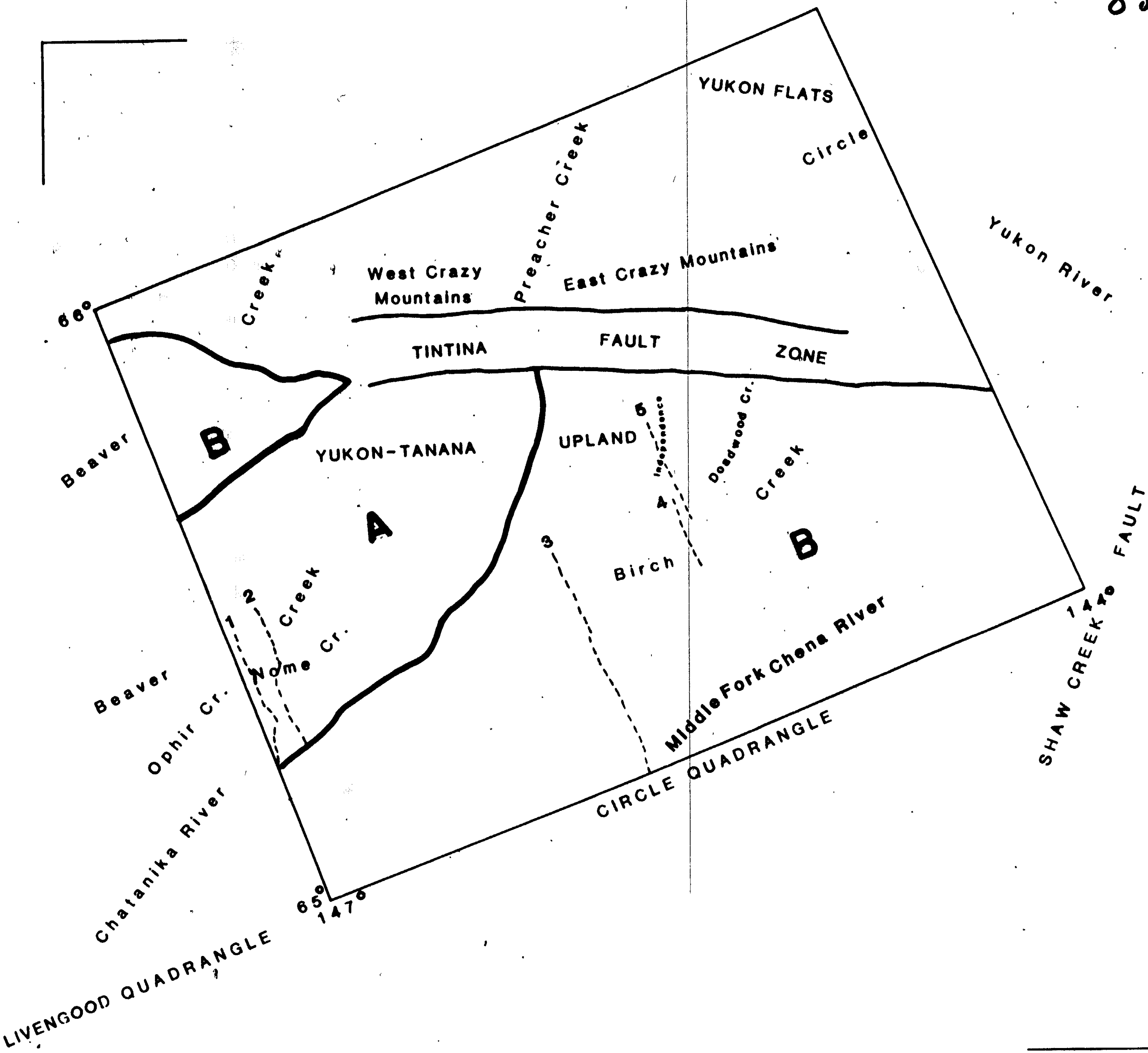

Plate 1a

83-170-E

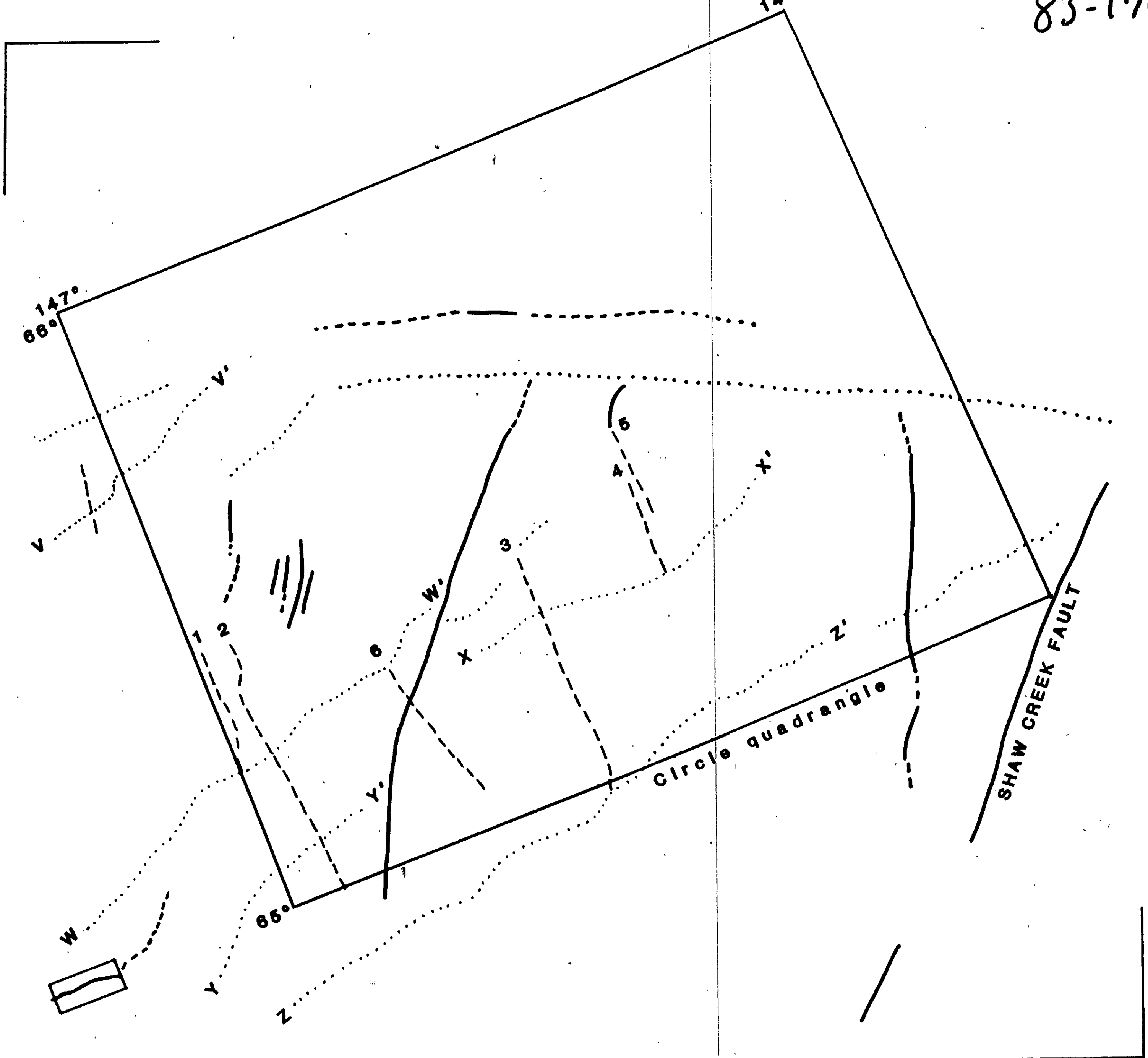

Plate 1b