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STRUCTURAL ANALYSIS OF PLUTONIC AND METAMORPHIC ROCKS IN AN AREA EAST OF WRANGELL, ALASKA

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ABSTRACT

A geometric structural analysis was performed on measurements of joints, foliations, lineations, and axial planes which were taken in the course of reconnaissance mapping in the Petersburg quadrangle of Southeastern Alaska during the summer of 1978. Approximately 170 stations scattered throughout the area were used. The map area was subdivided into domains of basically similar structural orientation and the data for each domain were plotted on a Schmidt equal area net, working outward from plutonic bodies.

The area under consideration is approximately 20 km by 35 km in area, lies east of Wrangell between the Stikine River and Eastern Passage, and is underlain by a complex of metamorphic and plutonic rocks. There are at least three types of plutonic bodies--a portion of a regionally mapped latest Cretaceous-early Tertiary tonalite "sill", several 90 Ma garnet-biotite granodiorite bodies, and a small 20 Ma alkali granite. The latter was not included in the study. The country rocks were mostly fine-grained schists with abundant metavolcanics and a few lenses of marble. The metamorphic grade ranges from greenschist to amphibolite facies, generally increasing eastward.

The results of the structural analysis show a predominant N 20 W-trending regional foliation in the metamorphics which is locally affected by the intrusion of the 90 Ma granodiorite bodies. The presence of a dominant foliation-normal joint set in the metamorphics seems to confirm a NE-trending compressional regime in effect during metamorphism. The 90 Ma granodiorite bodies appear to post-date the metamorphism and deformation. The data do not present any positive evidence that the Coast Range Megalineament is a major structural discontinuity.

INTRODUCTION

During the summer field season of 1978 a reconnaissance mapping project was begun in the Petersburg quadrangle of southeastern Alaska by a team of geologists from the Alaskan Branch of the U. S. Geological Survey. The Petersburg quadrangle, located in the central portion of Southeastern Alaska (see figure 1), encompasses a wide variety of lithologies suggested to represent several different accreted "terranes" (Berg, Jones, and Coney, 1978). The results of the geologic mapping have been reported by Brew and others (1984). The goal of this structural analysis was to provide some insight into the structural effects of metamorphism as well as that of various plutonic events.

The area being considered in this paper is a small part of the quadrangle, but one which received a relatively concentrated mapping effort. Located just east of the town of Wrangell (figure 1), the area is bounded on the north by the Stikine River, on the southwest by Eastern Passage, and on the east by the 132^{o} meridian, which is the border with the Bradfield Canal quadrangle (figure 2). The area involved is approximately 20 km by 35 km, and is underlain by a complex of various plutonic and metamorphic rocks of the Taku and Tracy Arm terranes of Berg, Jones, and Coney (1978). During field mapping at a scale of 1:63,360 (1 inch = 1 mile), structural measurements of joints, foliation, lineation, and fold orientations were taken on a routine basis at approximately 170 stations. These stations are scattered throughout the area, with local concentration along ridgelines. The measurements were systematically plotted on a Schmidt equal area net, and contoured where the number of points merited it. An attempt was made to limit each plot to a single "domain" of generally similar structural orientaton, in order to evaluate the possible causes of fluctuations in the orientation. These plots, as well as others which synthesize some of the data, are included in the following sections. They are all lower hemisphere plots with North at the top. In the case of planar elements, the plots show poles to the planes. Contouring was done using the Schmidt grid method (Turner and Weiss, 1963, p. 61-62), and intervals were generally 0.5%, 2%, 4%, and 8% per 1% area.

Other geologists involved in the geologic mapping were D. A. Brew, A. B. Ford, C. Huie, R. D. Morrell, and R. A. Sonnevil. This report was originally prepared as a class project in advanced structural geology at the San Jose State University. It has been revised slightly by D. A. Brew for open-file release, but the analysis and conclusions are those of the author. This is the only quantitative study of structural elements in this part of the Petersburg quadrangle; and it is being released to facilitate its use by others newly interested in the geology, structure, and metamorphism in the area. I thank R. A. Loney for his technical review and W. M. Trollman for typing the text.

GENERAL GEOLOGY

The area under consideration displays a complex pattern of metamorphic and plutonic rocks which was incompletely mapped at the time of this study (see figure 2). The metamorphic rocks are part of the Wrangell-Revillagigedo belt which extends for some distance along the western side of the Coast Range in Southeastern Alaska (Buddington and Chapin, 1929; Gault and others, 1953; Beikman, 1975; Brew and others, 1984). Lithologies are mostly fine-grained schists and gneisses with minor phyllitic marble, and amphibolite. These represent protoliths of clastic sedimentary rocks with minor carbonates and volcanics, which have been metamorphosed to the greenschist and amphibolite facies (generally increasing in grade to the east). The rocks are strongly foliated, and locally contain isoclinal folds. Associated with the metasediments, near the center of the mapped area, is a zone of rhyolite dikes or sills which generally parallel compositional layering. The age of the country rocks is as yet unknown, but indications are that they are Paleozoic to Mesozoic and possibly Permo-Triassic (Brew and others, 1984).

In addition to the metamorphic rocks this area contains at least three types of plutonic bodies which collectively equal or exceed the metamorphics in outcrop area. Bounding the map area on the northeast are portions of a regionally mapped biotite-hornblende tonalite "sill" of latest Cretaceous or Early Tertiary age (Gehrels and others, 1984). This linear body has been mapped discontinuously as far north as the Haines area and as far south as Prince Rupert, B. C. (Brew and Ford, 1981; Ford and Brew, 1981). It is strongly foliated and in the study area is restricted to the northeast side of the Coast Range Megalineament along the valleys of South Fork and Nelson Glacier.

The most abundant plutons are the numerous garnet-biotite granodiorite-tonalite-quartz diorite bodies which are more equidimensional in outline and range from less than a kilometer to several kilometers in diameter. Indications are that these are all part of the same event, if not the same body, with the possible exception of a small, more porphyritic hornblende-bearing body in the northern part of the area (see figure 2). These bodies are similar to other plutons dated at 80-85 Ma in the Ketchikan area (Berg, Elliott and others, 1978) and have been studied by Burrell (1984 a, b, c). They show moderate to weak foliation at the contacts with the metamorphic rocks. Inclusions of metamorphics are common, and the contact is often more of a transitional mixed zone than a sharp boundary.

The third type of pluton is a small 20 Ma alkali granite which is associated with the mineralization at Groundhog Basin (fig. 2). Structural data were not collected from this body, and it has not been shown on the map of figure 2. In addition to these plutonic rocks, the country rocks and occasionally the plutons themselves are cut by a variety of dikes and veins. Lithologies vary from basaltic to pegmatitic and aplitic, and include the rhyolite dike zone mentioned above.

Jointing is common in both the metamorphic and plutonic rocks, and numerous measurements were obtained. Only one small fault was measured, however, and for the most part, these rocks do not appear to have been affected by large scale faulting. The Coast Range Megalineament (Brew and Ford, 1978) is prominent in the map area, trenching northwest-southeast along the South Fork of Andrew Creek and across the divide into the Nelson Glacier valley. As currently mapped, the tonalite "sill" and the garnet-biotite granodiorite bodies are separated by this feature. The boundary between the Taku and Tracy Arm terranes of Berg, Jones, and Coney (1978) also more or less coincides with this lineament. One of the initial hopes for this study was that it might test whether or not the Megalineament is a major structural boundary in this area.

STRUCTURAL ANALYSIS

The 168 stations produced 199 foliation measurements and 27 lineation measurements, as well as measurements of 281 joints, 22 dikes, and 13 folds. Instead of plotting these data on composite diagrams, a method was devised to allow local patterns to be analyzed. The area was divided into 14 domains, lettered A through N and shown on figure 3. For the most part, each domain encompasses a single intrusive-metamorphic contact of fairly constant orientation. Plotting started at the center of the exposed pluton and moved outward into the adjacent metamorphics, usually following the paths of ridgeline traverses performed in the field. The determination of domain boundaries was facilitated by the lack of data from the intervening valleys. As a result, domains can generally be seen to radiate from the cores of plutonic bodies, and in some cases overlap at the center. In order to test the significance of the Coast Range Megalineament, the stations northeast of this lineament were placed into separate domain (N). Unfortunately, data on the northeast side were not very extensive at the time of this analysis and only one domain was formed.

Foliation

The first structural element to be considered is the foliation, which is well developed in the metamorphics and less strong in the plutons. It is usually manifested as compositional banding, schistosity, cleavage, and occasionally by the orientation of schlieren. Field observations reveal that for the most part, foliation in the metamorphics parallels both compositional layering and the contacts between adjacent metamorphic lithologies. The impression received from the map patterns and field observatons is that there is a general strong northwest trend to the strike of foliation. This is confirmed by the contoured plot of figure 4. (This figure and all other contoured plots are based on the percentages of structural elements present per one percent of the plot area.) The maximum of this composite diagram, which includes all foliation measurements taken southwest of the Megalineament, strikes between 348 and 338 and dips 58°-84° to the northeast. The symmetrical distribution of contours about this single large maximum indicates a very strong regional preferred orientation to the foliation. A significant number of poles plot elsewhere on the diagram and generally define a shallowly south-dipping girdle; this suggests deformation of the foliation about some later, steeply north-plunging axis.

Looking at plots from individual domains, it becomes apparent that this broader distribution of poles is due to local influence of the garnet-biotite intrusive bodies. The metamorphic rocks in domain A, shown in figure 5, display foliation ranging in strike from 360 to 040, the latter being nearest to the NE-trending contact between schist and granodiorite. Moving clockwise around the exposed plutonic body in A, the foliation changes dramatically (see figure 6). The foliation in domain B1, a narrow band of schist between two granodiorite bodies, reflects the NW trend of the contacts. Further west, in domain B2, however, the foliation in both metamorphics and the pluton show a general NE strike paralleling the contact zone in this area.

On the east side of the pluton, in domain C (see figure 7), the foliation in all rocks again strikes parallel to the intrusive contact —025-040 in the southern part (C1) and 360 to 025 in the northern part (C2)—reflecting the changing orientation of the contact. In domain D1 on the north side of the circular body, the parallelism still holds (figure 8). The scatter of poles is greater, but the concentration averaging 280 is obvious. The evidence thus indicates that, at least in the area of domains A through D, the intrusion of the granodiorite has profoundly affected the orientation of the foliation in the country rocks. It should be noted that in each case the foliation not only strikes sub-parallel to the intrusive contact, but it also dips away from the intrusive, usually steeply (50°-90°).

As noted in the geology section above, domain D contains another intrusive body that is more porphyritic than the abundant granodiorite bodies of the area. Structurally, it parallels the foliation in the metamorphics near its southern contact where it is fairly close to the granodiorite (domains A through C). However, at some distance from the latter, the foliation in both the pluton and the associated metamorphics becomes quite variable, as indicated by the scattered plot of domain D2. There are too few data points to make any definitive statements, but there does appear to be something different affecting this body. In domain D3, at considerable distance from the granodiorite contact, the foliation again reflects the general regional NW trend.

Domain E represents an area which is entirely within a large exposure of granodiorite. Foliation could not be measured at all stations, but where it does occur, it shows quite a variability and a tendency to be shallow to moderately dipping (see figure 9). A very gross NW trend is perhaps discernable, but it is certainly not the prominent orientation seen in the country rocks. The foliation may be of flow origin in part.

The remaining domains lack the circumferential distribution about a pluton as seen above, but they still illustrate the influence of the intrusion upon local structure. Looking at domain F (figure 10), a bimodal sort of distribution can be seen. In the center of the pluton (F1) a prominent 030 trend is apparent. The foliation within the pluton makes a dramatic switch within less than a kilometer to a NW trend in domain F2, parallel to the intrusive contact. In this case it may be argued that it was the strong foliation in the country rocks influenced the contact and thus the foliation in the intrusive, rather than vice versa. It may also be that both the pluton and the metamorphic rocks in this sub-domain have been affected by younger events.

A similar switch in foliation within this same body also occurs northward from domain F1 into domain G1 (see figure 11), where the foliation is clustered around a mean of 340. This orientation becomes more NS in domain G2, as the intrusive contact appears to swing more NS. To the southwest, in domain H (figure 12), the foliation again dramatically shifts to a 340 trend at the contact. Here the folation is dippingly vertical, while in the two previous domains it dipped away from the intrusive at a steep to moderate angle, consistent with previous observations.

At this point, a secondary outcome of this study should be noted. Field workers had hypothesized a contact across the valley at the point marked by a circled "X" on figure 3 (domain H) based on apparent continuity of contacts on either side. However, this would require that the very strong foliation of this domain be truncated at a right angle by the hypothetical contact. The consistent parallelism of foliation with intrusive contacts noted in this map area and in adjoining quads (R. L. Elliott, personal communication, 1979), argues against such a connection. Instead it is suggested that the western of the two contacts may connect to the north with that in domain C1.

Further to the southeast, in domain I (figure 13), the picture is relatively simple. Foliation shows an average strike of about 340 and dips consistently away from the intrusive at moderate to steep angles. As this trend parallels both the regional pattern and the intrusive contact, it is impossible to distinguish the primary determining structure. Domain J (see figure 14) also shows an average foliation of about 340. In this case, however, there appears to be a general progression from more NNE and NS trends in J1 (in proximity to the intrusive), to more NW trends in J2. Such a progression may mark the waning influence of the almost NS intrusive contact with increased distance away from the contact.

The foliation in domain K (figure 15) has an average strike of 345 consistent with the regional trend, but the contact relations in this region are unclear. A previously inferred contact across the area marked by a circled "Y" on figure 3 (domain K) was eliminated, as it would cross-cut the foliation trend. The anomalous pole shown in this diagram occurs in the pluton, and may imply an intrusive contact on the northwest end of the domain.

Domain L (figure 16) shows a wider variation in the foliation than in previous plots, but the maximum still falls at about 340, generally parallel with the intrusive contact. Of particular note is the dip of foliation which is toward the intrusive in this domain and rather shallow in some cases. An additional anomaly is the wide mixed zone of intrusive plus metamorphic rocks which occurs in place of a sharp contact in this region. Perhaps in this area the intrusive chose to interfinger with the country rocks instead of shoving them aside.

Finally, in domain M (figure 17) the regional foliation trend is again prominent at about 340. Some of the spread may be caused by the numerous small plutons in the area, but contact relations are unclear. At the area marked by a circled "Z" on figure 3 (domain M) an inferred contact is now in question because it would cross-cut foliation.

The domains covered so far, A through M, represent the mapped area southwest of the Megalineament, and these foliations are summarized in the composite diagram that is figure 4. In order to evaluate any possible differences across the lineament, the area to the northeast has been placed into a separate domain (N), shown in figure 18. Comparison of figures 4 and 18 indicates it is not possible to differentiate to two sides of the Megalineament on the basis of foliation. The maximum of domain N seems to be slightly more westerly and shallower in dip, but this is not really a significant difference, especially considering the much smaller data set involved.

The domain does have three "sub-domains", although their significance is not clear. Domain N1, which is basically all the values in close proximity to the schist-tonalite contact, shows a tight distribution and 45° dip—shallower than in the schists to the west, and consistent with the contact relations. The difference between N2 and N3 is basically a change in strike from NS to NW and a slight shallowing of the dips. This distribution may reflect a change in foliation within the tonalite "sill" due to proximity to the contacts.

Summarizing the foliation data, it appears that a regional 340-striking foliation dominates the map area. It generally parallels compositional layering and metamorphic contacts, but is profoundly influenced on a local scale by the later intrusion of garnet-biotite granodiorite plutons. This regional orientation is also apparent on the northeast side of the Coast Range Megalineament in the tonalite "sill" and accompanying gneiss.

Lineation

Lineation in these rocks consists of aligned minerals and mineral streaks in the foliation planes. The measurements obtained are all plotted on a single diagram in figure 19 and display quite a wide variation in trend. There are not enough values within any one domain to rigorously analyze the results, but some general statements can be made. Those domains lying on the northeast side of the large central pluton (see figure 3, domains G, J, N, and the northern part of I) seem to have generally NE plunging lineations. Those on the south side of the pluton (domains H, M, and K) show lineations with SE trends. These values agree with the observed contact effects on foliation; in other words, they dip away from the intrusive. They also indicate that even though the foliation in all these domains is roughly parallel (striking NW), the effects of the granodiorite intrusion can be seen in the apparent rotation of an assumed originally parallel lineation direction. Finally, it appears that here again domain N, northeast of the megalineament, cannot be distinguished structurally from the region southwest.

Fold Axes and Axial Planes

Isoclinal folds are not abundant in the map area, but they do occur locally within the metamorphic sequence, where they were noted to occur most commonly close to an intrusive contact. The orientations of those fold axes and axial planes that were measured are plotted in figure 20. Except for one fold axis measured in each of domains C, H, and I, all of the plotted points represent domains J and L. It appears that the ambiguity noted in the foliation in these two areas may reflect a complexity due to small scale folding.

For the most part the axial planes are subparallel to the generalized foliation. The axes form a crude subparallel girdle which is also in the plane of foliation. These orientations are not unexpected, and suggest that the stress which produced the foliation orientation affected (or produced) the isoclinal folds as well.

Joints

The 281 joints which were measured during field mapping display a very wide variation in orientation. This is apparent in figure 21, a plot of all of the 249 measurements taken on the southwest side of the trace of the Coast Range Megalineament. The joints were plotted by domain as were the foliation orientations, but they failed to display any definite patterns and were therefore lumped into a single larger domain to permit contouring. In figure 21, several maxima can be discerned among the broad scatter of points. There appears to be a strong NE-striking vertical set, another set that strikes almost EW, and a broad NS-striking, E-dipping set.

In order to better evaluate these joint sets on the southwest side of the Megalineament, the points were replotted by lithology. Figure 22 represents joints within the metamorphic country rocks, and figure 23 joints within the plutonic rocks. Both plots contain an almost equal number of joints, but a comparison of the two shows striking differences. In the metamorphic rocks, the joints show a very strong NE orientation, with possibly two maxima—one at 040 and one at 070. There is also a lesser concentration about 080. These sets are all steeply dipping, but there is also a significant number of shallow dipping joints, some of which may be interpreted to fall into a vague girdle around a NE axis. The strong NE orientation is of interest because it is perpendicular to the general foliation trend and is thus the usual "ac" set. Although the distinction between tension joints and shear joints was not attempted in the field, it seems reasonable that the NE set is a tension set formed in response to the same NE-trending stress that produced the foliation.

Speculating on the stress system involved, the joints and foliation together would be compatible with a situation at some depth where a compressional stress (σ_1) is oriented horizontal at 070, and the overburden stress is great enough to make σ_2 vertical (greater than σ_3 and less than σ_1.

The least stress direction would be horizontal, producing vertical tension joints. Given these orientations for σ_1, σ_2, and σ_3, one would also expect conjugate shear joints oriented approximately 280 and 040. The two maxima that fall about 30° to either side of the maxima at 070 may represent this conjugate set. The subhorizontal set may represent scatter due to later events, or to a variation in the σ_2 and σ_3 directions, producing non-vertical joints. The spread of points may be due to fluctuations in local stress, however, and thus a more detailed study would be required to determine if the attitudes vary with more spatial distribution.

The joints in the plutons show quite a different picture, as seen in figure 23. In these rocks the EW-trending vertical set is quite prominent, but there is a NS set as well which dips moderately to the E. Although there are some joints which coincide with the NE maxima of figure 22, for the most part they tend to fall on either side of it. A lesser concentration at about 300 also is present. Of these various sets, the orthogonal NS- and EW-trending sets appear to dominate the diagram.

It seems obvious then, that the jointing in the plutons has formed in response to a different sort of stress pattern than that which produced jointing in the metamorphics. The orthogonal nature of the dominant joints would be compatible with a vertical principal stress (σ_1) due to the upward movement of the pluton. In this case σ_2 and σ_3, oriented horizontally, would be approximately equal, producing perpendicular joints, a common phenomena in plutonic bodies. The presence of some NE-trending joints may indicate that the compressional regime (or a parallel residual stress) was still present, at least locally. The deviation of the NS-trending set from the vertical coincides with a similar deviation in foliation, and might suggest some regional eastward tilting, following the formation of these structures. Such a tilt would fail to influence the EW-trending vertical joints.

As a final note, the joints in plutonic rocks and gneiss northeast of the Megalineament are considered (see figure 24). The data set is much smaller than on the southwest side, but some patterns are still apparent. The orthogonal (NS/EW) sets seen in figure 23 also appear in this domain as prominent sets, as is a set subparallel to foliation (325). Note that the 040-070 set seen in the metamorphics on the southwest side is conspicuously absent. In terms of joint patterns, the tonalite "sill" and adjacent rocks bear a considerable resemblance to the granodiorite bodies on the opposite side of the megalineament.

It appears that here, too, a different sort of stress pattern from the regional compression has operated to produce jointing. Preliminary indications from this admittedly small data set would be that this pluton was also emplaced vertically and post-dated the event which produced the jointing in the adjacent metamorphics. The possibility that the joints reflect differences in lithology, however, cannot be completely overlooked.

Dike and Sill Orientations

A variety of dikes and veins cut both the metamorphic and plutonic rocks in the study area, and the orientations of 22 of them are plotted in figure 25. The most noticeable pattern is that they are generally vertical; otherwise the strikes are quite scattered. Considering each one individually, however, many are parallel to joint sets in the surrounding rocks. Several dikes which cross-cut foliation are themselves foliated parallel to the country rock. This indicates that the dikes, and thus joints, preceded or accompanied the event responsible for the metamorphism. There are also quite a few sills which parallel foliation, perhaps following planes of weakness along foliation or bedding. The rhyolite dikes are the most prominent examples of this type.

CONCLUSIONS

It appears from this study that the Coast Range Megalineament is not a major structural discontinuity confirming the conclusions of Brew and Ford (1978). Preliminary evidence shows no obvious influence of the granodiorite bodies on the structures on the northeast side, which supports the suggestion that the tonalite sill family of plutons was emplaced syntectonically (Brew and Ford, 1981).

This study also provides some evidence regarding the sequence of events within the mapped area. A dominant regional metamorphic event, imparting a NW-striking foliation, appears to have affected all of the metasedimentary country rocks. The joint and foliation orientations in the metasediments agree quite well with a 070 regional compressional stress.

Foliation trends seem to imply that the tonalite "sill" was affected by the same event or by another event with the same orientation. The dissimilarity in joint patterns contradicts this somewhat. Alternately, the parallel foliation may be flow banding produced during intrusion. Because the intrusion was sub-parallel to foliation, possibly injected vertically along a then-vertical foliation, the flow banding also parallels foliation. It should be noted, however, that the story is not a simple one—petrographic evidence indicates that the tonalite body has locally been metamorphosed to a degree similar to the country rocks described here. Regional considerations indicate that more than one metamorphic event occurred..

The foliation in rocks south of the Megalineament has been subsequently affected on a local scale by numerous granodiorite plutons. Foliation trends have been warped into parallelism with the intrusive contact and both the foliation and lineation tend to dip away from the pluton. This intrusive event obviously post-dates the metamorphism. Douglass and others (1985) describe in some detail the superposition of a metamorphic event associated with the 65 Ma tonalite sill on both a metamorphism associated with the 90 Ma granodiorite bodies and on a pre-110 Ma metamorphism which is the same as the one that is here concluded to precede the 90 Ma plutons. These different events are probably the reasons for some of the contrasts on either side of the Coast Range megalineament.

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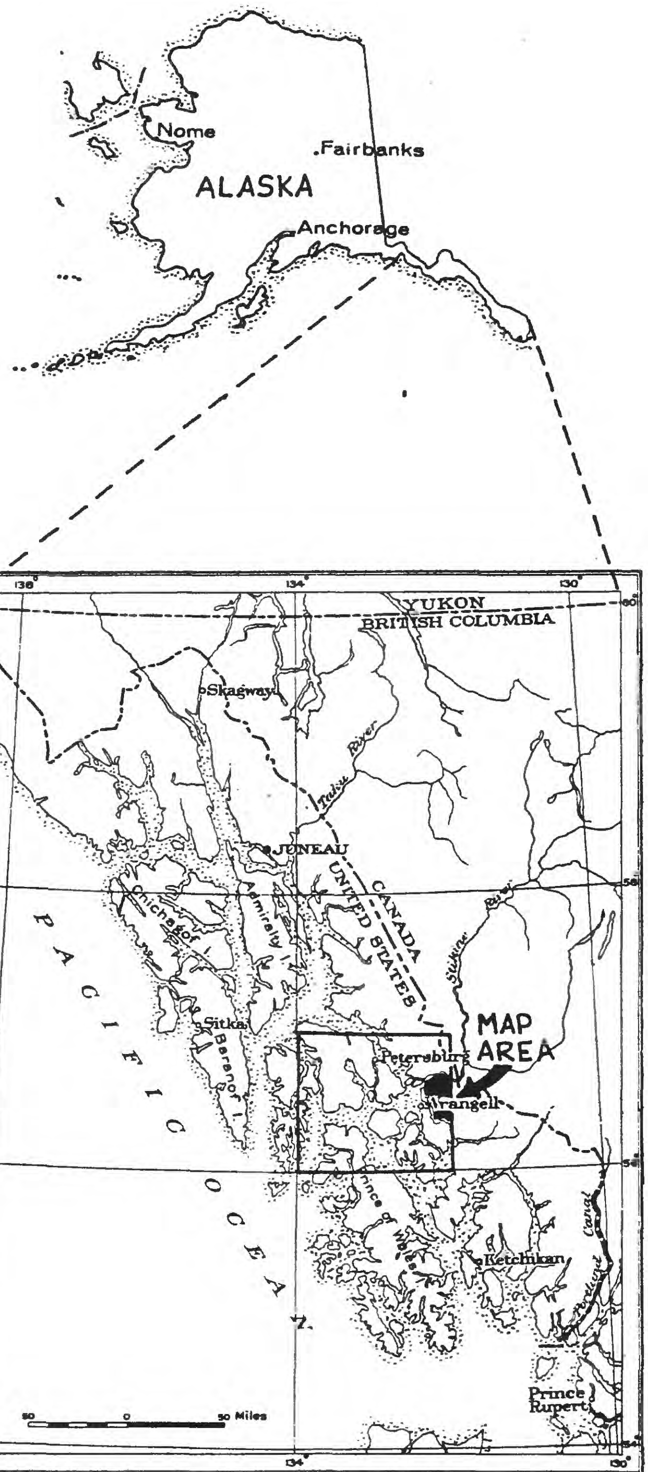


Figure 1. Index map of Southeastern Alaska, showing outline of Petersburg quadrangle (heavy line) and the map area of Figures 2 and 3 (solid).

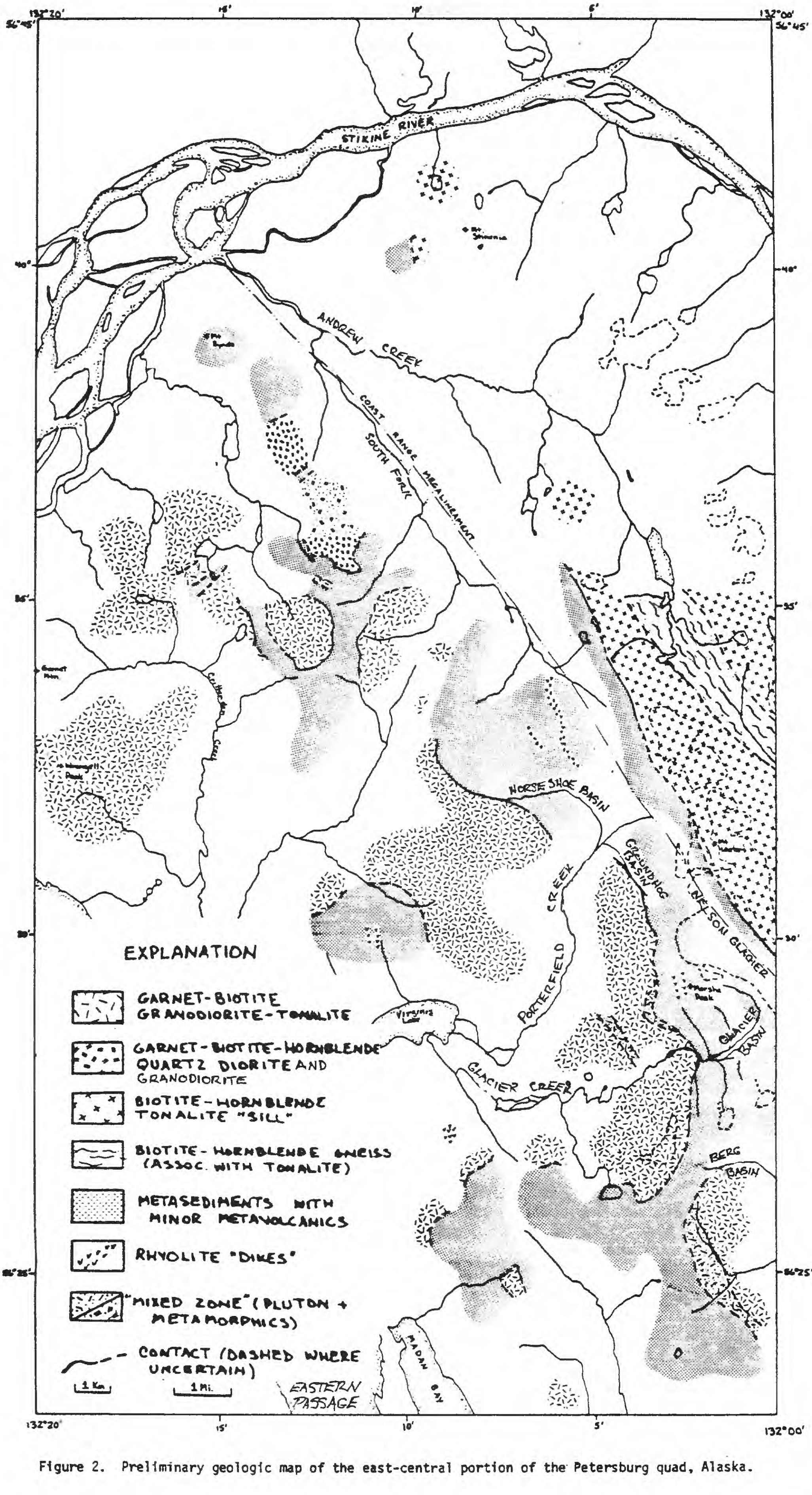


Figure 2. Preliminary geologic map of the east-central portion of the Petersburg quad, Alaska.

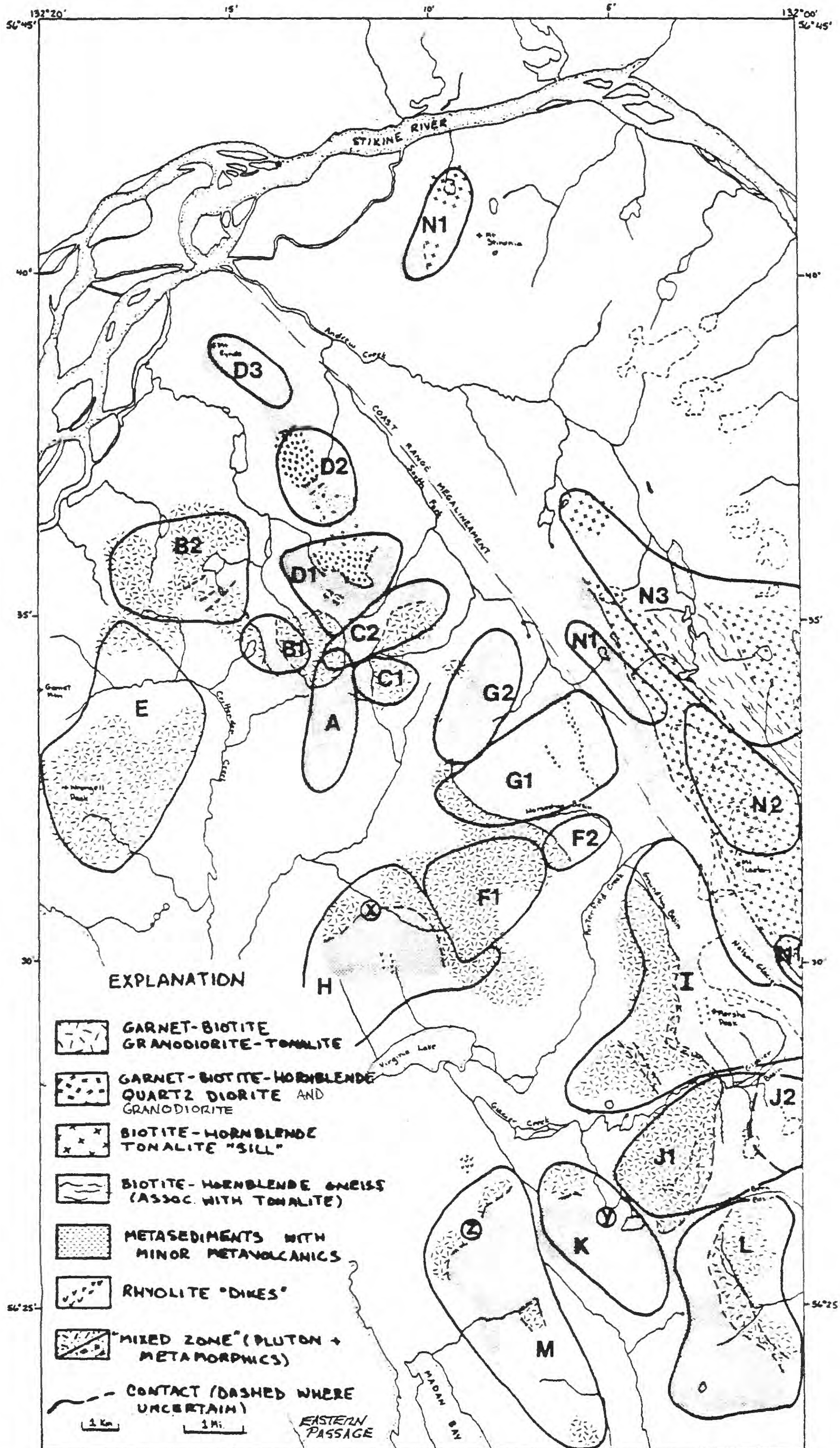


Figure 3. Map showing preliminary geology and the boundaries of structural domains (heavy lines) described in text. Lower case letters (x,y,z) designate specific areas discussed in text.

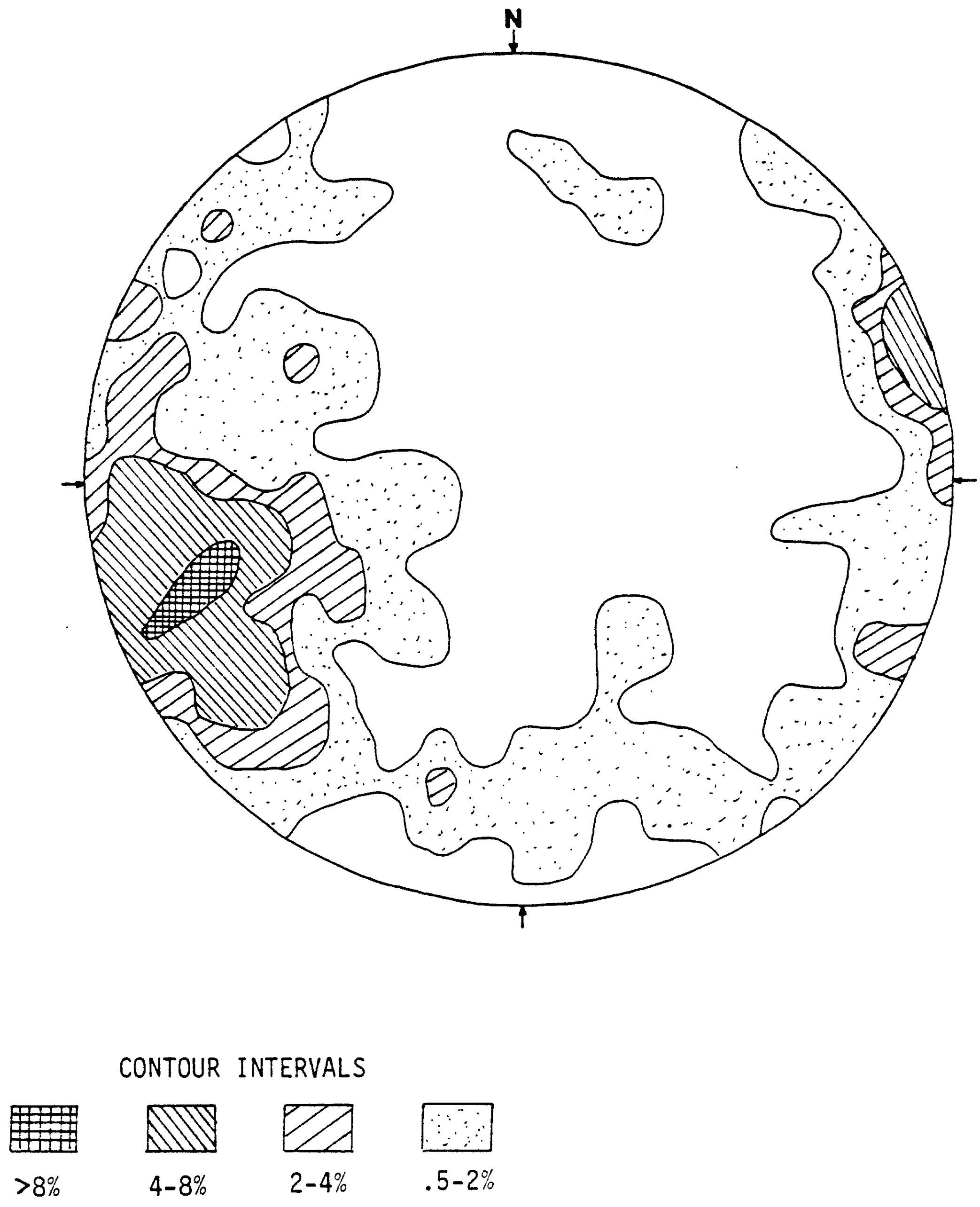
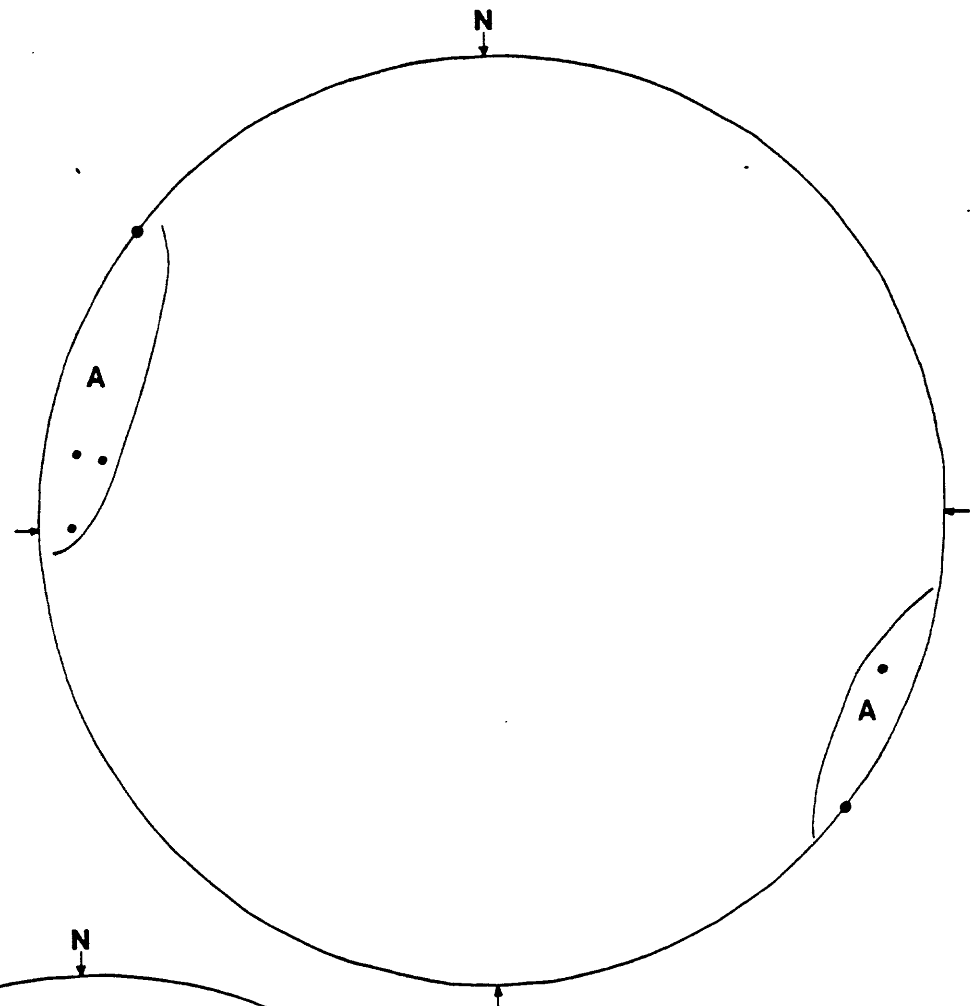


Figure 4. Contoured equal area plot of 179 poles to foliation from the area southwest of the Coast Range Megalineament. Contour intervals are as shown; lowest interval includes all poles.

Figure 5.

Equal area plot of poles to foliation in domain A.



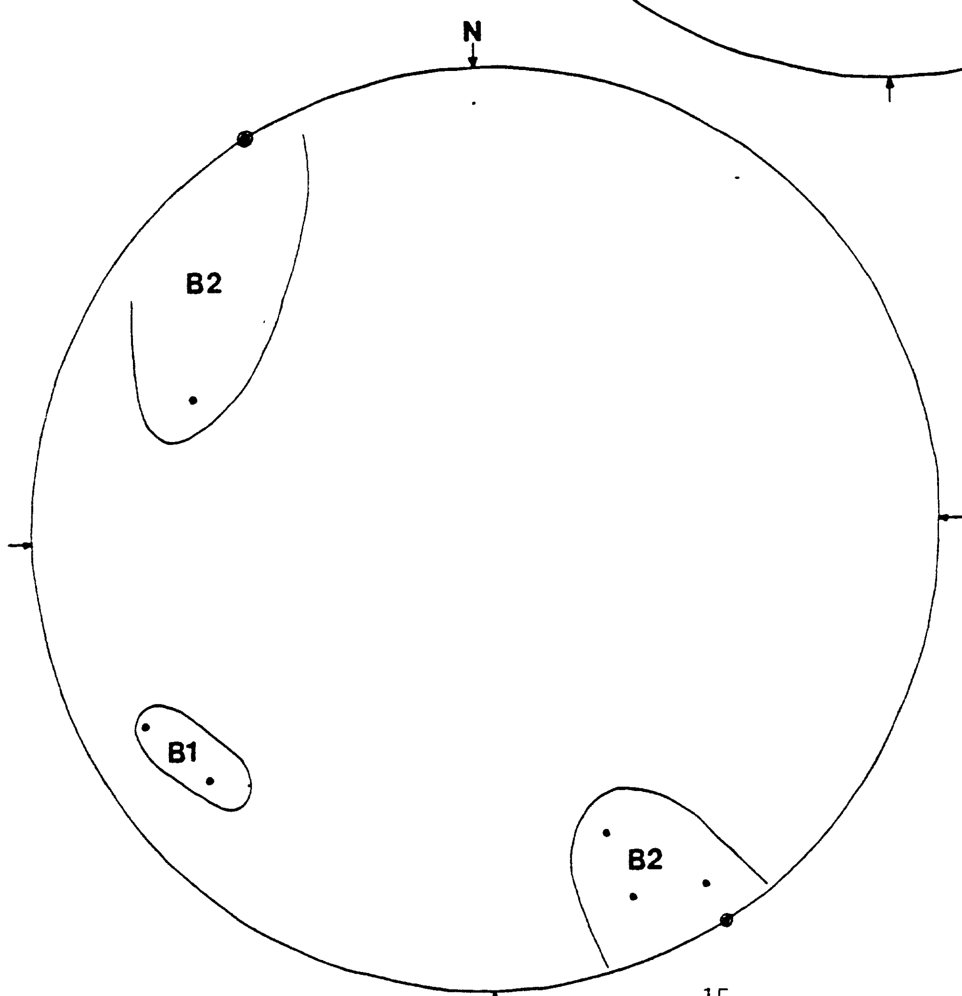
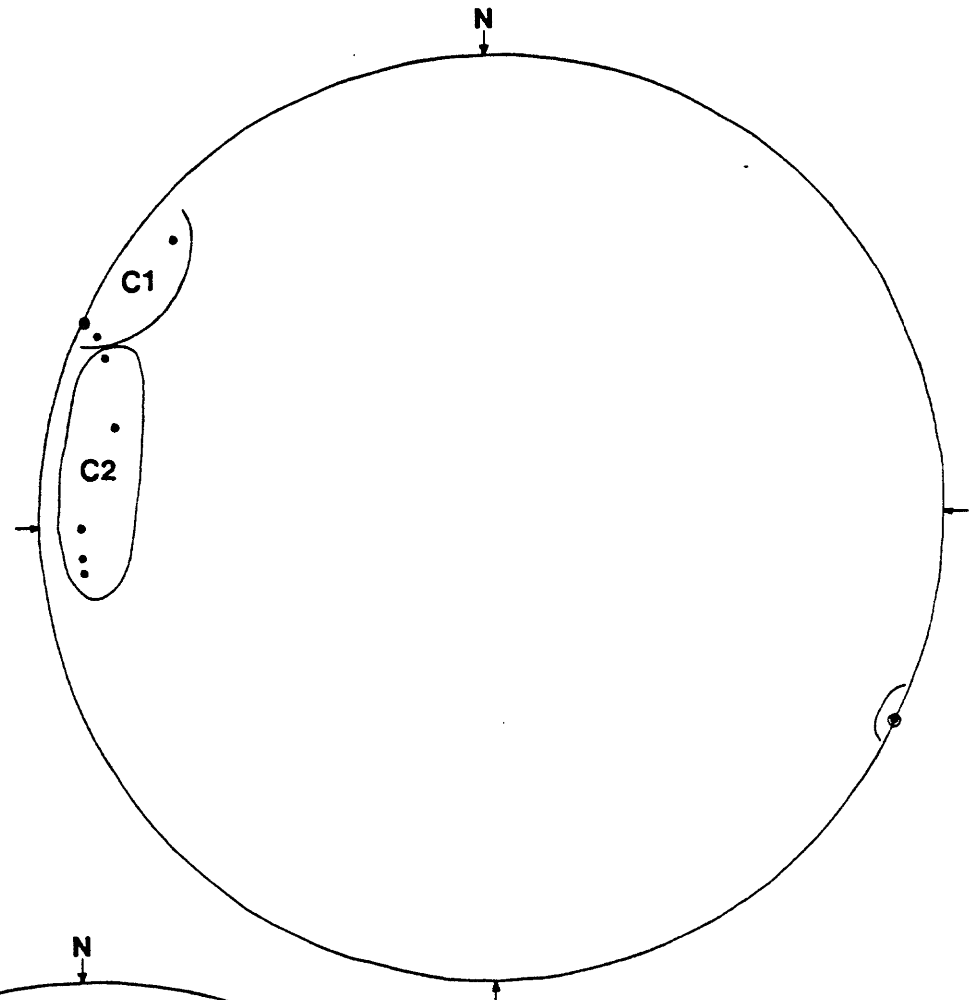


Figure 6.

Equal area plot of poles to foliation in domains B1 and B2.

Figure 7.

Equal area plot of poles to foliation in domains C1 and C2.



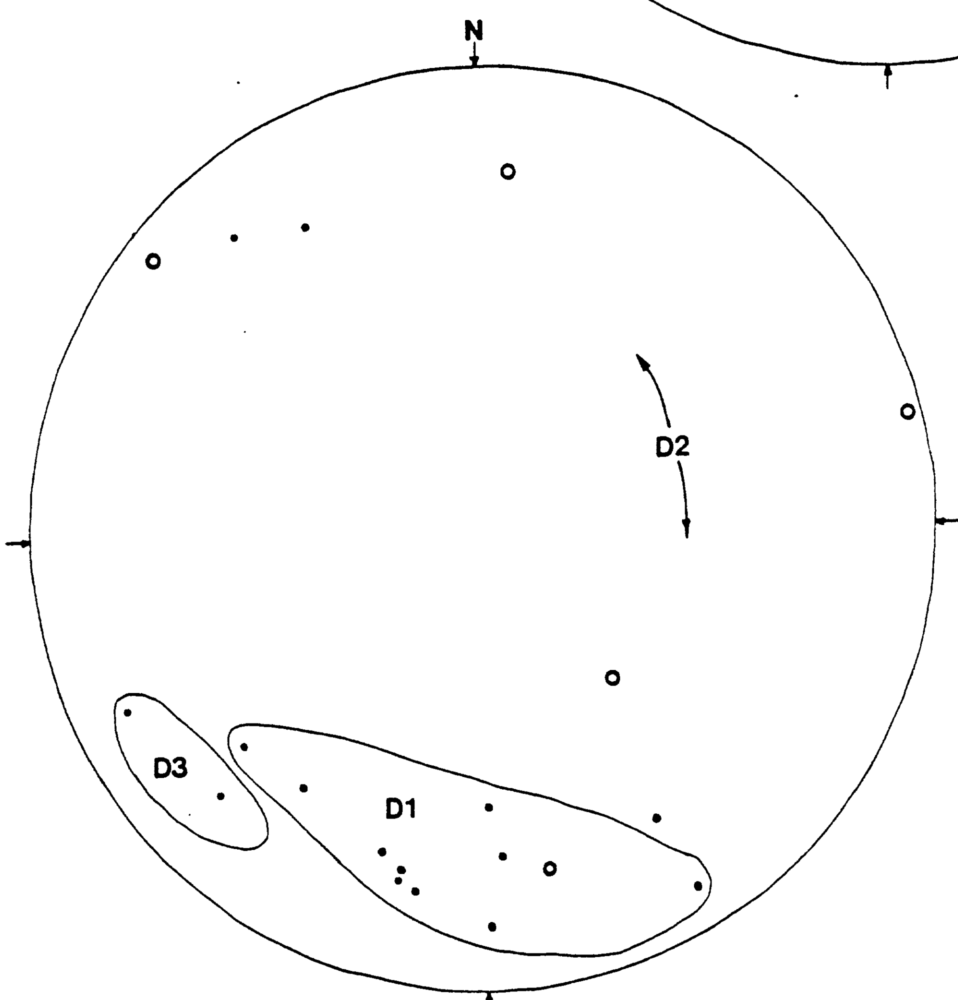
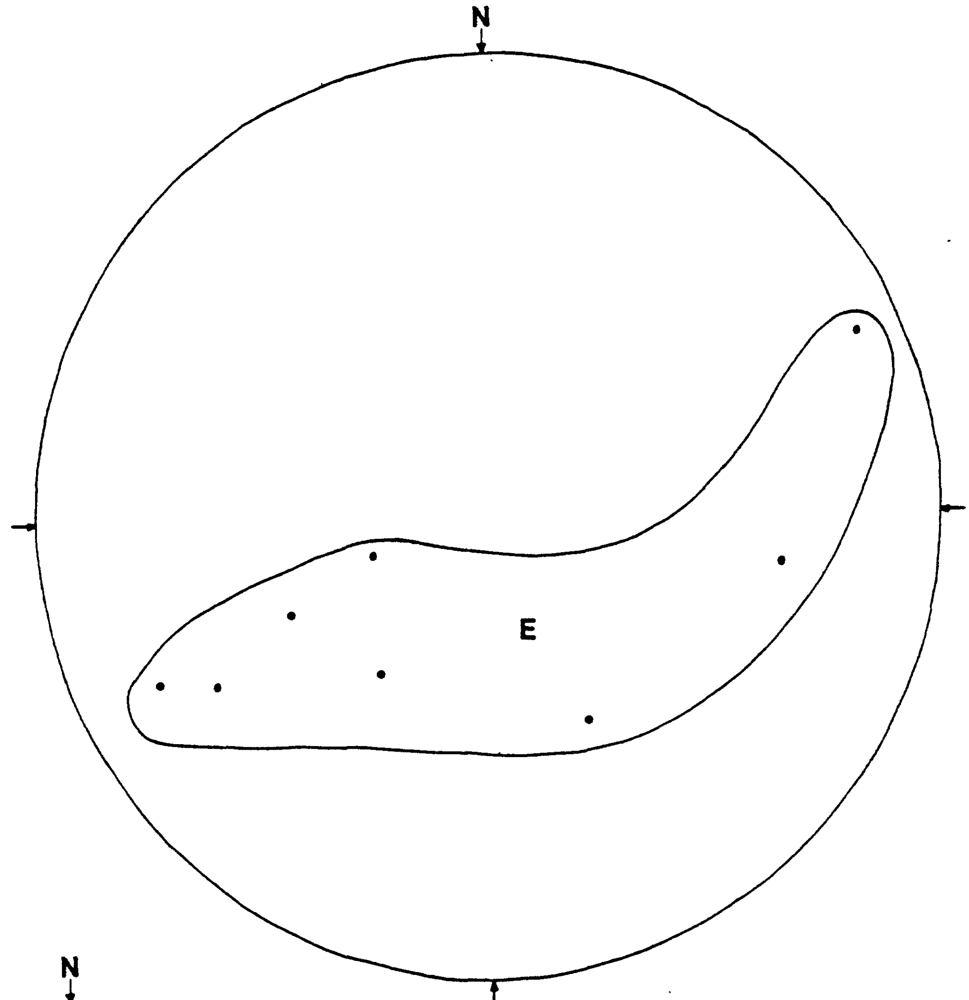


Figure 8.

Equal area plot of poles to foliation in domains D1, D2, and D3. Circles represent garnet-biotite-hornblende quartz diorite.

Figure 9.

Equal area plot of poles to foliation in domain E.



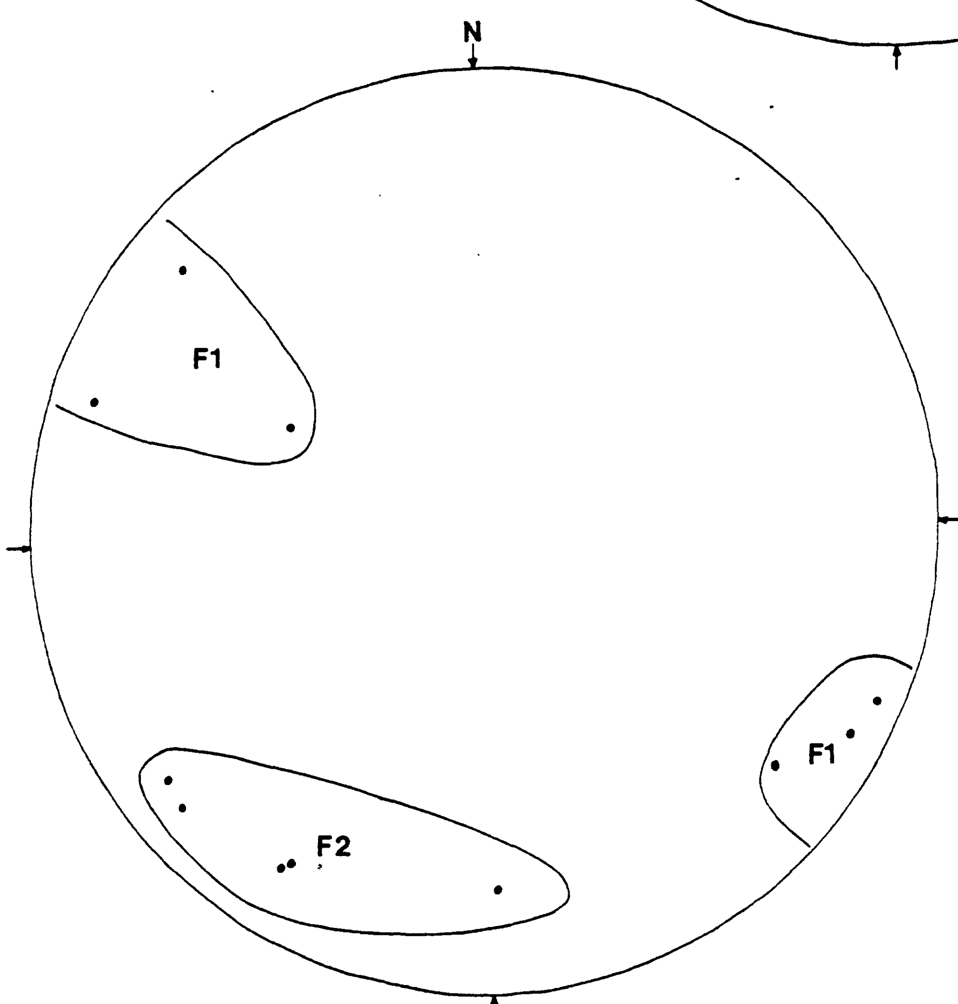
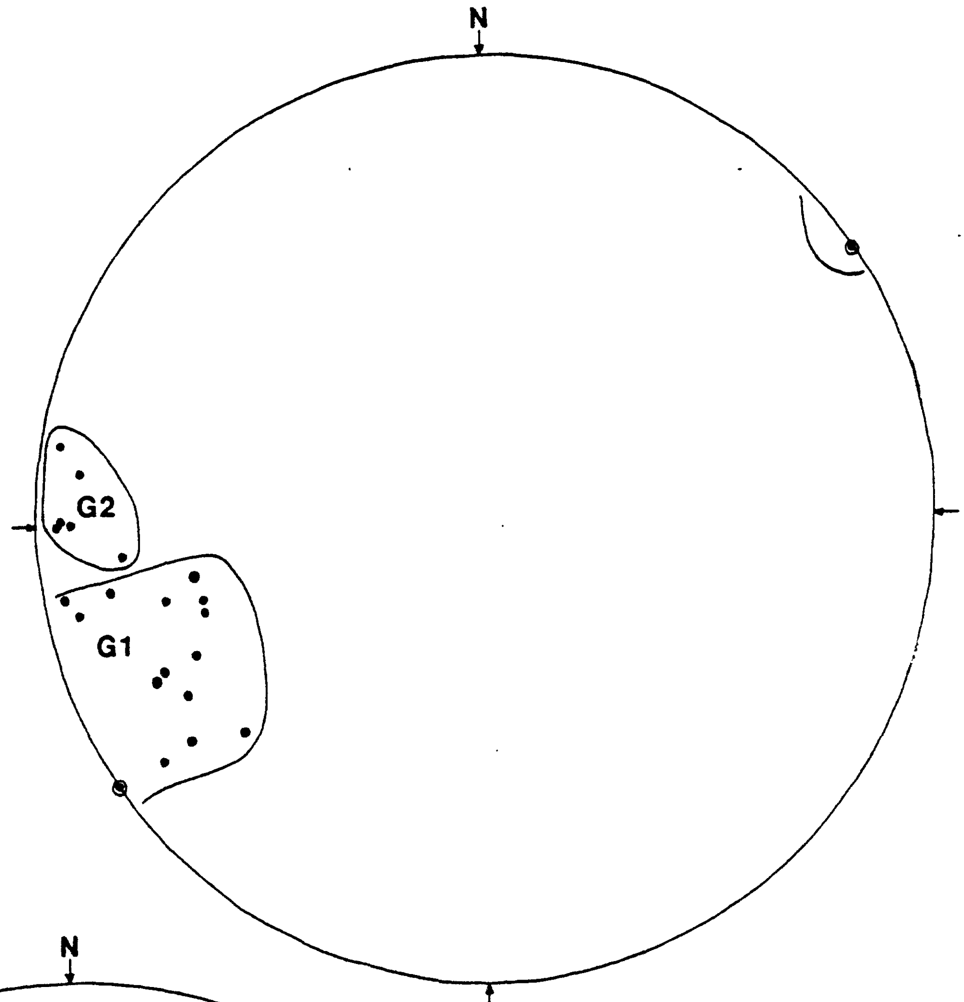


Figure 10.

Equal area plot of poles to foliation in domains F1 and F2.

Figure 11.

Equal area plot of poles to foliation in domains G1 and G2.



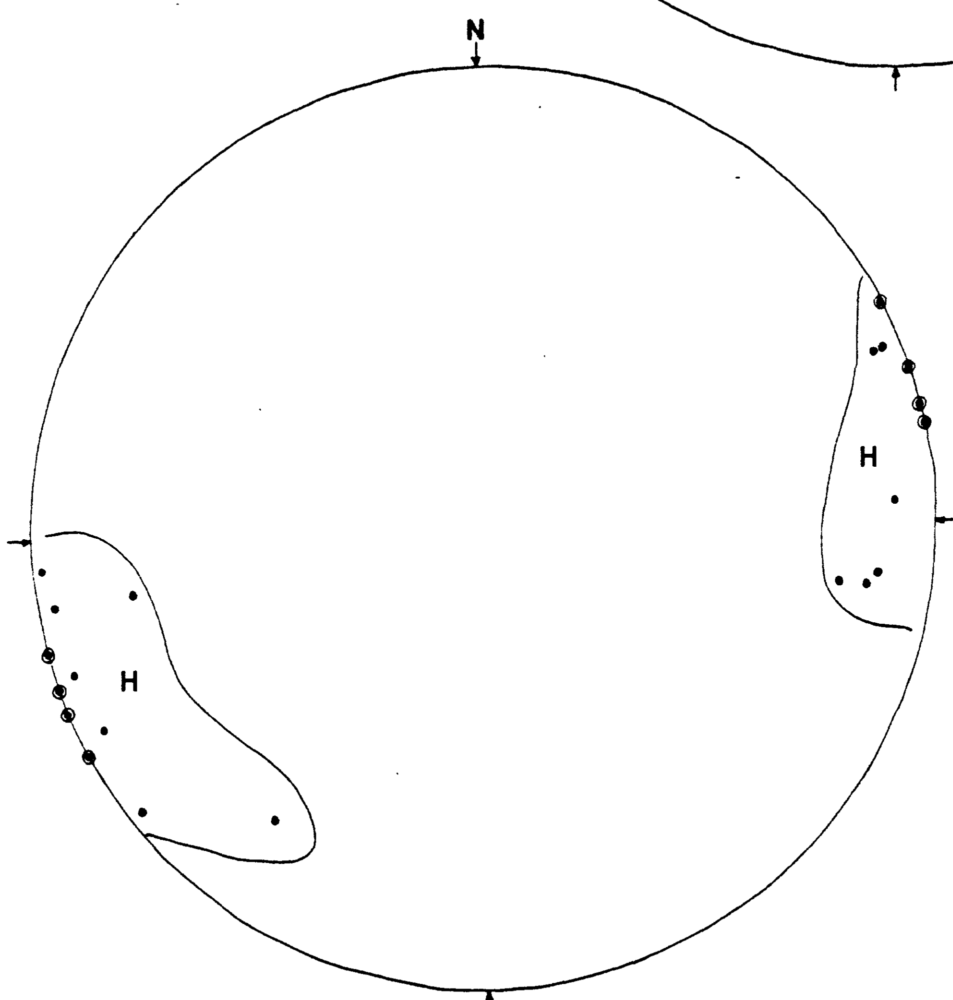


Figure 12.

Equal area plot of poles to foliation in domain H.

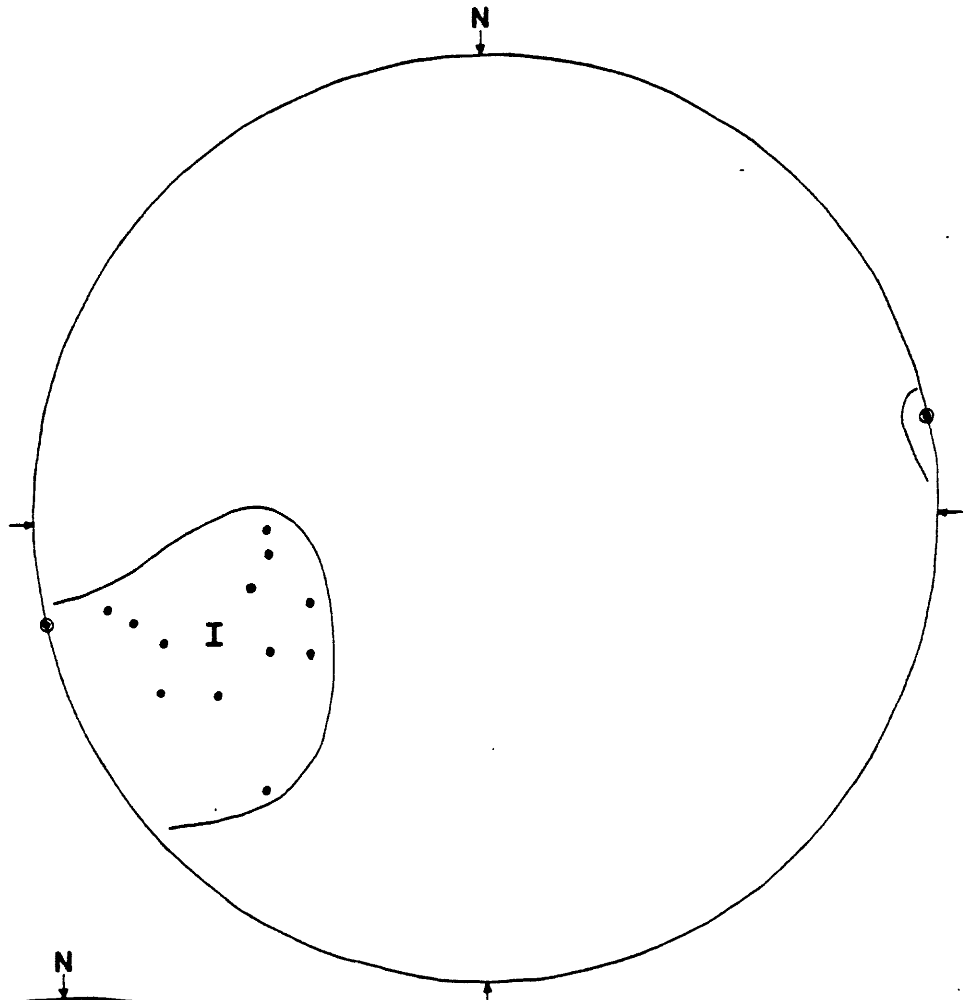


Figure 13.

Equal area plot of poles to foliation in domain I.

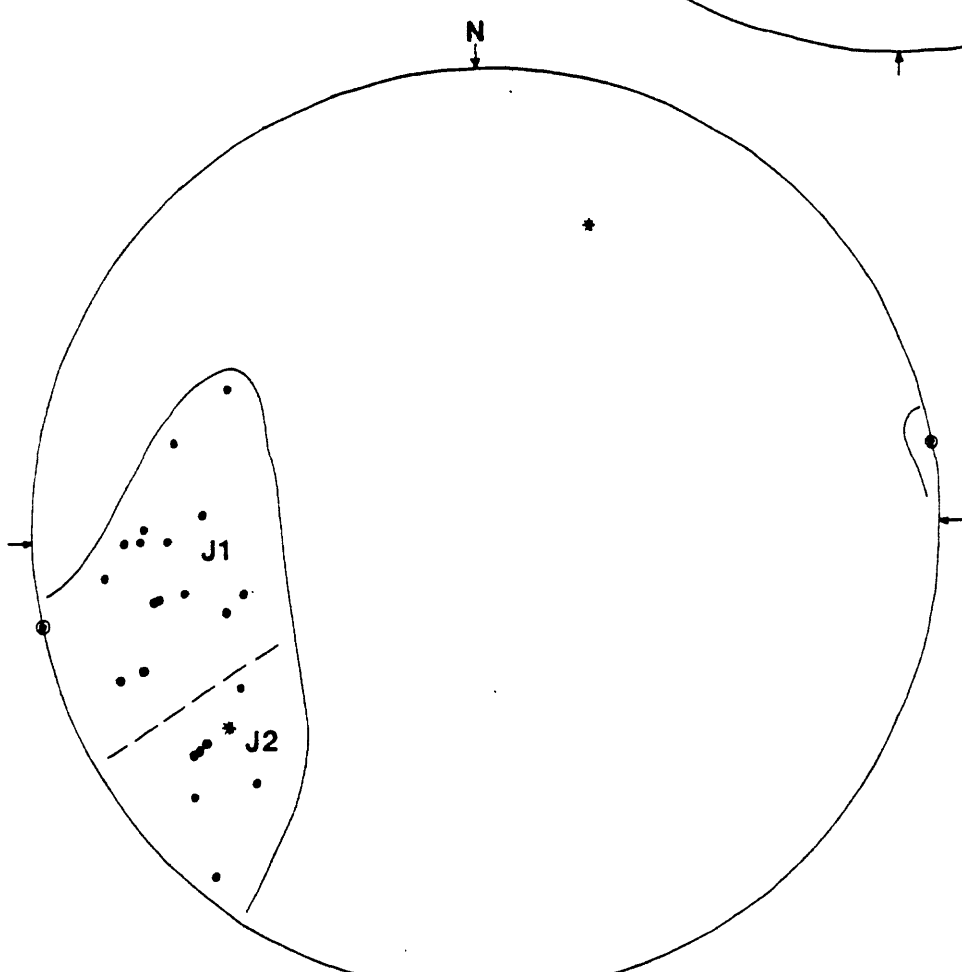
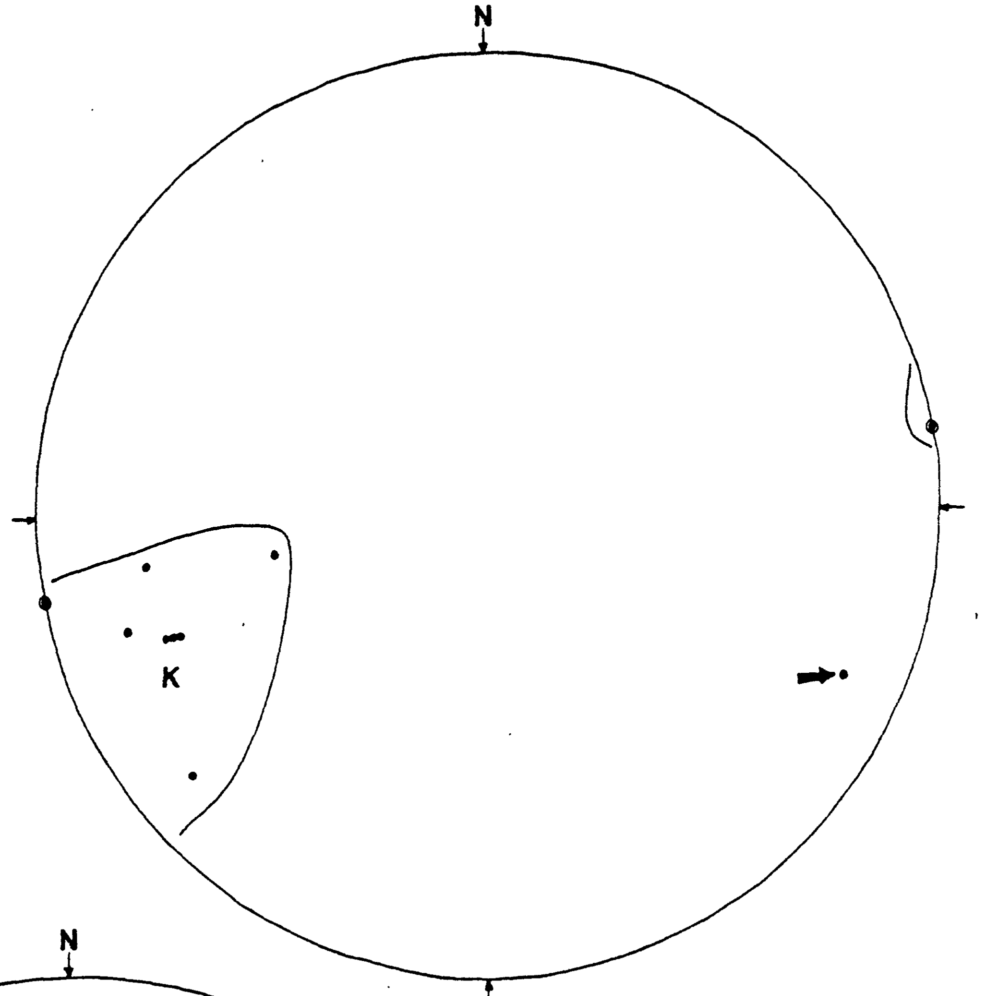


Figure 14.

Equal area plot of poles to foliation in domains J1 and J2. Asterisks represent rhyolite dikes.

Figure 15.

Equal area plot of poles to foliation in domain K. Arrow indicates anomalous pole referred to in text.



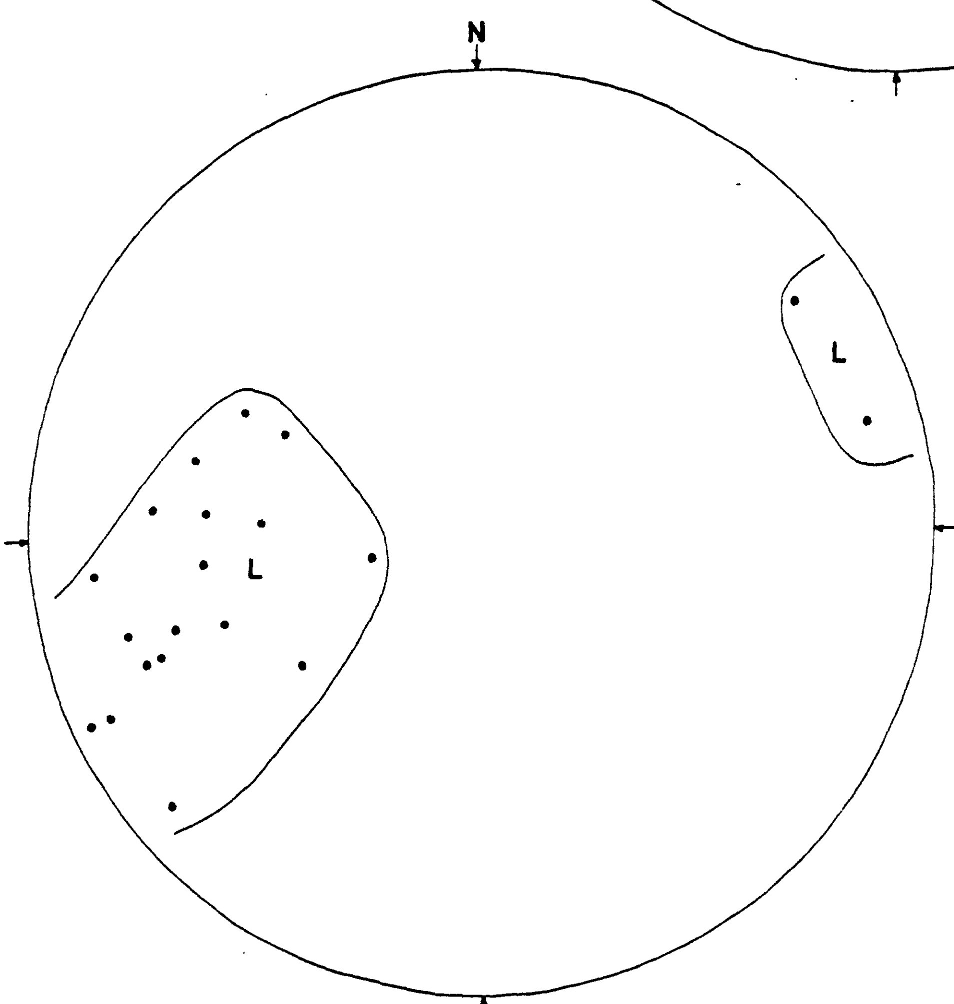


Figure 16.

Equal area plot of poles to foliation in domain L.

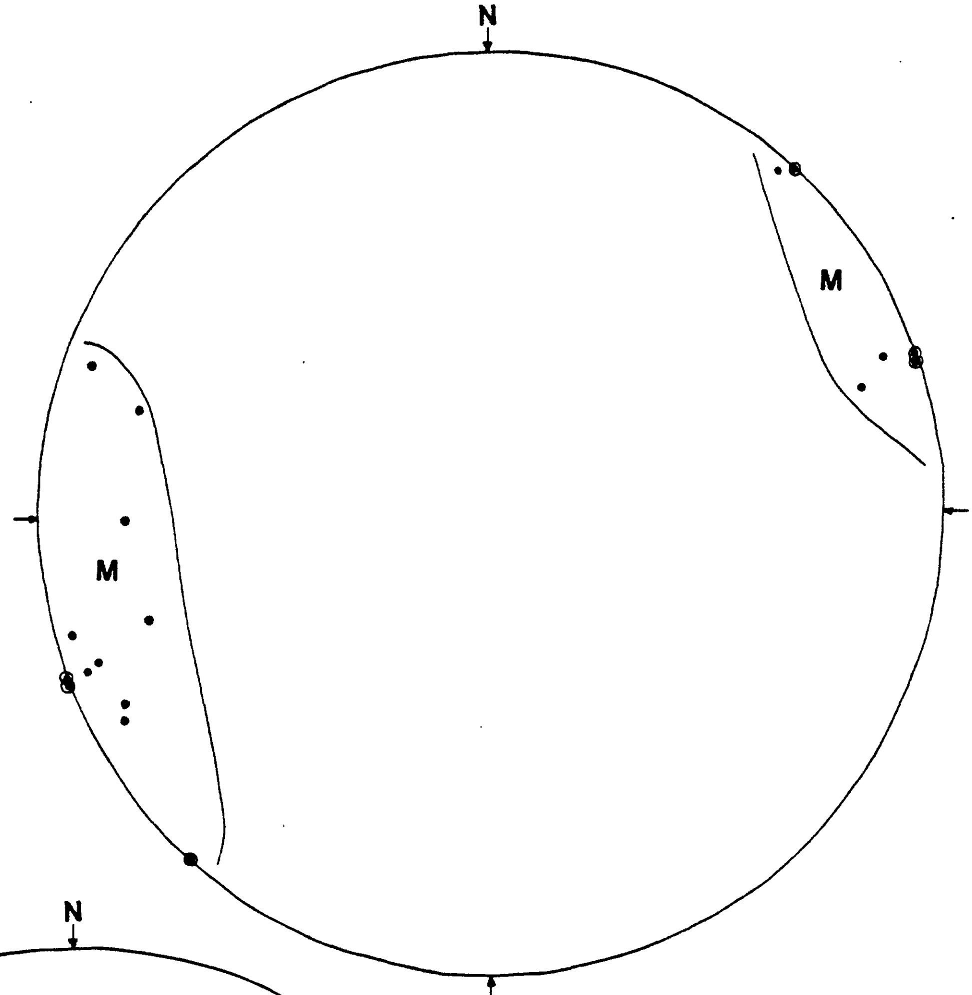


Figure 17.

Equal area plot of poles to foliation in domain M.

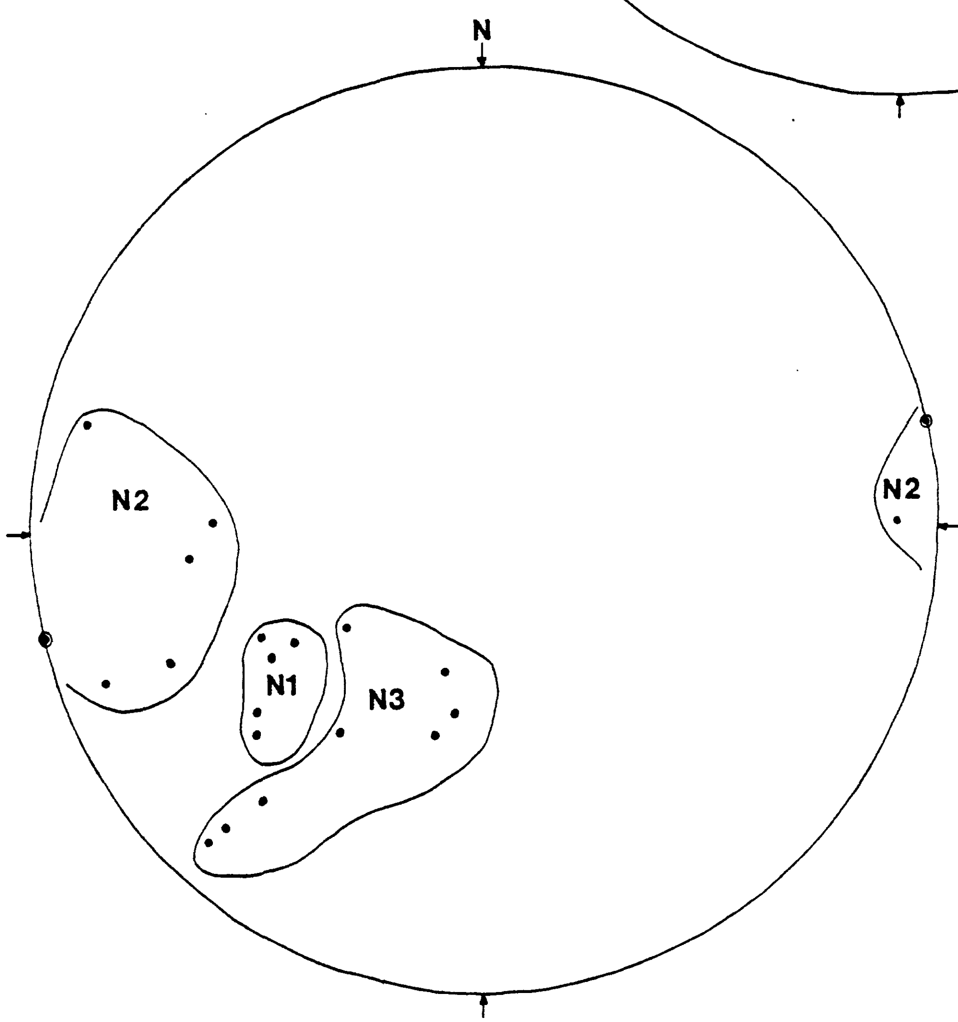


Figure 18.

Equal area plot of poles to foliation in domains N1, N2, and N3.

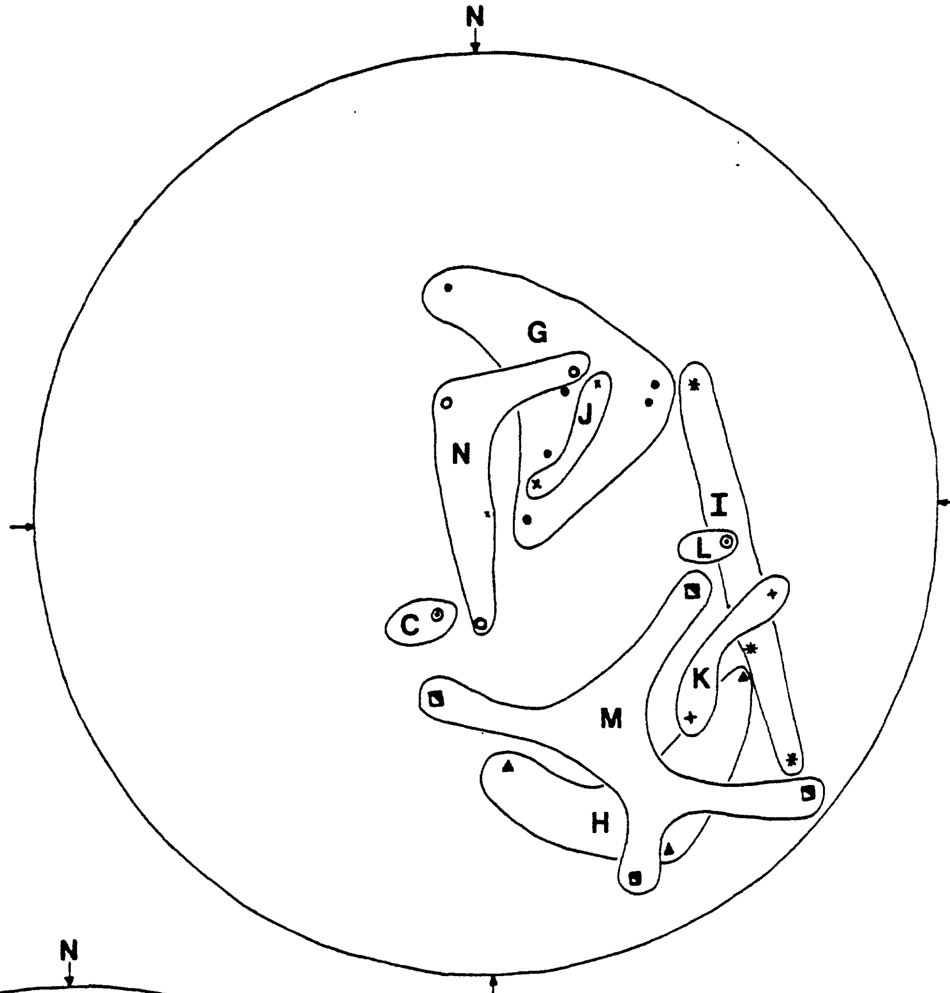


Figure 19.

Equal area plot of lineation orientations. Heavy lines group points by domain.

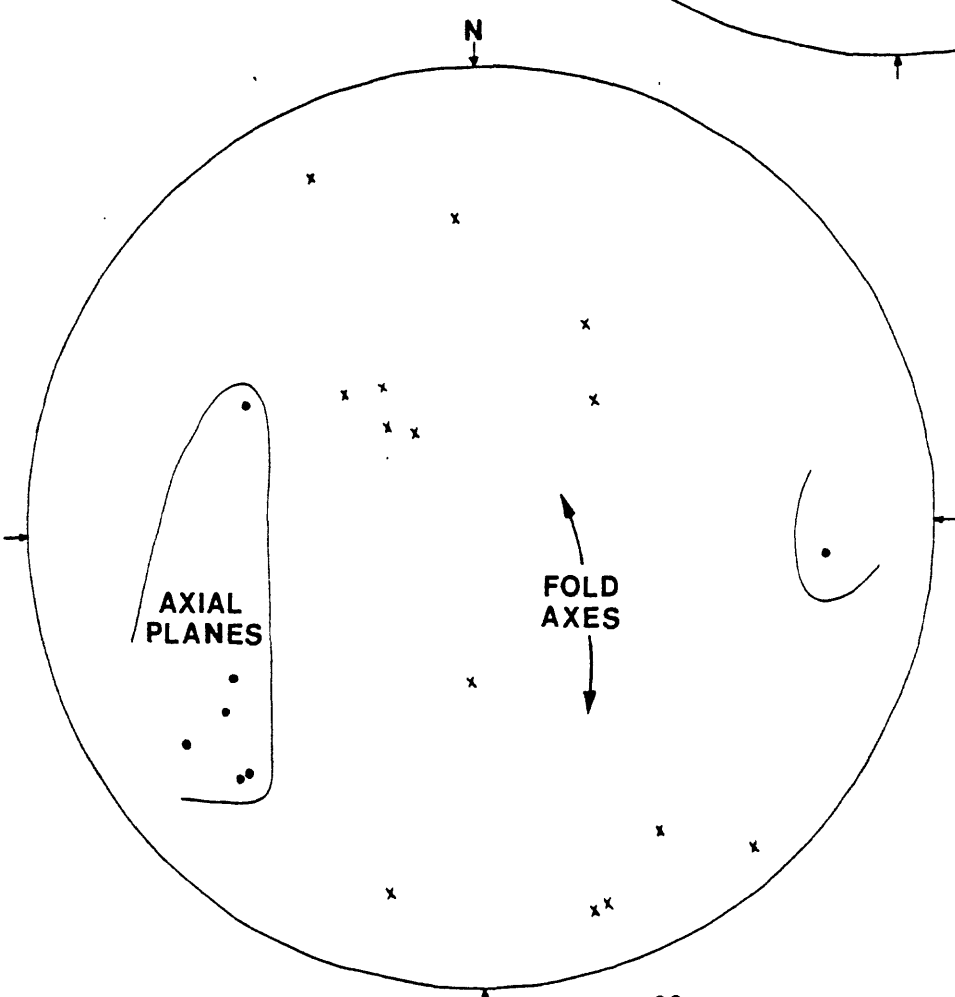


Figure 20.

Equal area plot of fold axes and poles to axial planes, from several domains as discussed in text.

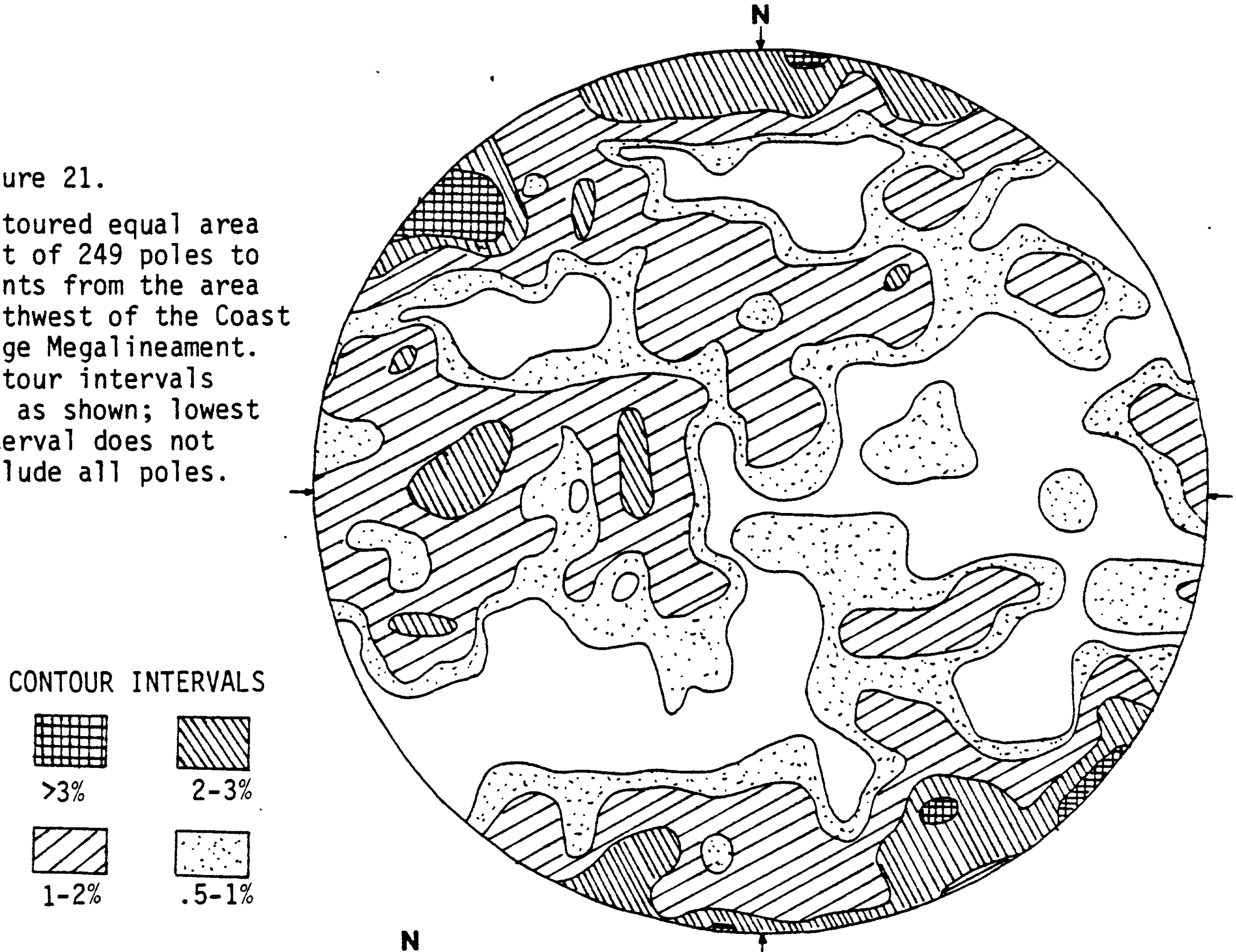


Figure 21.

Contoured equal area plot of 249 poles to joints from the area southwest of the Coast Range Megalineament. Contour intervals are as shown; lowest interval does not include all poles.

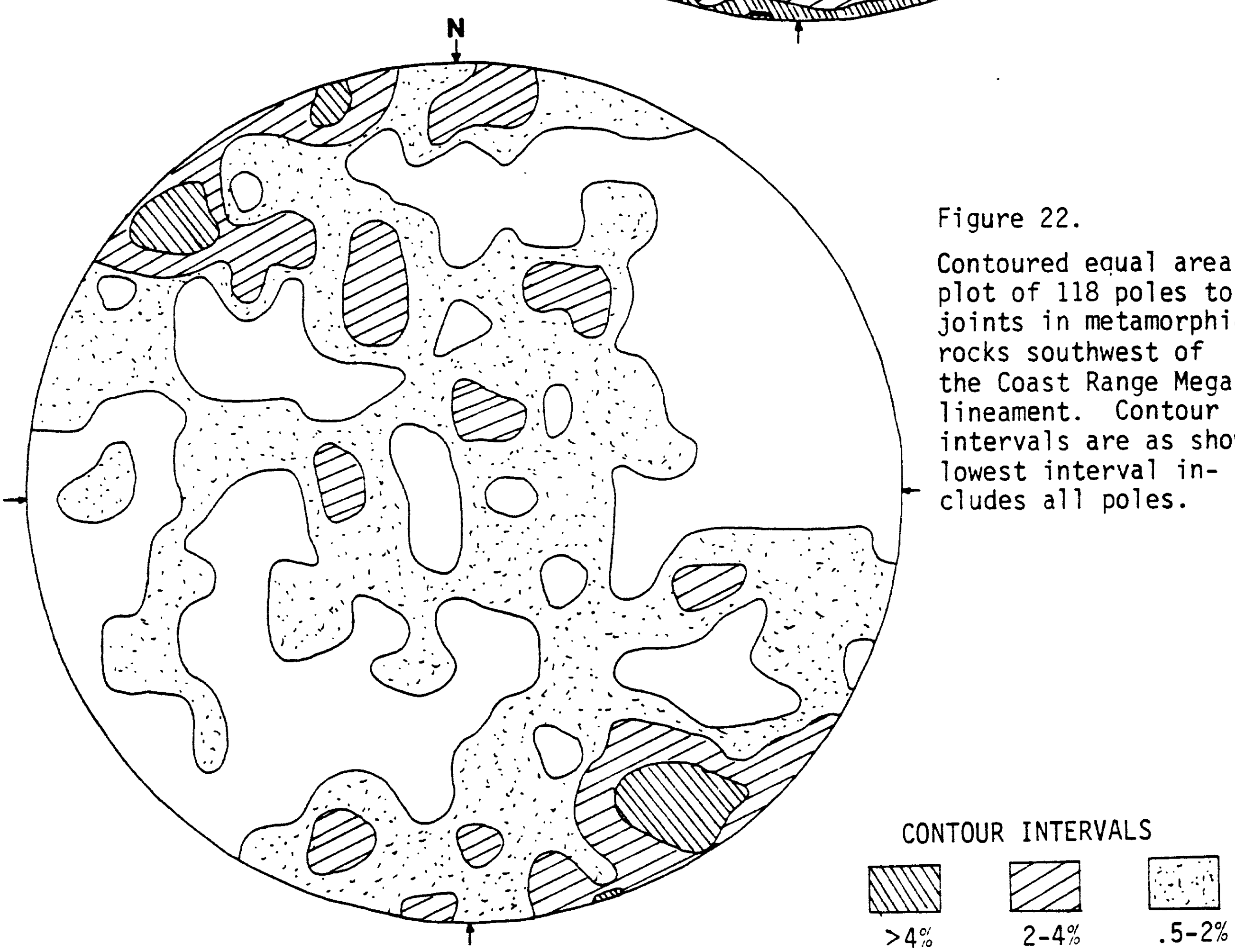
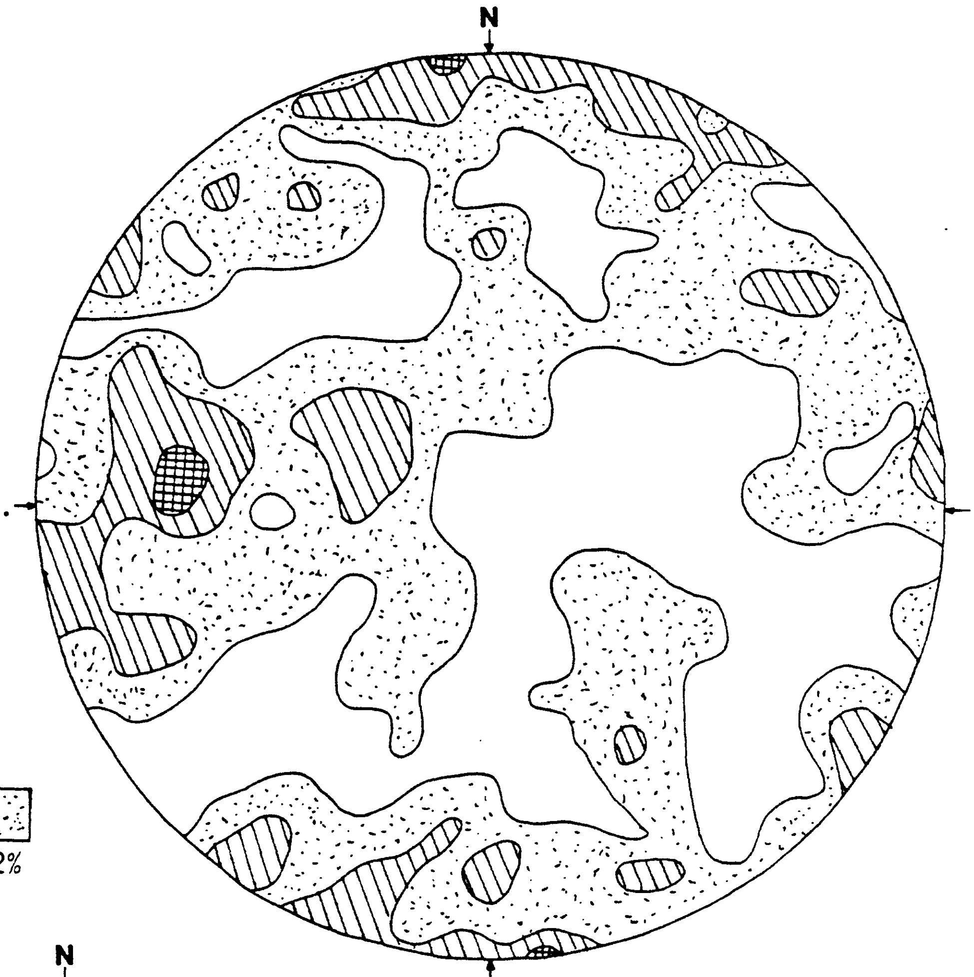


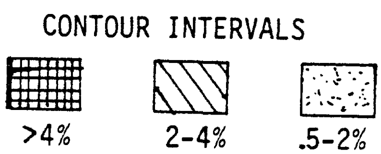
Figure 22.

Contoured equal area plot of 118 poles to joints in metamorphic rocks southwest of the Coast Range Megalineament. Contour intervals are as shown; lowest interval includes all poles.

Figure 23.

Contoured equal area plot of 131 poles to joints in plutonic rocks southwest of the Coast Range Megalineament. Contour intervals are as shown; lowest interval includes all poles.





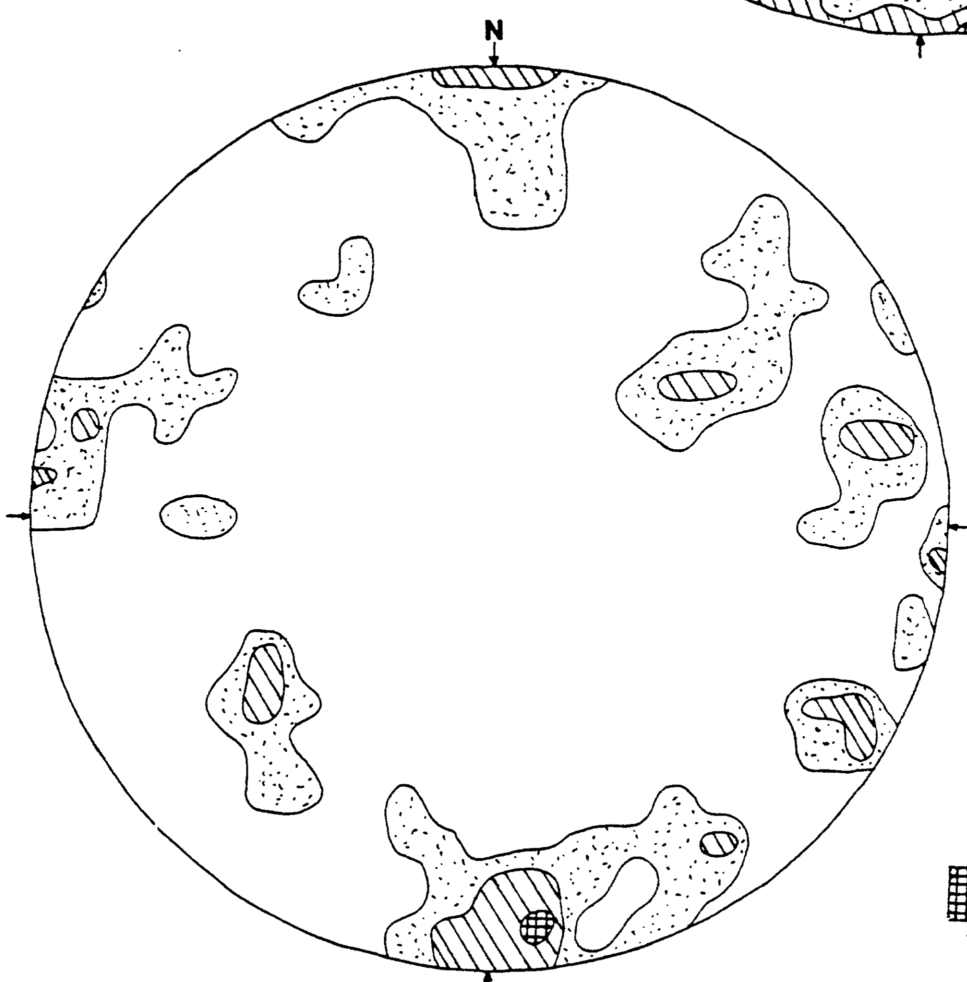
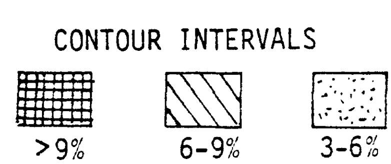


Figure 24.

Contoured equal area plot of 32 poles to joints from the area northeast of the Coast Range Megalineament. Contour intervals are as shown; lowest interval includes all poles.



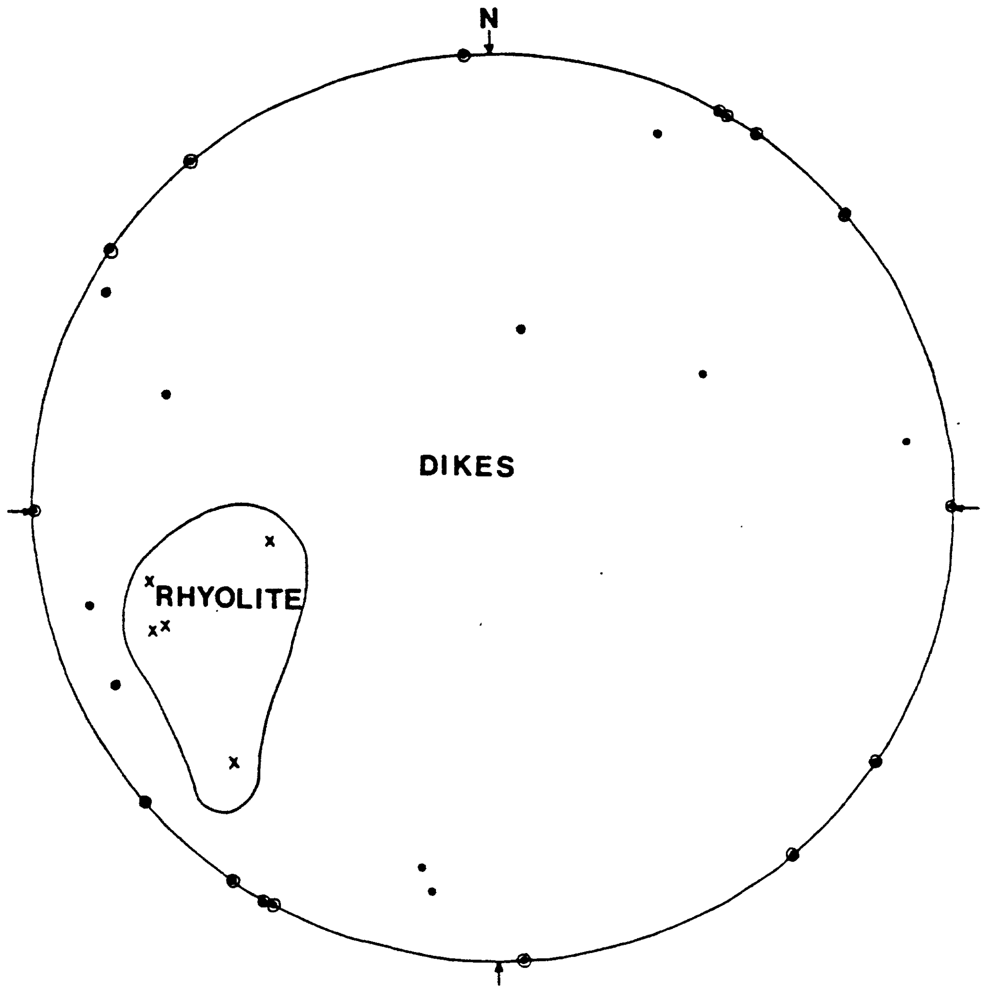


Figure 25. Equal area plot of poles to dikes from throughout the map area. Rhyolite dikes are indicated by an x.