# AN ANALYSIS OF AIR PHOTO LINEAMENTS IN
# GUNDY AND BRODERICK TOWNSHIPS, ONTARIO

A Thesis

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the Faculty of Graduate Studies and Research

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Master of Science

by

Shah Fazlul Bari

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ABSTRACT

This thesis presents the results of a study of first order and second order lineament orientations in Gundy and Broderick Townships, Kenora District, Ontario. The influence of rock types on the variation in lineament orientation is presented and an attempt is made to establish the relationship of lineaments to joints and to gneissosity.

The first order lineaments are the surface expression of persistent fractures or faults. There appears to be a definite relationship between the rock type and the orientation of first order lineaments. Their development is also controlled to a certain extent by the gneissosity of the rocks.

The orientation of second order lineaments does not appear to be controlled either by rock type or by gneissosity. One of the prominent orientation directions, however, is parallel to the glacial movement direction within the study area.

The joints measured in the field do not appear to be expressed by either order of lineaments.

## ACKNOWLEDGEMENTS

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# CHAPTER I

# INTRODUCTION

## Statement of Problem

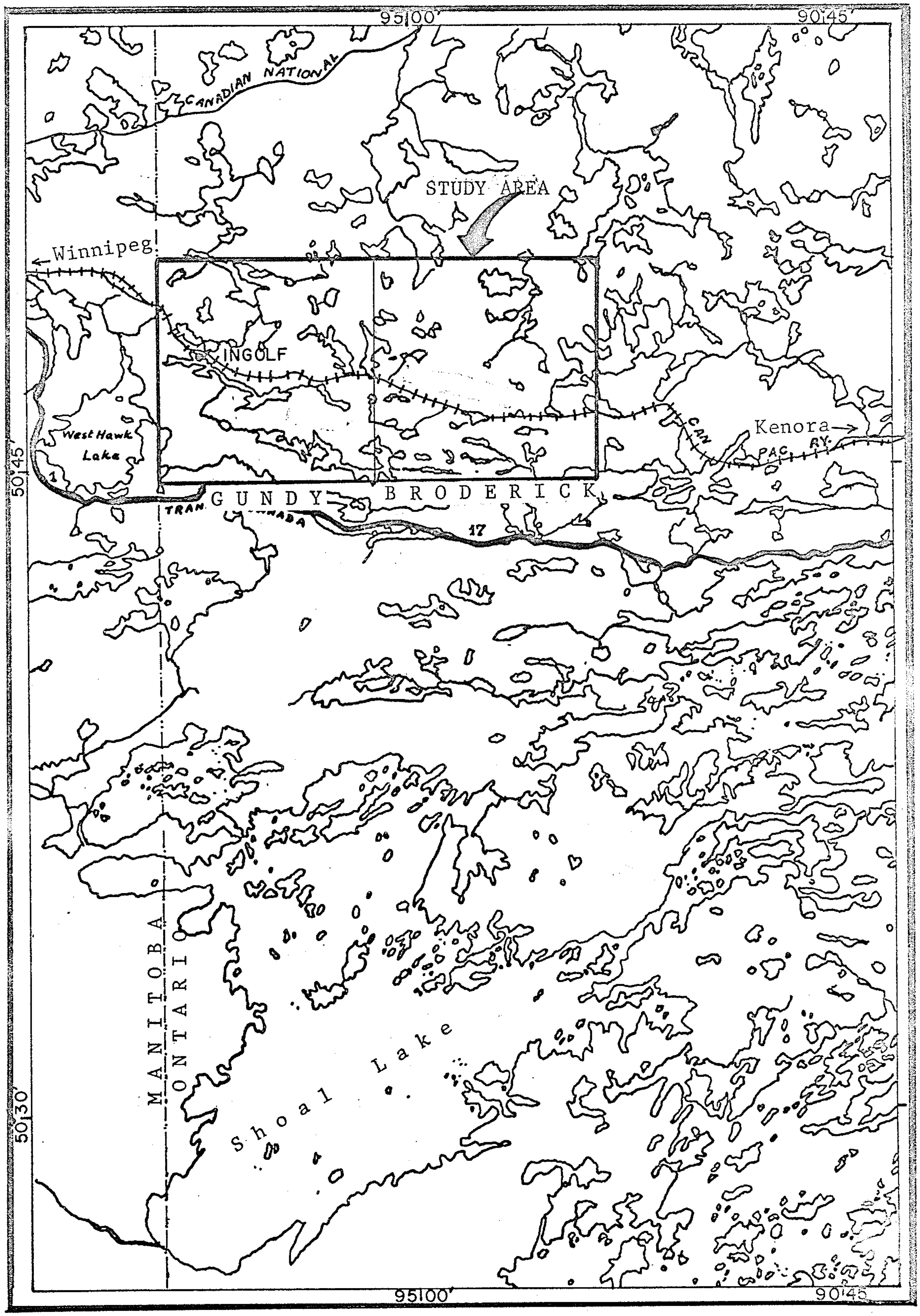
Prominent air-photo linear features are abundant in Gundy and Broderick Townships. The objective of this study is to delineate and to interpret the lineament pattern within the study area.

## Geographic Location

Gundy and Broderick Townships, Kenora District, Ontario, are adjacent to the Manitoba border, between north latitudes 49° 50' and 49° 44' 29". The eastern and western limits of the study area are the meridians of 94° 53' 24" and 95° 09' 11" west longitude respectively (Figure 1). The study area comprises 70.21 square miles.

## Accessibility

The main line of the Canadian Pacific Railway passes through the central parts of Gundy and Broderick Townships. Ingolf, Ontario, on the Canadian Pacific Railway near the Manitoba border, is also accessible by a secondary road, which leads from Manitoba Highway No. 4. The northern parts of Gundy and Broderick Townships are most easily reached by float equipped aircraft.




Index Map
Location of Gundy and Broderick Townships, Kenora District, Ontario.

Miles 4 3 2 1 0 4
Scale

# CHAPTER II

## GENERAL GEOLOGY

The geology of the study area is described in Ontario Department of Mines, Geological Report No. 41 (Davies, 1965). A summary is presented in the following paragraphs and a generalized geologic map is presented in Figure 7.

The bedrock of the area is all of Precambrian age. The metamorphosed sedimentary and volcanic extrusive rocks which occupy a small portion at the southwestern part of the study area have been intruded by a variety of igneous rocks (Figure 7).

The metamorphosed sedimentary and volcanic extrusive rocks in the southwestern Gundy Township consist of interbedded flows, tuff, arkose and greywacke. The sedimentary rocks are intimately associated with the volcanic rocks and are almost wholly of clastic origin. Davies assigned these rock types to the Keewatin group. This terminology is the same as that used in describing the Precambrian geology of Minnesota (Goldich, et al, 1961). These rock types appear to be highly deformed and have a pronounced foliation.

The igneous rocks within the study area range in composition from acid to basic. According to Davies (1965), the basic intrusive rocks are older than the acid intrusive rocks.

A large body of basic intrusive rocks, primarily dioritic in composition, occurs in northern Gundy Township. These rocks weather dark grey to black and consist essentially of hornblende and altered plagioclase. Basic intrusive rocks also occur as a number of separate zones in northeastern Broderick Township. Here, their composition is hornblende diorite and diorite with much injected granodiorite, and they have been interpreted by Davies (1965) to represent remnants of an original larger dioritic body, which was intruded by the later granodiorite.

Most of Broderick Township and over half of Gundy Township are underlain by the younger acid intrusive rocks. Important members of this group are grey gneissic granodiorite and pink quartz monzonite. The origin of the pink quartz monzonite is in doubt. Davies (1965) has presented evidence to support both igneous and metasomatic origins for the pink quartz monzonite. The granodiorite has been considered by Davies (1965) to be an intrusion of pre-Timiskaming age. All acid intrusive rocks are considered by Lawson (1885) to be Laurentian in age.

The Pleistocene deposits in the study area are unconsolidated glacial deposits composed largely of till.

The Recent deposits include clay, mud and sand, and are the results of recent weathering and transportation processes. The cumulative total thickness of these deposits, as stated by Davies (1965), does not exceed 15 feet.

# TABLE OF FORMATIONS

# FOR

# GUNDY AND BRODERICK TOWNSHIPS

(After Davies, 1965)

CENOZOIC

Recent: Lake, stream, and swamp deposits

Pleistocene: Sand, gravel, clay, till.

G R E A T   U N C O N F O R M I T Y

PRECAMBRIAN

Archean:

Later Acid Intrusive Rocks -

Pink quartz monzonite and granodiorite, with some grey foliated granodiorite.

Intrusive Contact

Quartz monzonite; grey granodiorite; gneissic hornblende-biotite granodiorite, with aplite, pegmatite, and dark inclusions; grey granodiorite with much pink granodiorite; tonalite and diorite; border phase of hybrid rocks and lit-par-lit gneiss; granodiorite with large feldspar "eyes".

Intrusive Contact

Basic Intrusive Rocks -

Quartz-hornblende diorite; hornblende diorite; diorite with much injected granodiorite; gabbro.

Intrusive Contact

Keewatin Group:

Metamorphosed Sedimentary Rocks -

arkose; greywacke, arkosic greywacke; conglomerate, reworked conglomerate; iron-rich greywacke; slate, iron-rich slate; siliceous siltstone, cherty sedimentary rocks; garnet-rich greywacke.

Metamorphosed Acid Volcanic Rocks -

bedded rhyolitic and dacitic tuff, minor flows and agglomerate; massive fine-grained rhyolitic and dacitic tuff.

Metamorphosed Basic Volcanic Rocks -

andesite; basalt; tuff; lapilli tuff; agglomerate and tuff; interbanded lensy tuff, flows and sediments; hornblende-biotite-plagioclase schist; gabbro, coarse-grained tuff and flows (possibly gabbro).

## STRUCTURAL GEOLOGY

A general east-west foliation is present throughout the study area. Within the metamorphosed sedimentary and volcanic extrusive rocks in the southwestern portion of the study area, the foliation is in the form of a penetrative schistosity. This foliation is present in all rock types within this area and in many places is discordant to, and cuts across the layering of the rocks. There seems to be little doubt that the foliation has a tectonic origin in these rocks. Within the igneous intrusive rocks foliation is present in the form of gneissosity. This gneissosity is generally parallel to the gneissosity developed within the areas of metamorphosed sedimentary and volcanic extrusive rocks. Whether this gneissosity has a tectonic origin or is primary and associated with the emplacement of the intrusive mass of magma, is not known.

Within the study area, joints are present in all rock types. The pattern of joints appears consistent throughout the whole study area. Davies' 1962 field notes indicate one major joint set striking north-northeast, and minor joint sets whose strikes vary from northwest to north-northwest. All the joint sets dip steeply.

The geological map accompanying the Ontario Department of Mines, Report No. 41, shows a number of continuous rectilinear and curvilinear topographic features. Davies (1965) interpreted some of these as lineaments and some as assumed faults. The presence of faults within the study area was based largely on the interpretation of air photographs, although some of the lineaments were known to coincide with narrow schistose zones within the rocks. No displacement has been observed along these topographic features where they cut across the contacts of different rock types.

# CHAPTER III

## STRUCTURAL ELEMENTS

### Introduction

Prominent air-photo linear features are abundant in Gundy and Broderick Townships. The objective of this study is to delineate and interpret the lineament pattern within the study area. To achieve this objective, statistical analyses of orientation data on lineaments, joints and gneissosity were carried out. Lineaments were analyzed in two dimensions. Joints and gneissosity were analyzed in three dimensions.

### Definition of Structural Elements

#### Lineaments

"Lineament" is a purely descriptive term for any natural rectilinear or curvilinear feature observed on aerial photographs, mosaics, topographic maps and relief maps.

Lineaments may be reflected in topography or soil in the form of: (a) glacial movement direction, (b) vegetation trends, (c) contacts between different vegetation types, (d) alignment of drainage, (e) escarpments in bedrock, (f) topographic features such as bluffs or topographic lows, (g) tonal changes in soil, etc.

These surface features are usually caused by Joints, faults, fractures, contacts or glacial processes. Blanchet (1957), Henderson (1960), Lattman and Nickelsen (1958), and Mollard (1957) agree that the majority of the lineaments in areas which they have studied in detail are surface traces of fractures.

Joints

Joints may be defined as sets of parallel fractures in rock in which there is no discernible displacement along the fracture surfaces. The term "joint" includes both open fractures ("Spalten") and closed fractures ("Klufte") as distinguished by Cloos, H., (1936, p. 214).

Fractures

A fracture may be defined as a single break in rocks. Fractures do not occur in sets and there is no discernible displacement of one face of the fracture relative to the other. Fractures may be miles in length, thousands of feet deep, and proportionately wide, or they may be microscopic in all dimensions.

Faults

Faults may be defined as fractures or fracture zones along which there has been displacement of the two sides relative to one another. The displacement may be a few inches or many miles (Reid, 1913).

Gneissosity

Gneissosity is the planar alignment of tabular or linear minerals in igneous or metamorphic rocks. Rocks in which this property exists often have a banded or streaky appearance.

CHAPTER IV

# COLLECTION AND STATISTICAL TREATMENT OF DATA

This chapter presents the principles used in collecting lineament, joint, and gneissosity data. The diagrammatic presentation of these data is also reviewed.

## A. Lineament

### Principles used in Collecting Data

Continuous or nearly continuous, rectilinear and curvilinear topographic lows and highs were selected as lineaments from the aerial photographs. The true north on the aerial photographs was determined by correlating with the geographic features on the topographic map.

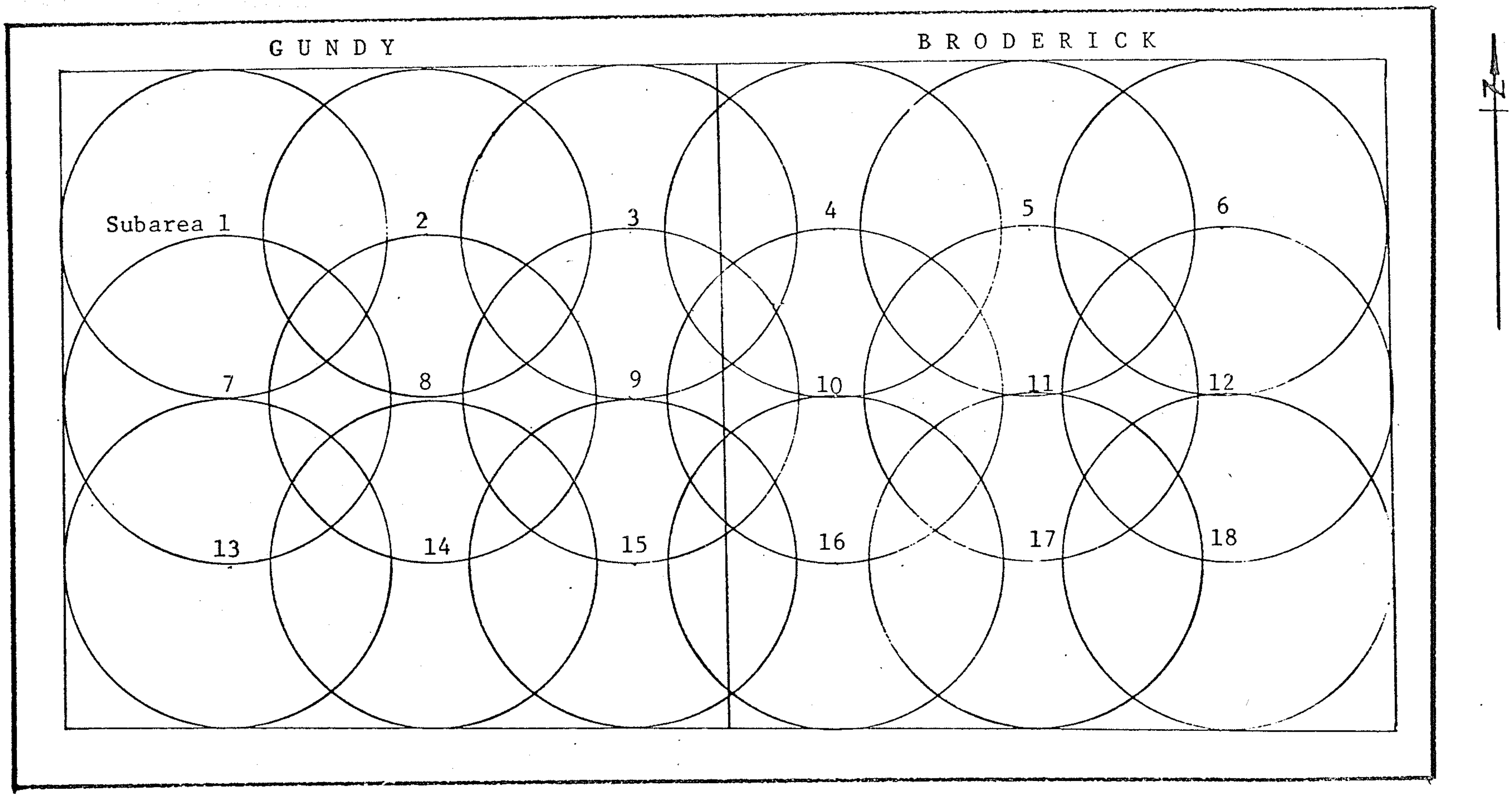
It was obvious that some lineament sets were better defined than others. The lineaments were arbitrarily designated as first order or second order on the basis of their persistence. Lineaments greater than 1,320 feet in length were called first order lineaments; those less than 1,320 feet were called second order lineaments. In determining the total number of first order lineaments, a length of 1,320 feet was taken as a unit, as was done by Haman, (1961).

### Data Presentation

(a) To study the areal variation in lineament direction:

The whole study area was divided into eighteen circular sub-areas (Figure 4) to study areal variations or changes in the directional

FIGURE 4.




DIVISION OF GUNDY AND BRODERICK TOWNSHIPS INTO EIGHTEEN CIRCULAR SUBAREAS
SUBAREA NUMBER IS PRINTED AT CENTRE OF SUBAREA

SCALE: 1 INCH = 1.5 MILES

properties of the lineaments. Each circular sub-area represents ten percent of the total study area. The strikes of lineaments were tabulated in azimuth groups, having a 5-degree range and presented in the form of rosette diagrams for each of the sub-areas. Areal variation of first order lineaments is presented in Figure 5; areal variation of second order lineaments is presented in Figure 6. The radius of the circle in each rosette diagram represents ten percent of the total number of lineaments within the sub-area. The method follows that outlined by Badgley, (1965).

(b) To study the relationship of first order lineament direction to rock types:

The relationship betwen the first order lineament orientation and the rock type was studied by preparing rosette diagrams showing the orientation of first order lineaments falling within areas underlain by the following rock types,(Figure 7):

Rock type 1 - Acid intrusive rocks: pink quartz monzonite and granodiorite, with some grey foliated granodiorite.

Rock type 2 - Acid intrusive rocks: quartz monzonite; grey granodiorite; gneissic hornblende-biotite granodiorite, with aplite, pegmatite, and dark inclusions; tonalite and diorite; border phase of hybrid rocks and lit-par-lit gneiss; granodiorite with large feldspar "eyes".

Rock type 3 - Basic intrusive rocks: quartz-hornblende diorite; hornblende diorite; diorite with much injected granodiorite; and gabbro.

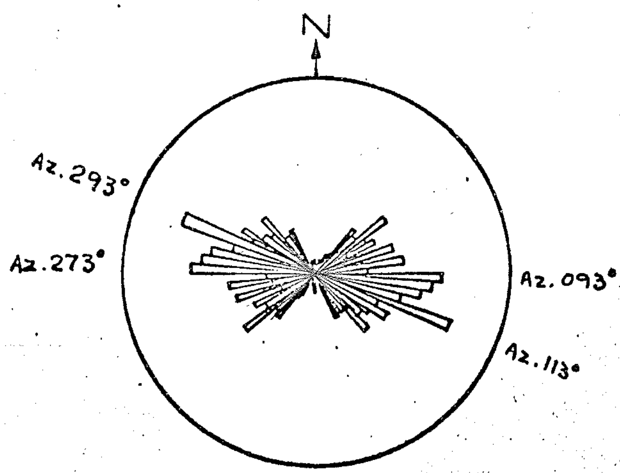
Rock type 4 - Metamorphosed sedimentary rocks and metamorphosed volcanic extrusive rocks: arkose; greywacke; conglomerate;

slate; siliceous siltstone; cherty sediments; garnet-rich greywacke; andesite; basalt; tuff; agglomerate and tuff; interbedded lensy tuff, flows and sediments; hornblende-biotite-plagioclase schist; gabbro; pillow lava.

(c) Synoptic:

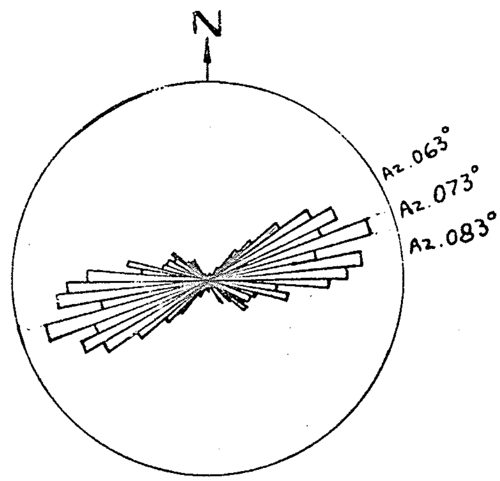
A rosette diagram, (Figure 8), summarizing the bearings of 695 units of first order lineaments, was prepared for a study of the regional pattern and for comparison with the regional pattern of joints and gneissosity. A similar synoptic rosette diagram, (Figure 9), summarizing the bearings of 1,859 second order lineaments was also prepared for the same purpose.

FIGURE 8.




SYNOPTIC ROSETTE DIAGRAM, SUMMARIZING THE STRIKE READINGS OF 695 UNITS OF THE FIRST ORDER LINEAMENTS. RADIUS OF THE CIRCLE REPRESENTS TEN PERCENT OF THE TOTAL NUMBER OF FIRST ORDER LINEAMENTS.

FIGURE 9.




SYNOPTIC ROSETTE DIAGRAM, SUMMARIZING THE STRIKE READINGS OF 1,859 SECOND ORDER LINEAMENTS. RADIUS OF THE CIRCLE REPRESENTS TEN PERCENT OF THE TOTAL NUMBER OF SECOND ORDER LINEAMENTS.

## B. Joints

### Accumulation of Data

The attitudes of joints were obtained from Davies' 1962 field notes. The joints were measured at 184 stations located on a grid pattern with approximately 3,000-foot centres, throughout Gundy and Broderick Townships. A total of 1,178 measurements were made. All observed joints were measured at each station, the number varying from one to thirteen.

### Data Presentation

(a) Study in areal variation:

Eighteen equal-area contour diagrams (Figures 10 to 27) were prepared showing the concentration in the lower hemisphere, of poles to joint planes. A diagram was prepared for each of the eighteen sub-areas specified for the study of areal variation of lineaments. This follows the method outlined by Knopf and Ingerson, (1938).

(b) Synoptic:

A synoptic contour diagram (Figure 28), showing the concentration of poles to joint planes for the whole study area, was prepared to facilitate recognition and interpretation of the principal joint systems on a regional scale and for a comparison with the regional pattern of the first order and second order lineaments.

## C. Gneissosity

### Collection of Data

The attitudes of gneissosity at 318 observational locations were determined from the Ontario Department of Mines field work sheets of Davies for Gundy and Broderick Townships. The measurements of gneissosity were unequally distributed throughout the whole area and, as such, do not represent a statistical sampling.

### Data Presentation

Studies of the variation in attitude of gneissosity on an areal basis and according to rock types were not possible because of unequal distribution of the data on gneissosity throughout the study area and lack of a sufficient number of measurements.

(a) Regional gneissosity:

Three hundred and eighteen readings on the strike and dip values of gneissosity were plotted as poles on the Schmidt equal-area net and contoured to prepare the synoptic plot, presented as Figure 29. The figure was prepared for comparison with the regional pattern of first order and second order lineaments and joints.

## D. Fractures and Faults

The geological map of the study area (Davies, 1965) shows a number of continuous rectilinear and curvilinear features. Davies (1965) interpreted some of these as lineaments, and some as assumed faults. In this study, these features are recognized as first order lineaments only, although they may be fractures or faults.

## CHAPTER V

## RESULTS AND INTERPRETATION

### Introductory Statement

This chapter presents the results and interpretation of the (i) areal analyses of lineaments and joints, and (ii) the analyses of orientation of lineaments and joints with respect to the rock types. This chapter also discusses the geometric relationship between lineaments, and joints, and gneissosity.

### First Order Lineaments

Variation in orientation according to sub-areas:

Figure 5 presents eighteen rosette diagrams showing the orientation of first order lineaments in the sub-areas.

Figure 5 shows that, although every azimuth group having a 5-degree range has some concentration, the most prominent strike directions throughout the study area vary within a 40-degree range, from azimuth 073 degrees to azimuth 113 degrees. The average concentration along the most prominent strike directions within this range is 12.9 percent.

Although this general directional property prevails throughout the whole area, there are certain sub-areas and groups of sub-areas within which the pattern is modified by either a much higher concentration of first order lineaments, with a prevailing northwest to southeast trend, or by the existence of another first order lineament concentration superimposed on the regional pattern. The individual sub-areas and groups of sub-areas which differ from the regional pattern are described in the following paragraphs.

First order lineaments within sub-area 13 show a concentration of 26 percent along the most prominent strike direction, azimuth 107 degrees. The most prominent strike directions within this sub-area fall within the range exhibited by the major portion of the study area; however, the concentration is considerably above the average value of 12.9 percent. This higher concentration drops sharply within adjoining sub-areas 7 and 14.

Within sub-area 6, the first order lineament orientation pattern indicates that the most prominent strike direction varies from azimuth 053 degrees to azimuth 057 degrees, a departure of 38 degrees from the centre of the most frequent direction of the regional pattern. The same pattern is partially reflected within sub-areas 5 and 18, which show a strong preferred orientation along the same direction, as well as the regional pattern of the whole area.

Sub-areas 2, 3, 8 and 9 show characteristics in the orientation and the statistical frequency of first order lineaments which are different from the regional northwest to southeast pattern. The difference is caused by the presence of an additional preferred orientation along azimuth 043 degrees. The first order lineament pattern within sub-area 6 is similar to those within sub-areas 2, 3, 8 and 9.

The regional pattern is shown within sub-areas 1, 4, 5, 7, 10, 11, 12 and 14 to 18, without major interference from other trends.

A comparison of the distribution of rocks on the surface to that of the anomalous first order lineaments leads to the idea that rock types account for the anomalous areas.

The first order lineament patterns within sub-areas 2, 3, 8, 9, and 6 appear to be associated with the basic intrusive rocks.

The high anomalous concentration of first order lineaments along azimuth 107 degrees and azimuth 097 degrees within sub-area 13, located in the south-western corner of the study area, appears to be associated with the metamorphosed sedimentary and volcanic extrusive rocks.

The following analyses of first order lineament orientations with respect to rock types test this relationship.

Variation in Orientation According to Rock Types

The patterns of first order lineaments for each of the rock types is shown in Figure 7.

The rosette diagram for rock type 1 (pink quartz monzonite, etc. - acid intrusive rocks) shows that the general trend varies from azimuth 090 degrees to azimuth 105 degrees. Within this range the first order lineaments have a maximum value of 21 percent. The most prominent strike directions are azimuth 103 degrees and azimuth 093 degrees. There is also a preferred orientation of much lower concentration (6.3 percent) along a northeast to southwest direction. Between azimuth 340 degrees and azimuth 010 degrees, there is very low concentration.

The rosette diagram for rock type 2 (grey granodiorite, etc. - acid intrusive rocks) shows that the higher concentrations (up to 6.5 percent) are confined between azimuth 020 degrees and azimuth 155 degrees. The most prominent strike directions are azimuth 113 degrees and azimuth 083 degrees. Between azimuth 335 degrees and azimuth 030 degrees, the amount of concentration is less than 0.5 percent.

The first order lineament pattern developed within rock types 1 and 2 has a similar direction of maximum concentration but there are differences in the degree of concentration and variation in distribution. The first order lineament pattern within rock type 1 shows 21 percent concentration along the most prominent strike direction, whereas the pattern for rock type 2 shows only a 6.5 percent concentration. Rock types 1 and 2 are generally similar; however, rock type 2 underlies a larger percentage of the study area and has yielded a far greater number of lineaments than rock type 1, which may account for the difference in concentration.

The rosette diagram for rock type 3 (basic intrusive rocks) indicates two sets of strongly developed concentrations of first order lineaments along azimuth 343 degrees and azimuth 043 degrees. There is also a preferred orientation of much lower concentration along azimuth 132 degrees. Between azimuth 345 degrees and azimuth 015 degrees, the amount of concentration is below 0.5 percent.

The rosette diagram for rock type 4 (metamorphosed sedimentary and volcanic extrusive rocks) indicates that the direction of first order lineaments is concentrated between azimuth 090 degrees and azimuth 120 degrees. Within this range the concentration of first order lineaments has a maximum value of 28.2 percent along azimuth 098 degrees. There is also a preferred orientation of much lower concentration (4.9 percent) along a north-south direction. The first order lineament pattern within rock type 4 is distinctly different from those within rock types 2 and 3.

A comparison of Figure 5 and 7 indicates that the rock types account for most of the marked changes in first order lineament pattern observed in the areal variability study. Most of the study area is underlain by rock types 1 and 2. Sub-areas within these rock types show first order lineament patterns which are similar to the patterns for these rock types. The first order lineament pattern observed within sub-area 13, which is distinctly different from those within other rock types, corresponds to the pattern for rock type 4. The first order lineament pattern within sub-areas 2, 3, 8, 9 and 6 is similar to the pattern for rock type 3.

Synoptic rosette diagram for the first order lineaments

The synoptic rosette diagram (Figure 8), summarizing the bearings of 695 units of first order lineaments indicates that every azimuth group having a 5-degree range has some concentration; however, the maximum concentration lies within a range from azimuth 093 degrees to azimuth 113 degrees. Within this range the concentration has a maximum value of 7.4 percent along azimuth 113 degrees. Somewhat lower values of concentration (2 percent to 4 percent) are observed between azimuth 115 degrees and azimuth 150 degrees, and from azimuth 335 degrees to azimuth 040 degrees the concentration is less than 1.4 percent. The two major strike directions, in order of prominence, are azimuth 113 degrees and azimuth 093 degrees.

## Second order lineaments

Variation in orientation according to sub-areas

Figure 6 presents eighteen rosette diagrams showing the orientations of the second order lineaments according to sub-areas.

Figure 6 indicates that every azimuth group having a 5-degree range has some concentration; however, the most prominent strike directions throughout the study area vary within a 36-degree range, from azimuth 057 degrees to azimuth 093 degrees. Within these limits the concentration of the second order lineaments has a maximum value of 13.7 percent along azimuth 067 degrees in sub-area 18.

The areal variability study indicates that the second order lineament pattern is fairly consistent throughout the study area in contrast to the marked changes revealed for the first order lineaments. The absence of significant variation in the directional properties of the second order lineaments suggests that they are unaffected by rock type.

### Synoptic rosette diagram for the second order lineaments

The synoptic rosette diagram (Figure 9) summarizing the bearings of 1,859 second order lineaments indicates that every azimuth group having a 5-degree range has some concentration. However, the most prominent strike directions throughout the study area vary from azimuth 063 degrees to azimuth 083 degrees. Within this range the concentration of second order lineaments has a maximum value of 8.9 percent along azimuth 073 degrees; 8 percent concentration along azimuth 083 degrees and 7.3 percent along azimuth 063 degrees. Within a 55-degree range from azimuth 335 degrees to azimuth 030 degrees the concentration is less than 1 percent.

A comparison of the pattern of first order lineaments with that of second order lineaments for each sub-area or for the area as a whole (Figures 5 and 6; 8 and 9) indicates that first order and second order lineaments are distinctly different features and that separation on the basis of a 1,320 foot length has been effective. The first order lineament pattern shows considerable variation which appears to be dependent on rock types, whereas the pattern of second order lineaments is fairly consistent throughout the study area, and is independent of rock types. The most prominent strike directions of the first order lineaments shown on the synoptic diagram (Figure 8) are, azimuth 113 degrees and azimuth 093 degrees, in contrast to the second order lineaments for which the most prominent strike directions are azimuth 073 degrees, azimuth 083 degrees and azimuth 063 degrees, (Figure 9).

## Joints

### Variation according to sub-areas

Figures 10 to 27 present eighteen equal-area contour diagrams showing the attitude of joints according to sub-areas.

Figures 10 to 14, 16 to 18, 20, 22, 23 and 25 indicate a strong concentration (6 percent) of poles to the joints which represent joints the strike of which lies within a 36-degree range, from azimuth 005 degrees to azimuth 041 degrees. The central position of the most frequent strike direction is azimuth 023 degrees. The poles are concentrated primarily within 12 degrees of the periphery of the plots, indicating that the dip of most measured joints varies within 12 degrees of vertical.

Figures 10, 14, 16 and 17 indicate one additional strong concentration (6 percent). The spread of this additional concentration is less than the one already described. This concentration represents joints within sub-areas 1, 5, 7 and 8, whose strikes vary from (i) azimuth 134 degrees to 145 degrees, (ii) azimuth 007 degrees to azimuth 012 degrees, and (iii) azimuth 048 degrees to azimuth 055 degrees.

The concentration of poles to the joints in Figures 12, 18, 22, 23 and 25 is less well defined and probably represents a minor joint set with variation in strike direction, within a 34-degree range, from azimuth 126 degrees to azimuth 160 degrees. The central position of the most prominent strike direction is azimuth 143 degrees. These minor joints dip at high angles.

Figures 15, 19, 21, 24, 26 and 27, indicate 3 percent to 5 percent concentrations of poles to the joints. This concentration represents central positions of the most prominent strike directions at azimuth 035 degrees, azimuth 093 degrees and azimuth 140 degrees. The pole concentrations are mainly within 12 degrees of the periphery of the plots indicating that the dip varies within 12 degrees of vertical.

Differences in the plotted joint pattern throughout the study area are considered to be small, indicating that the joint pattern is independent of the rock types.

## Synoptic Contour Diagram

The joint contour diagram (Figure 28) summarizing 1,178 joint measurements indicates one concentration (3 percent) of poles to the joints. This concentration represents the major joint set whose strike varies within a 50-degree range, from azimuth 005 degrees to azimuth 055 degrees. The centre of the most prominent strike direction is at azimuth 025 degrees. The pole concentrations are mainly within 8 degrees of the periphery of the plot, indicating very high angles of dip.

The synoptic contour diagram also indicates another concentration (2 percent) of poles to the joints. This concentration has three peak points, which may represent three minor joint sets striking azimuth 140 degrees, azimuth 160 degrees and azimuth 098 degrees, or could be variation in concentration of a single set. These minor joint sets dip at very high angles.

Comparison of the patterns for individual sub-areas to the synoptic plot indicates that each sub-area differs little from the total regional pattern.

## Gneissosity

### Synoptic Contour Diagram

The synoptic plot of 318 poles to gneissosity from the study area indicates only one set of strongly developed maxima (6 percent) lying close to, or on, the periphery of the plot (Figure 29). This concentration represents gneissosity, the strike of which varies within a 48-degree range, from azimuth 088 degrees to azimuth 136 degrees. The central position of this most prominent strike direction is azimuth 112 degrees. The pole concentrations are greatest within 12 degrees of the periphery of the plot, indicating that the dip of gneissosity is mostly within 12 degrees of vertical.

Relationship between lineaments and joints.

A comparison of the orientation of first order and second order lineaments with that of joints for (a) each individual sub-area (Figures 5, 6, and 10 to 27), and (b) the area as a whole (Figures 8, 9, and 28) indicates that neither type of lineament has an orientation similar to that of the joints.

The strike of jointing within the whole study area is concentrated within a 50-degree range from azimuth 005 degrees to azimuth 055 degrees with the centre of concentration at azimuth 025 degrees (Figure 28). These directions are not represented by either first order or second order lineament directions (Figures 8 and 9). Less than 3 percent of the lineaments have strikes which correspond to azimuth 025 degrees.

It may be concluded that the majority of both types of lineaments are not the surface expressions of joints; although joints are abundant in the bedrock, they have little effect upon the lineament pattern.

## Relationship between lineaments and gneissosity

Gneissosity within the whole study area strikes between azimuth 088 degrees and azimuth 136 degrees and dips at high angle (Figure 29). The centre of concentration of the most prominent strike direction is azimuth 112 degrees. The maximum concentration of the first order lineaments lies within azimuth 093 degrees and azimuth 113 degrees (Figure 8). The most prominent strike direction of the first order lineaments is, therefore, similar to that of the gneissosity.

Although the strike directions are similar, the length of the first order lineaments precludes the possibility that they are directly a result of gneissosity. It is more likely that the gneissosity which constitutes a "strength" weakness in rocks, has controlled the development of fractures or faults, and hence has had an indirect effect on the orientation of the first order lineaments.

The most prominent strike directions of the second order lineaments are azimuth 073 degrees, azimuth 083 degrees and azimuth 063 degrees (Figure 9). None of these prominent strike directions coincide with the most prominent strike directions of the gneissosity.

## Relationship between lineaments and glacial movement direction

The third most prominent strike direction of the second order lineaments, azimuth 063 degrees (Figure 9) is similar to the direction of glacial movement in the study area. The directions of glacial striae in Gundy and Broderick Townships are shown in the geological map (Davies, 1965, p. 22). The direction of glacial striation within the study area varies from azimuth 230 degrees (050 degrees) to azimuth 245 degrees (065 degrees).

# CHAPTER VI

# DISCUSSION

This chapter presents a discussion of the results and interpretation of the analyses of orientation of lineaments, joints and gneissosity. As well, the possible relationship between lineaments, joints and gneissosity is reviewed.

## First Order Lineament Orientation

Interpretation of the data presented in the previous chapters has established that most of the marked changes in first order lineament pattern coincide with changes in rock types. The interpretation has further established that the most prominent strike direction of the first order lineaments is parallel to the regional bearing of the gneissosity. It has been suggested, also, that many of the first order lineaments are surface expressions of fractures or faults, the orientation of which has been controlled by gneissosity.

The first order lineaments within areas underlain by the acid intrusive rocks and the metamorphosed sedimentary and volcanic extrusive rocks (Figure 7), have the most prominent orientations similar to that of the gneissosity. However, the orientation directions of the first order lineaments within the areas underlain by basic intrusive rocks (Figure 7) show only partial similarities to that of the gneissosity. Although gneissosity appears to have controlled the development of fractures and faults to a large extent within areas of the acid intrusive rocks and within the metamorphosed layered sequence, apparently it has had little effect on the development of these features within the basic intrusive rocks.

Joints have neither a direct nor indirect control on the development of first order lineaments.

## Second Order Lineament Orientation

The interpretation of the previous chapter has established that of the three most prominent orientations of second order lineaments, azimuth 063 degrees is represented by the direction of glacial striae within the study area. The two most prominent orientations do not represent any known structural features. The development of second order lineaments appears to be independent of the rock types and does not appear to be controlled by jointing.

## Relationship between Lineaments, Joints and Gneissosity

The previous chapter has established that the attitude of joint sets in the areas of igneous intrusive rocks and the host rocks are identical; and that joints probably developed later than all of the rock types within the study area and have had no effect on the lineament pattern.

The synoptic contour diagram (Figure 29) for gneissosity indicates variation in strike direction with a 48-degree range. Strike of gneissosity within the study area varies over short distances, and on approaching rock boundaries gneissosity is approximately parallel to the contact. It is possible that the gneissic structure is primary, and produced by movements during the emplacement of the intrusive mass of magma. However, the regional pattern of gneissosity within the igneous intrusive rocks is similar to the regional pattern of the foliation in the host rocks. There is, therefore, a definite possibility that the gneissosity may be tectonic and superimposed on the igneous intrusive rocks and the host rocks after the intrusive mass of magma had solidified.

Both types of lineaments cut across the contacts within the study area which suggests that the lineaments developed later than all of the rock types within the study area. The only relationship that can be established between joints and lineaments is that both developed later than all of the rock types within the study area.

There are two possible relationships between joints and gneissosity (i) if gneissosity is primary, it is pre-jointing, and (ii) if gneissosity is secondary, both joints and gneissosity developed later than all of the rock types within the study area. The second possible relationship gives rise to situations where joints could develop either later than gneissosity or where both joints and gneissosity could develop at the same time.

If gneissosity and joints developed at the same time, some geometric relationship between their orientations would be expected. A stress analysis accounting for joints and gneissosity is possible under this condition and is attempted in the following paragraph.

The most prominent strike direction of joints is azimuth 025 degrees and that of gneissosity is azimuth 112 degrees. Both joints and gneissosity dip steeply. Planes of joint and gneissosity intersect at an acute of 087 degrees. A horizontal maximum principal stress direction would bisect the acute angle and the minimum principal stress direction would bisect the obtuse angle between joint and gneissosity. The maximum principal stress direction would be at azimuth 062 degrees, and the minimum principal stress direction would be at azimuth 152 degrees. The intermediate principal stress direction would be vertical. This set of stresses could account for the joint and gneissosity within the study area, providing they developed at the same time. If joints and gneissosity developed at different times, their development cannot be explained by the same stress mechanism.

## REFERENCES

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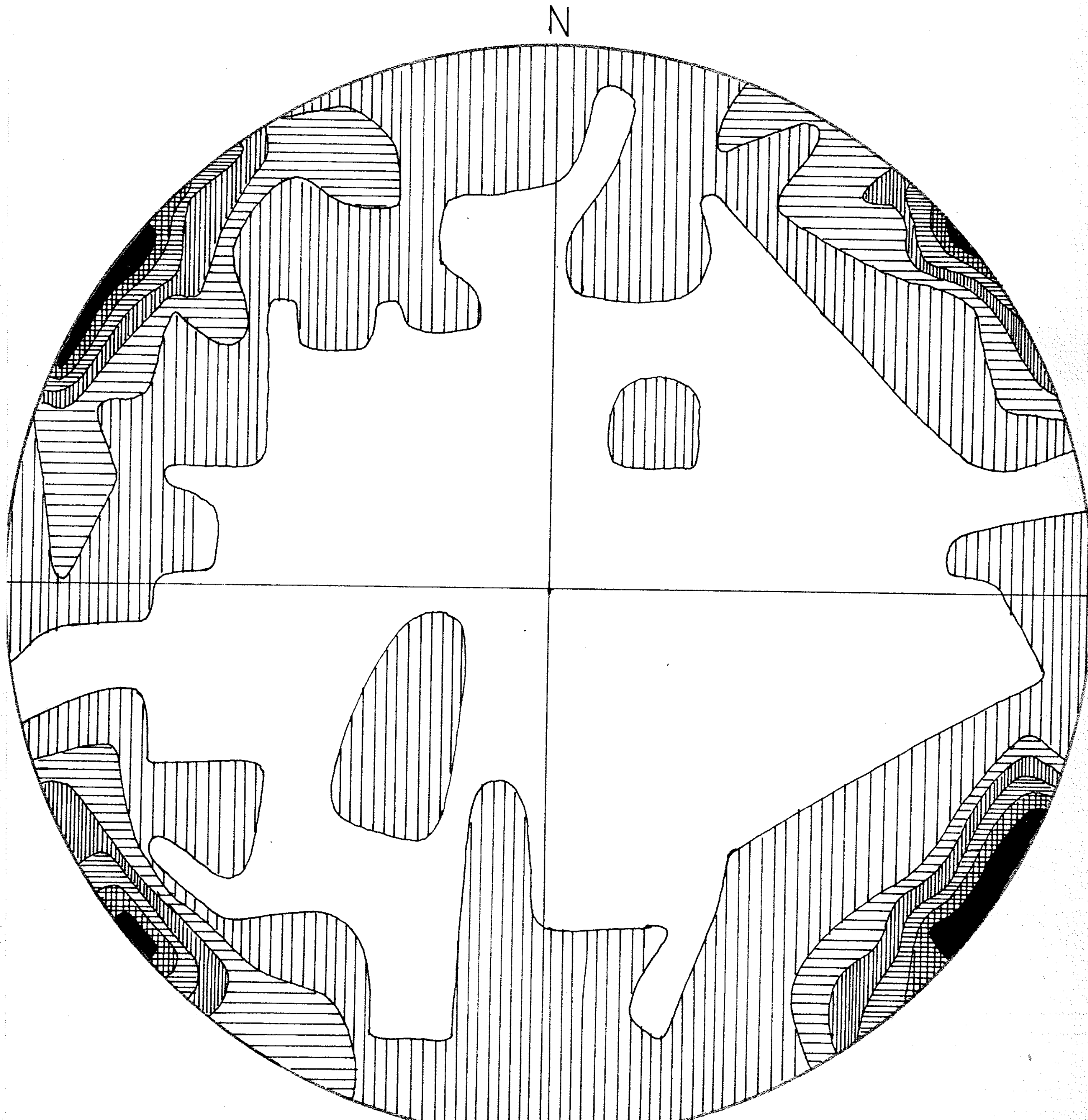
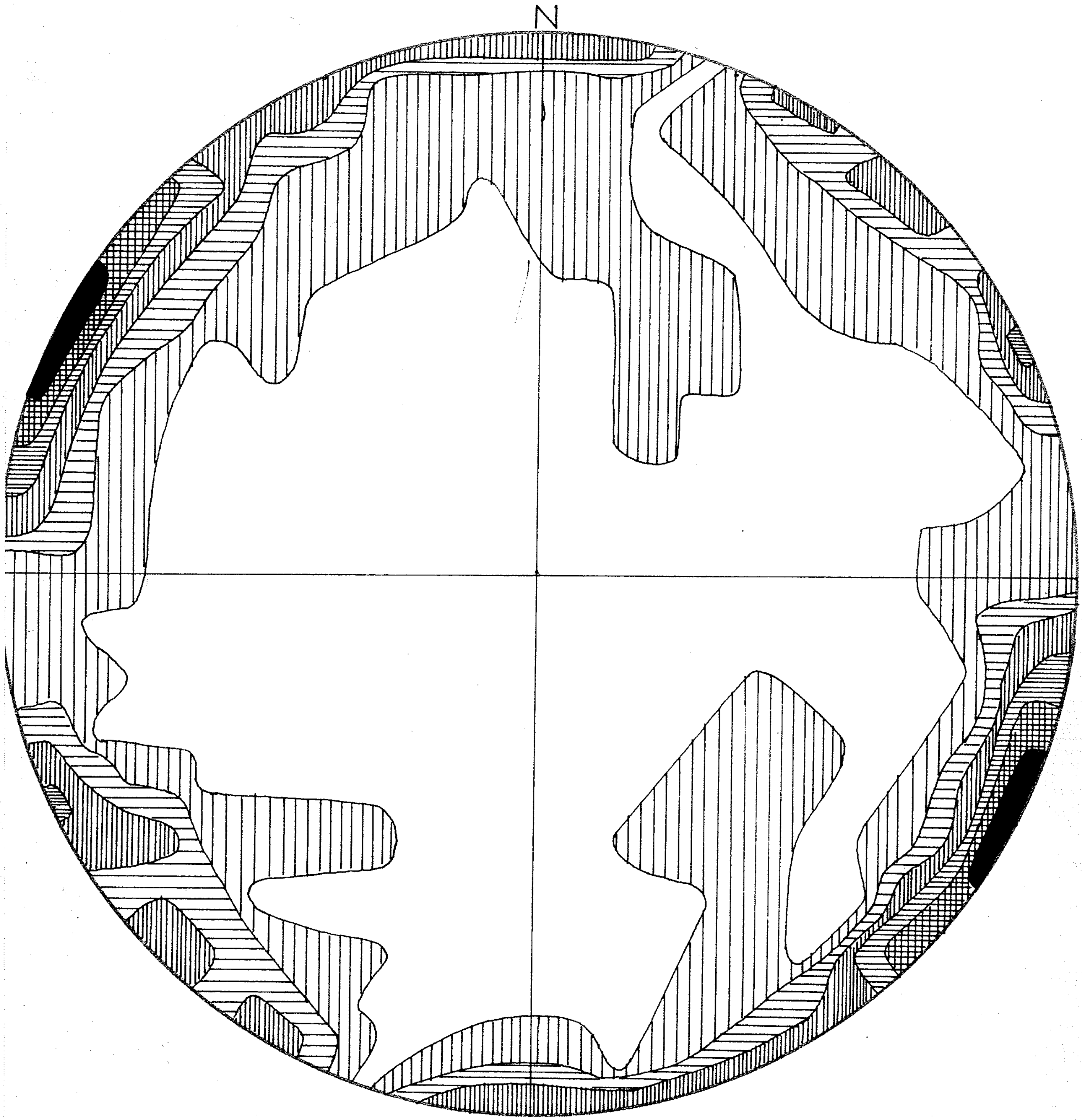
Figure 10.

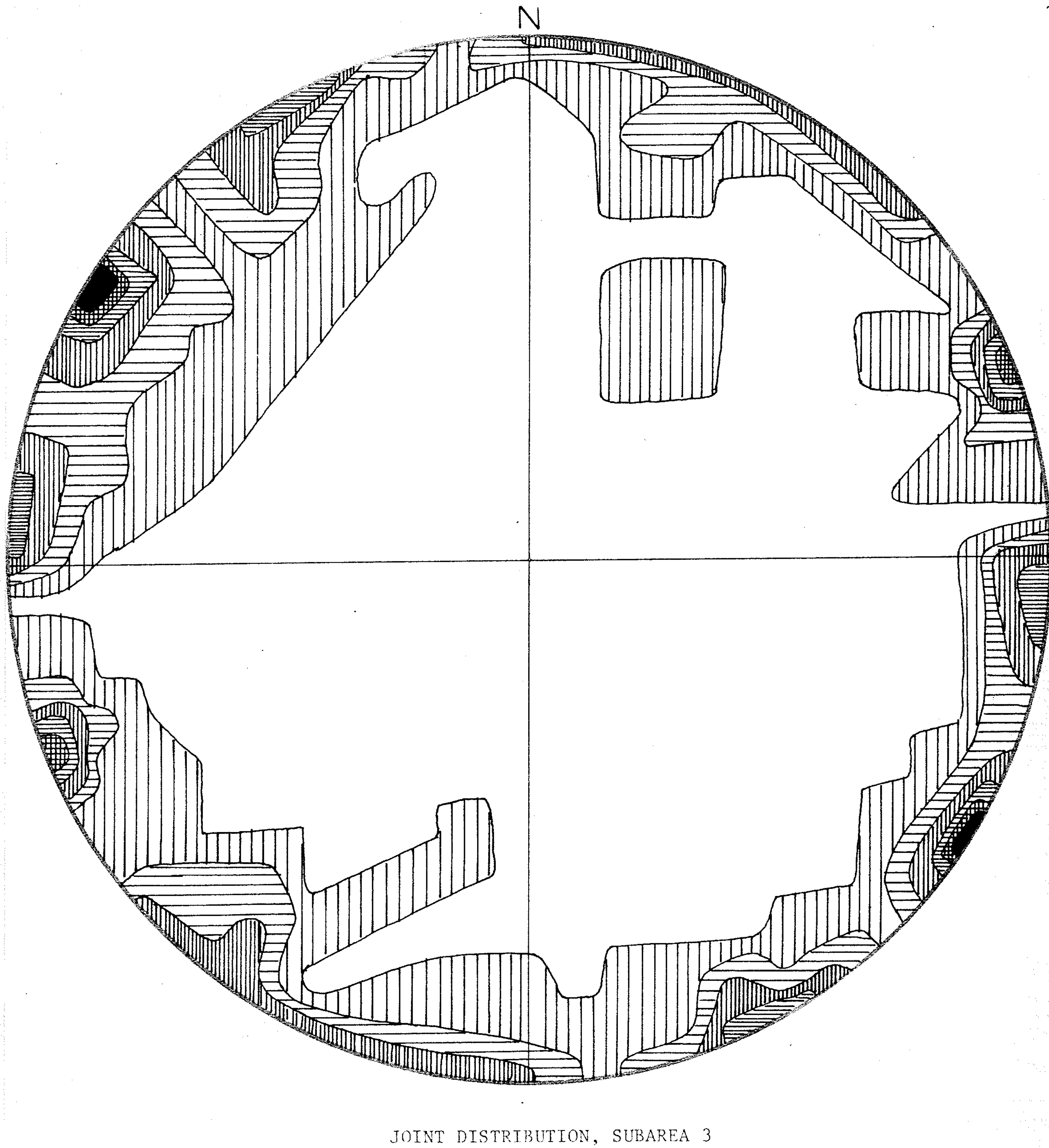



JOINT DISTRIBUTION, SUBAREA 1.
LOWER HEMISPHERE EQUAL AREA PROJECTION
(144 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.



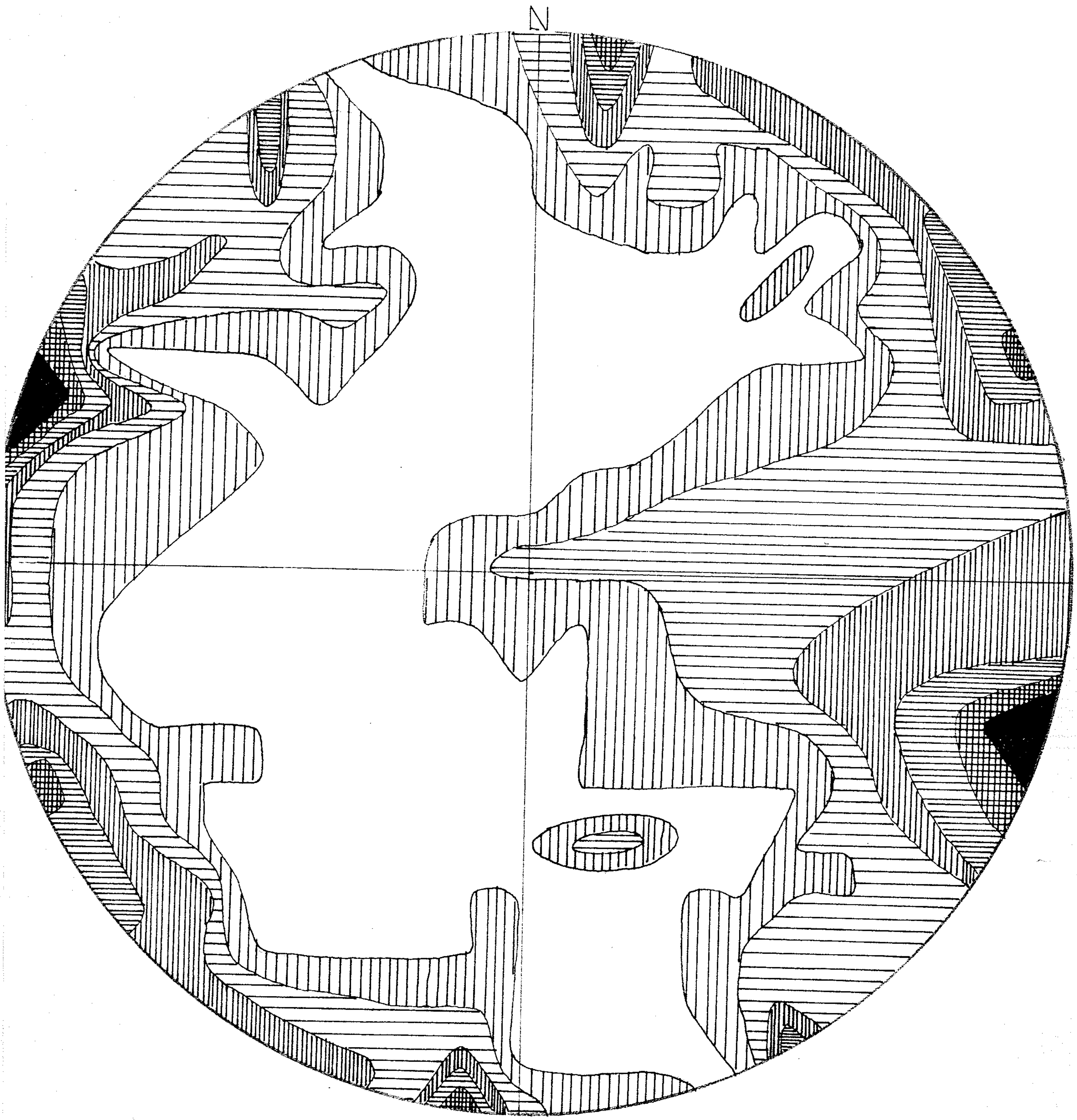

JOINT DISTRIBUTION, SUBAREA 2.
LOWER HEMISPHERE EQUAL AREA PROJECTION
(153 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, and 6%.

Figure 12.



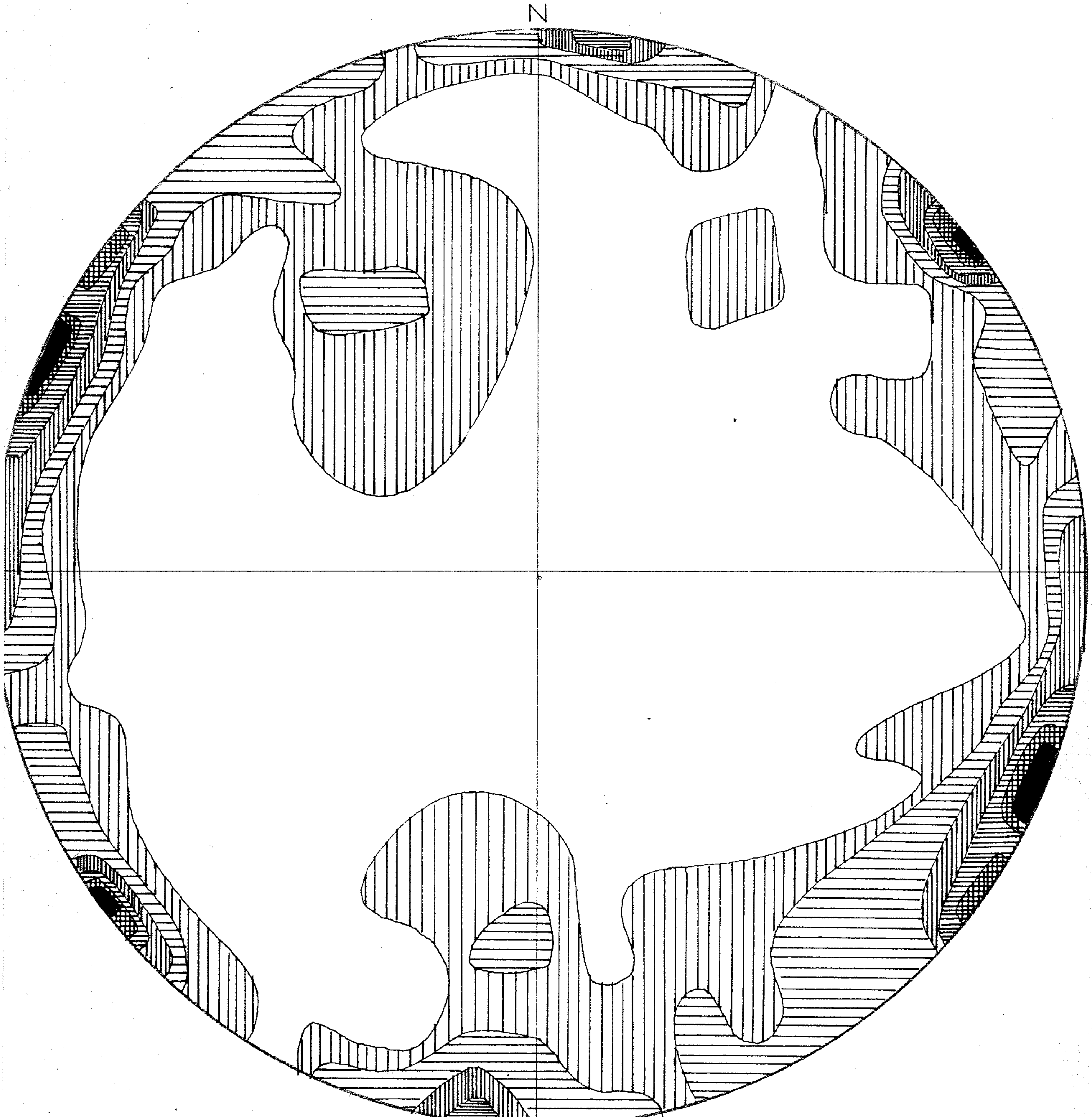

JOINT DISTRIBUTION, SUBAREA 3
LOWER HEMISPHERE EQUAL AREA PROJECTION
(127 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 13.



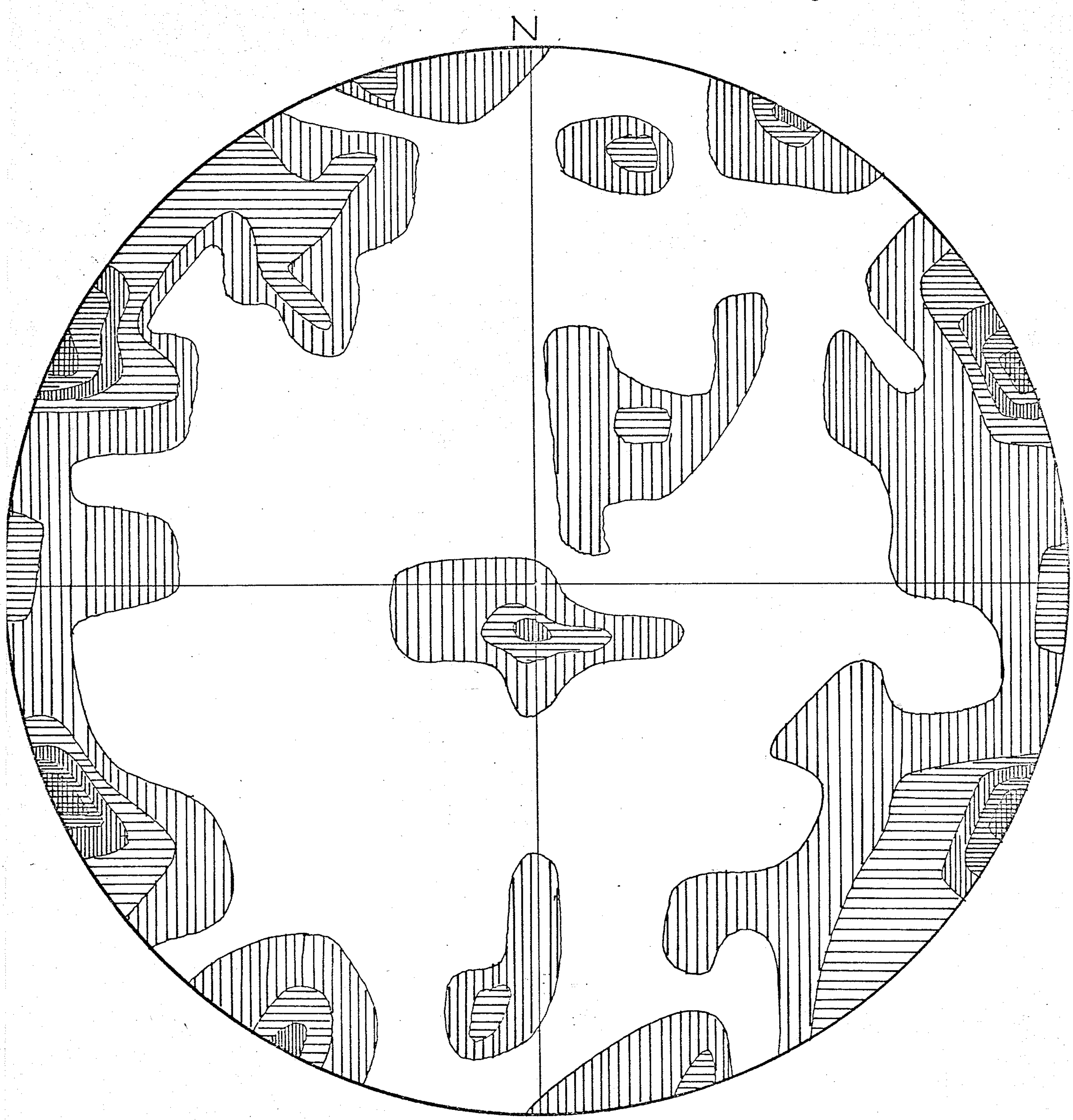

JOINT DISTRIBUTION, SUBAREA 4
LOWER HEMISPHERE EQUAL AREA PROJECTION
(91 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 14.

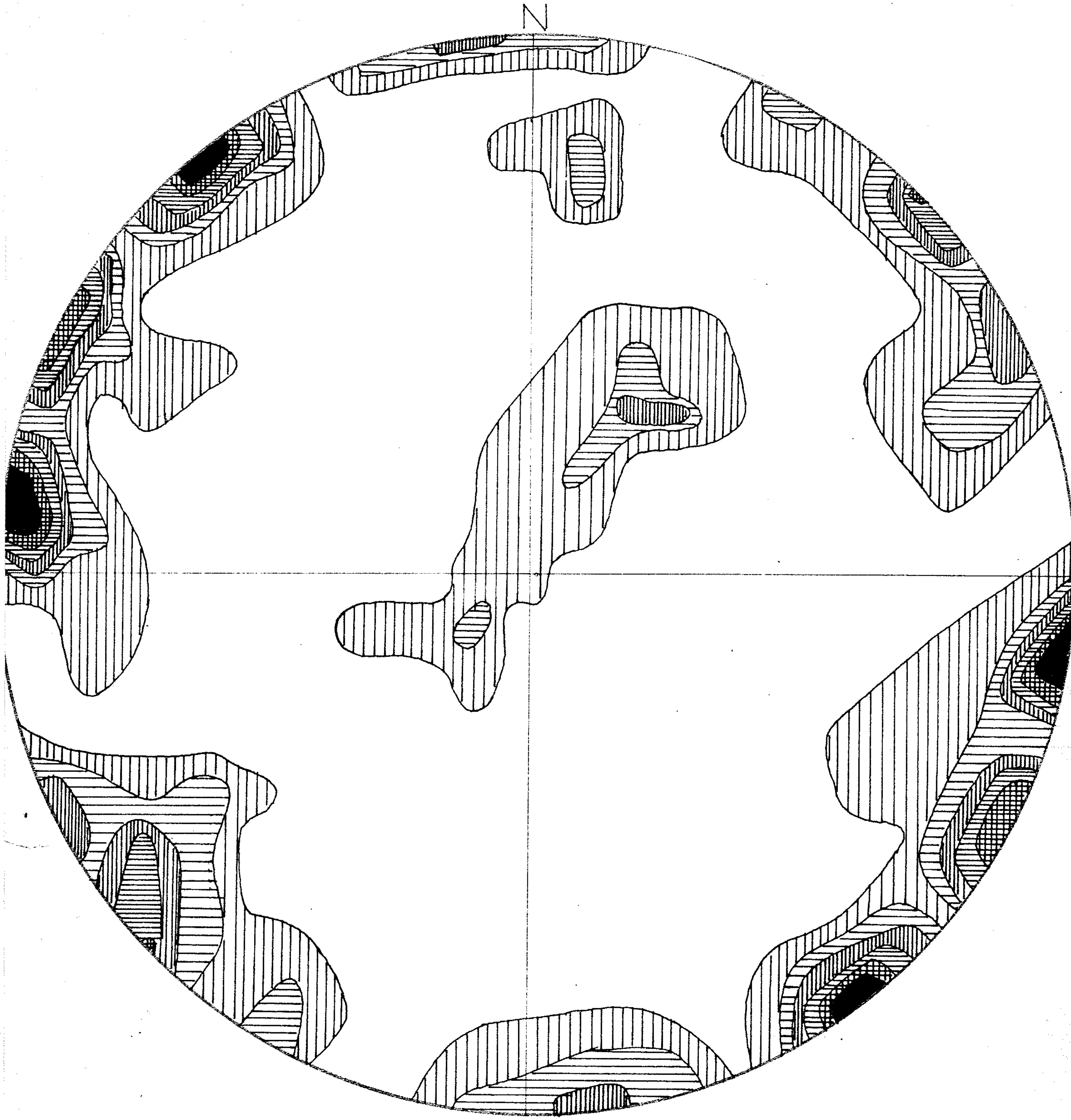



JOINT DISTRIBUTION, SUBAREA 5
LOWER HEMISPHERE EQUAL AREA PROJECTION
(132 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 15.

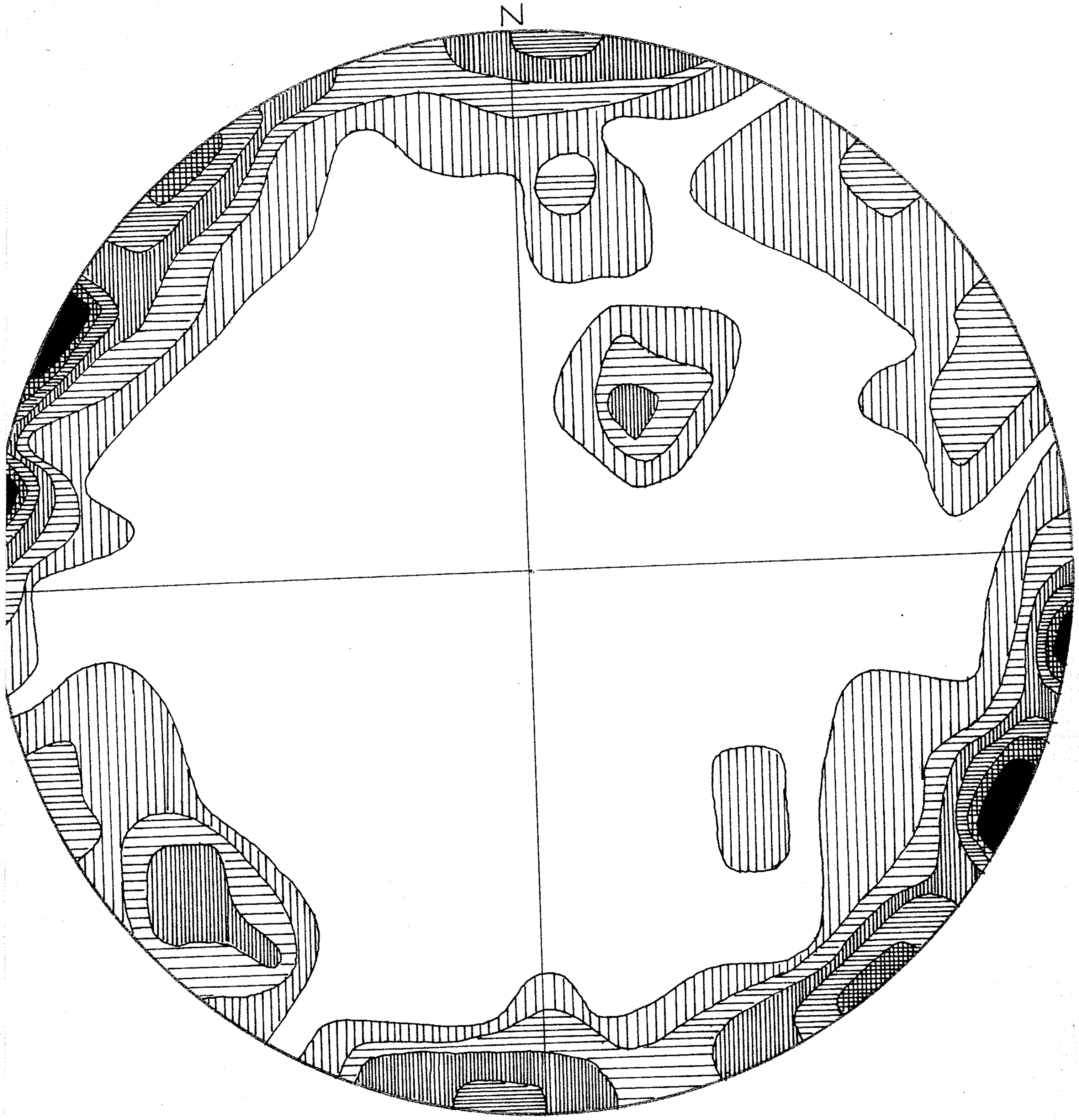



JOINT DISTRIBUTION, SUBAREA 6
LOWER HEMISPHERE EQUAL AREA PROJECTION
(135 POLES)
CONTOURS: 1%, 2%, 3%, 4%, AND 5%.



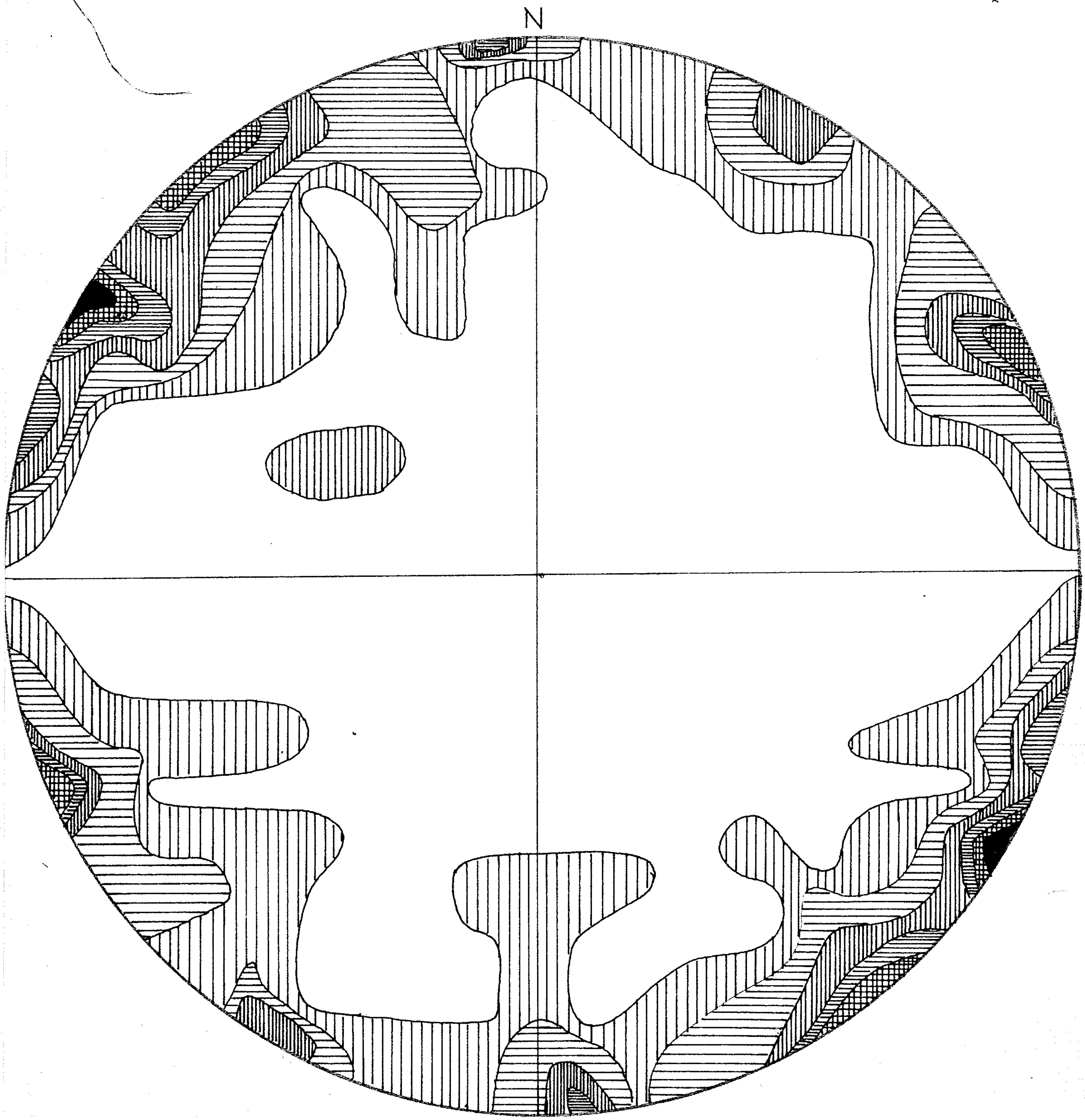

JOINT DISTRIBUTION, SUBAREA 7
LOWER HEMISPHERE EQUAL AREA PROJECTION
(117 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 17.

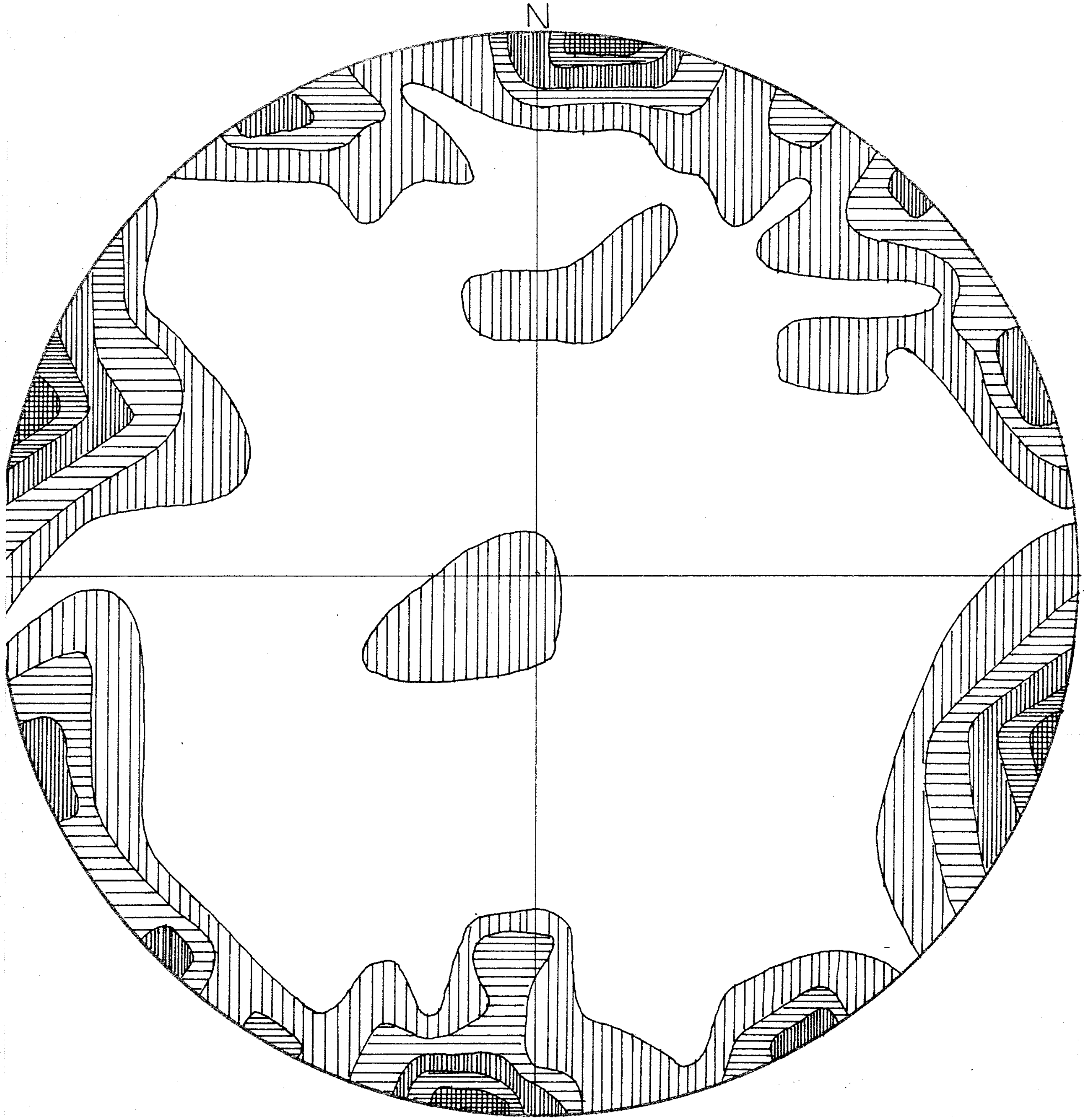



JOINT DISTRIBUTION, SUBAREA 8
LOWER HEMISPHERE EQUAL AREA PROJECTION
(122 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 18.

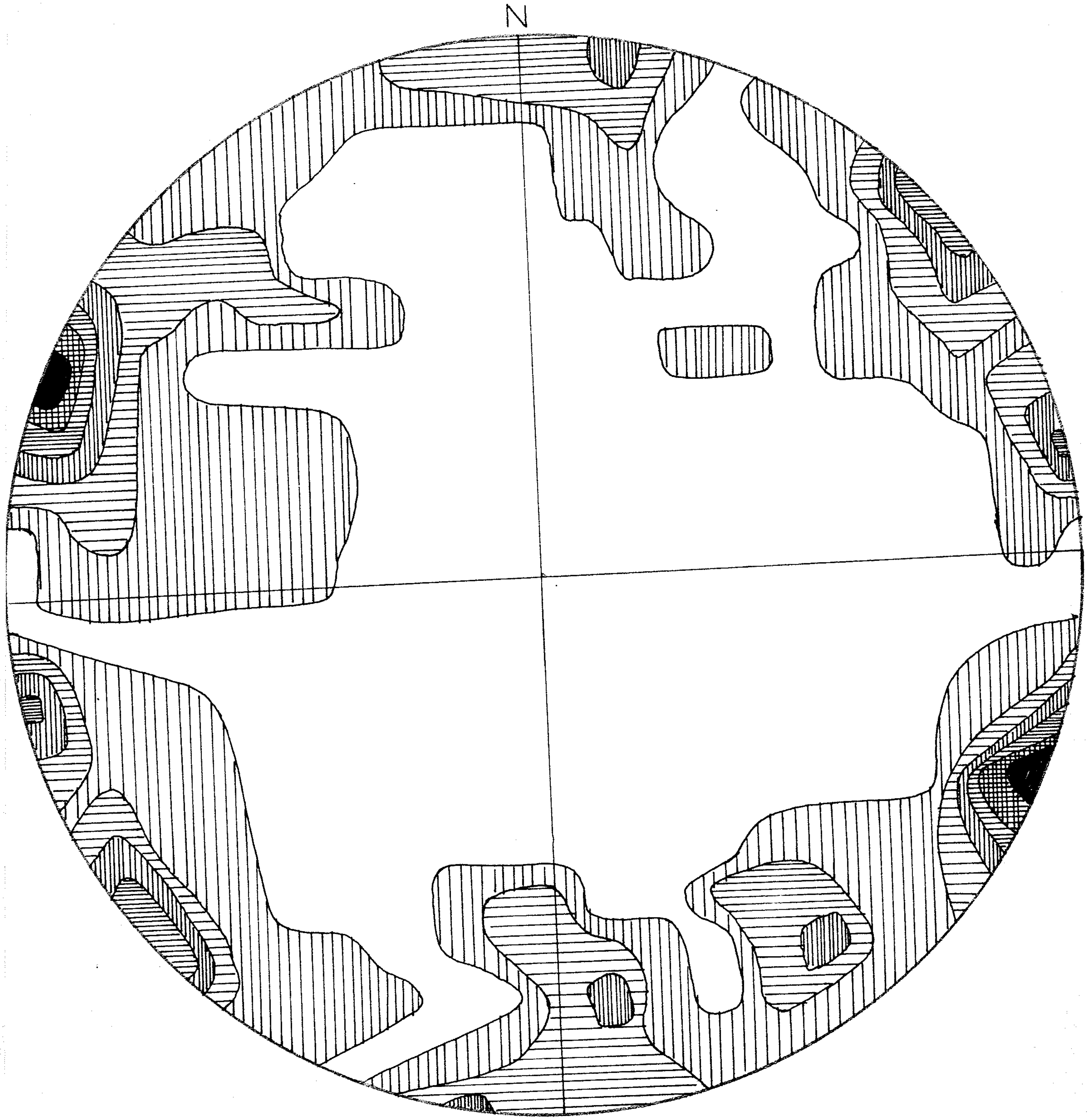



JOINT DISTRIBUTION, SUBAREA 9
LOWER HEMISPHERE EQUAL AREA PROJECTION
(104 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.



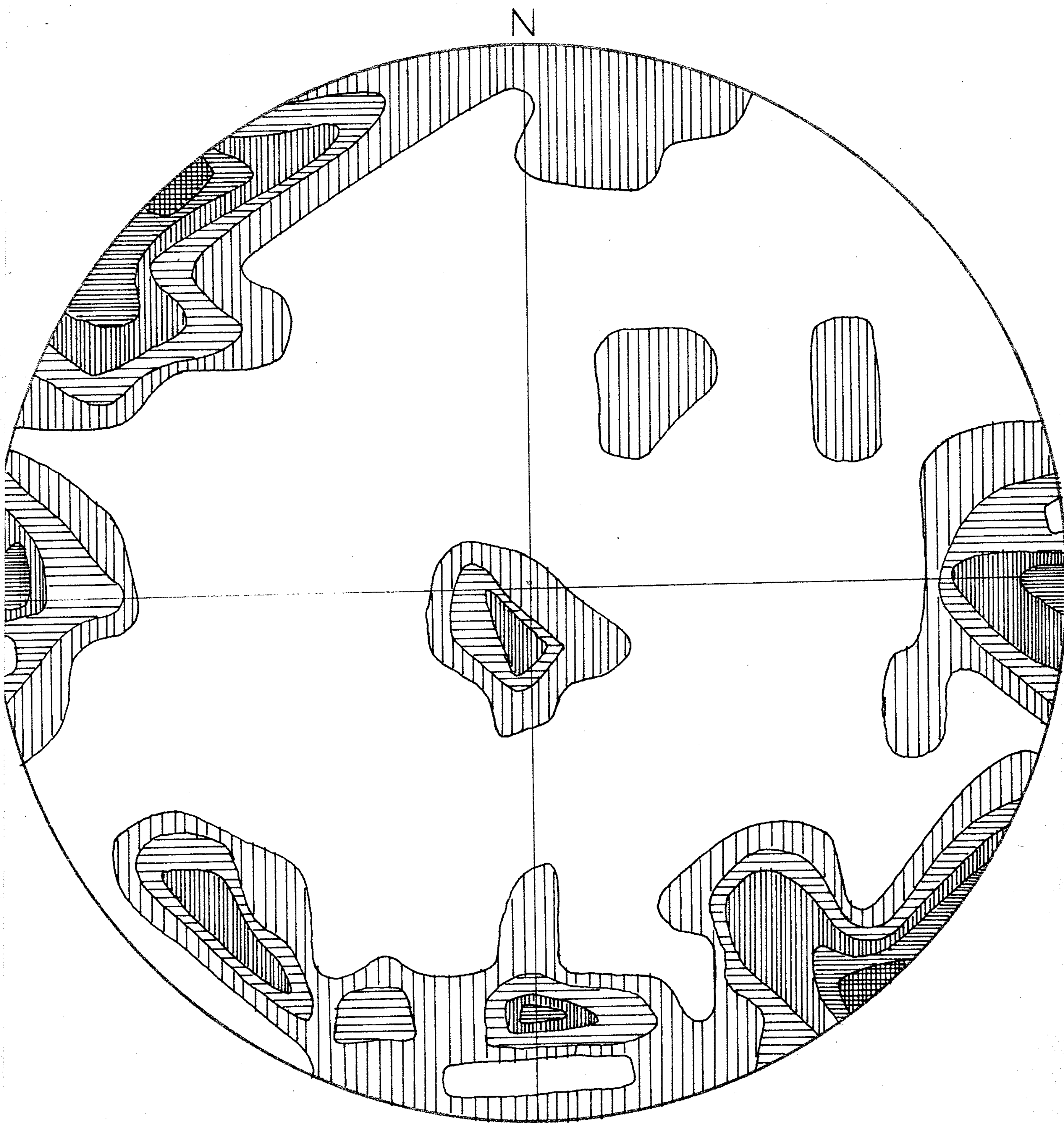

JOINT DISTRIBUTION, SUBAREA 10
LOWER HEMISPHERE EQUAL AREA PROJECTION
(109 POLES)
CONTOURS: 1%, 2%, 3%, 4%, AND 5%.

Figure 20.



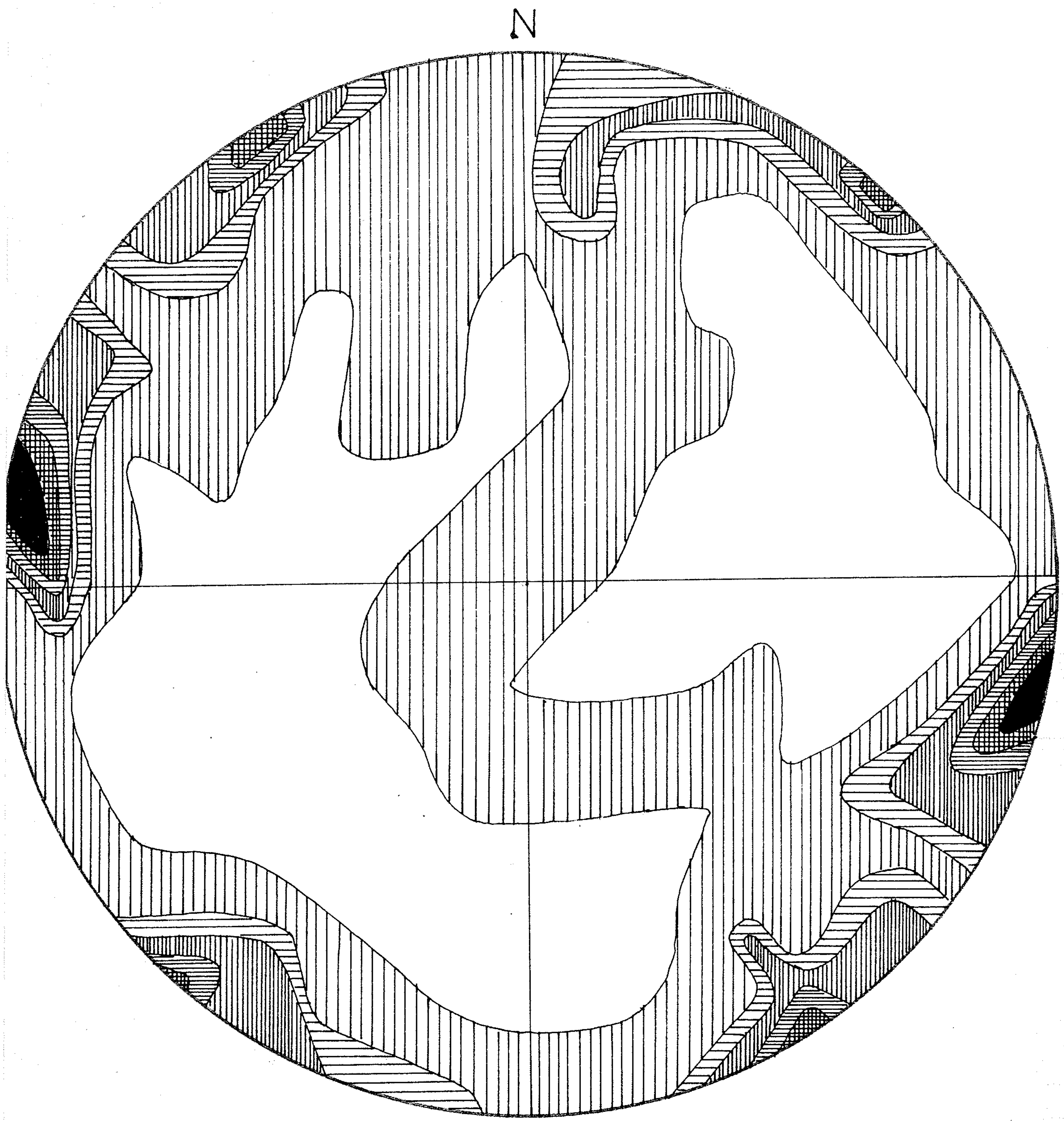

JOINT DISTRIBUTION, SUBAREA 11
LOWER HEMISPHERE EQUAL AREA PROJECTION
(139 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 21.



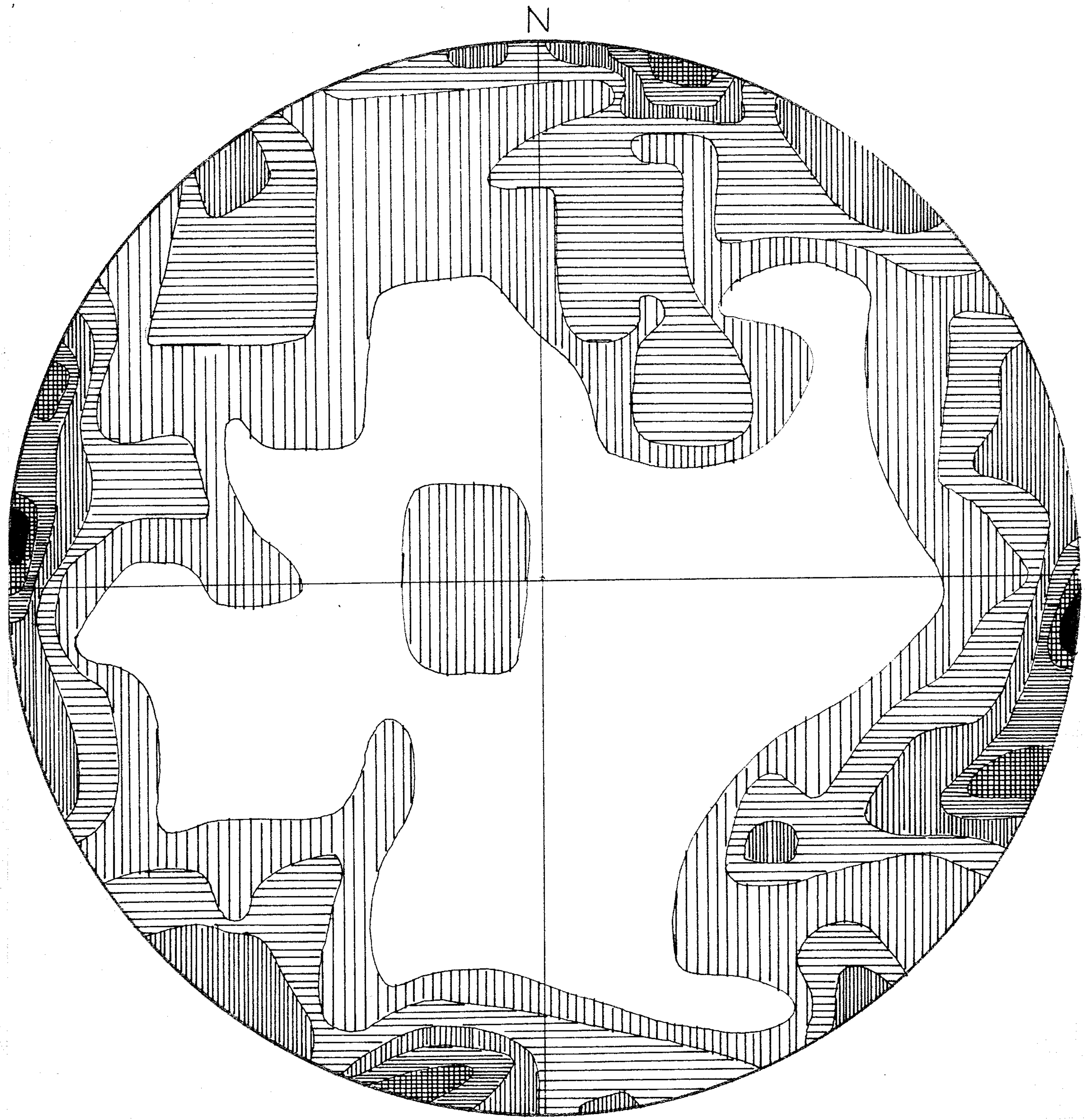

JOINT DISTRIBUTION, SUBAREA 12
LOWER HEMISPHERE EQUAL AREA PROJECTION
(102 POLES)
CONTOURS: 1%, 2%, 3%, 4%, AND 5%.

Figure 22.



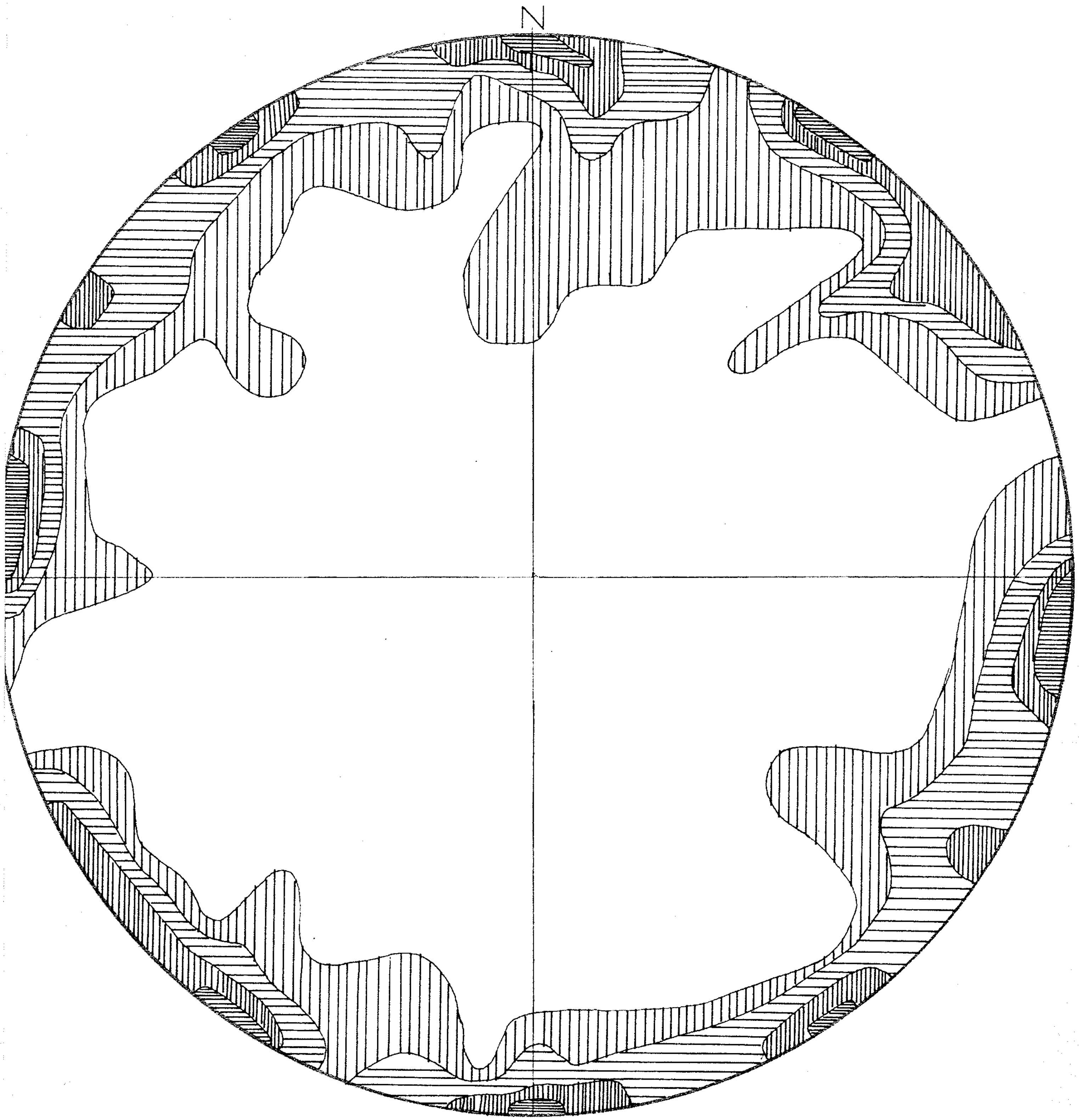

JOINT DISTRIBUTION, SUBAREA 13
LOWER HEMISPHERE EQUAL AREA PROJECTION
(54 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 23.



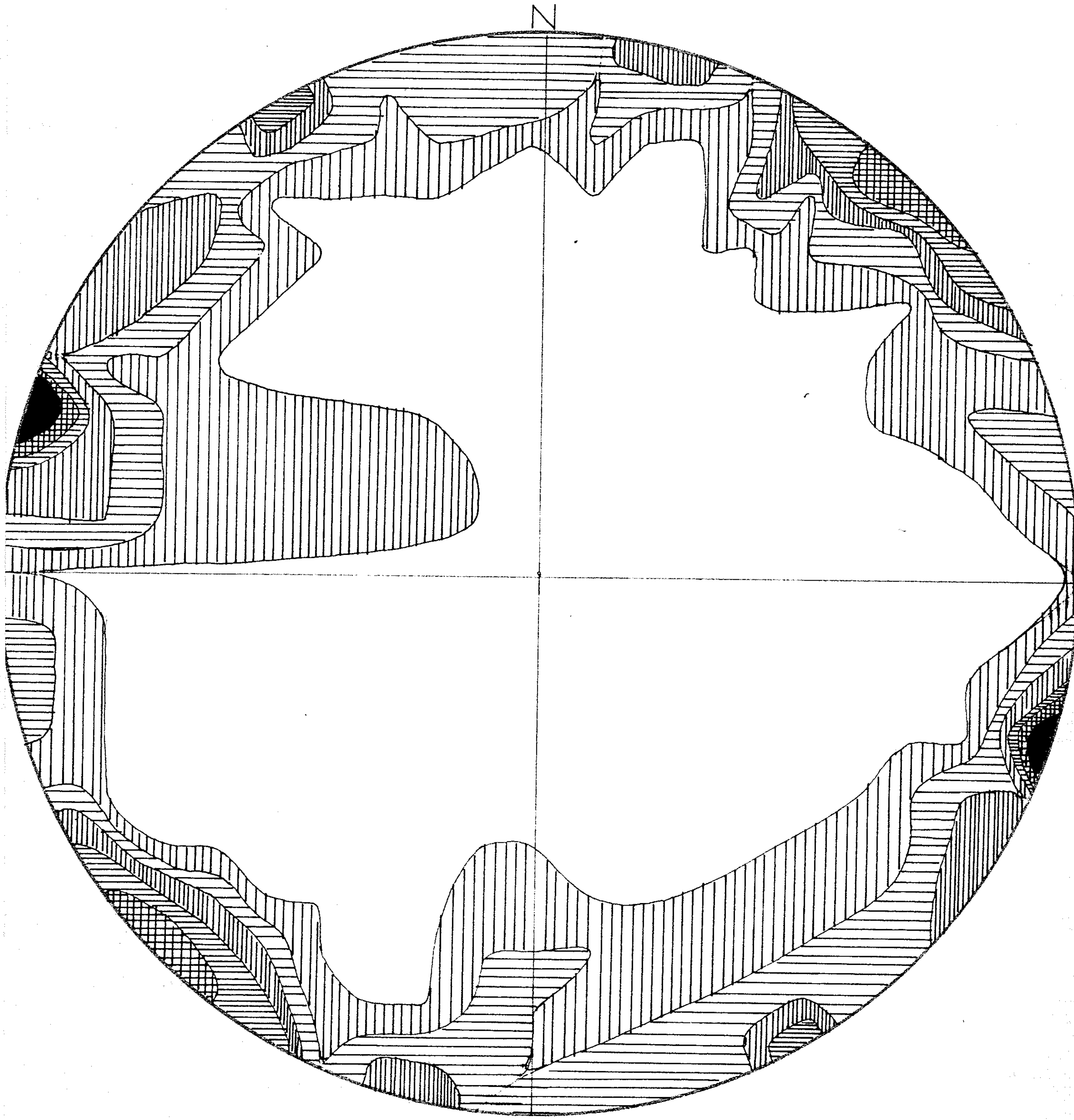

JOINT DISTRIBUTION, SUBAREA 14
LOWER HEMISPHERE EQUAL AREA PROJECTION
(87 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 24.



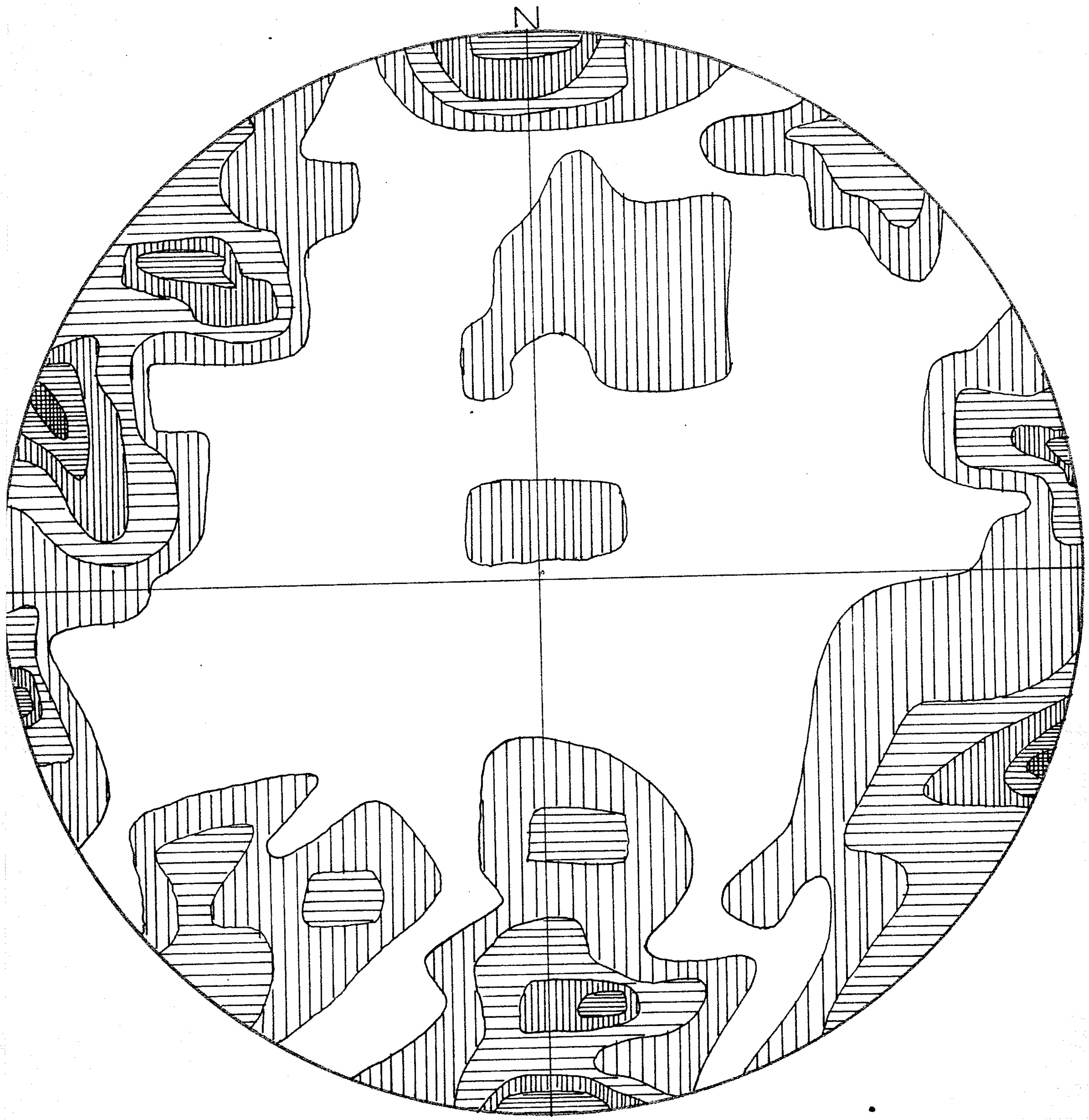

JOINT DISTRIBUTION, SUBAREA 15
LOWER HEMISPHERE EQUAL AREA PROJECTION
(109 POLES)
CONTOURS: 1%, 2%, 3%, AND 4%.

Figure 25.



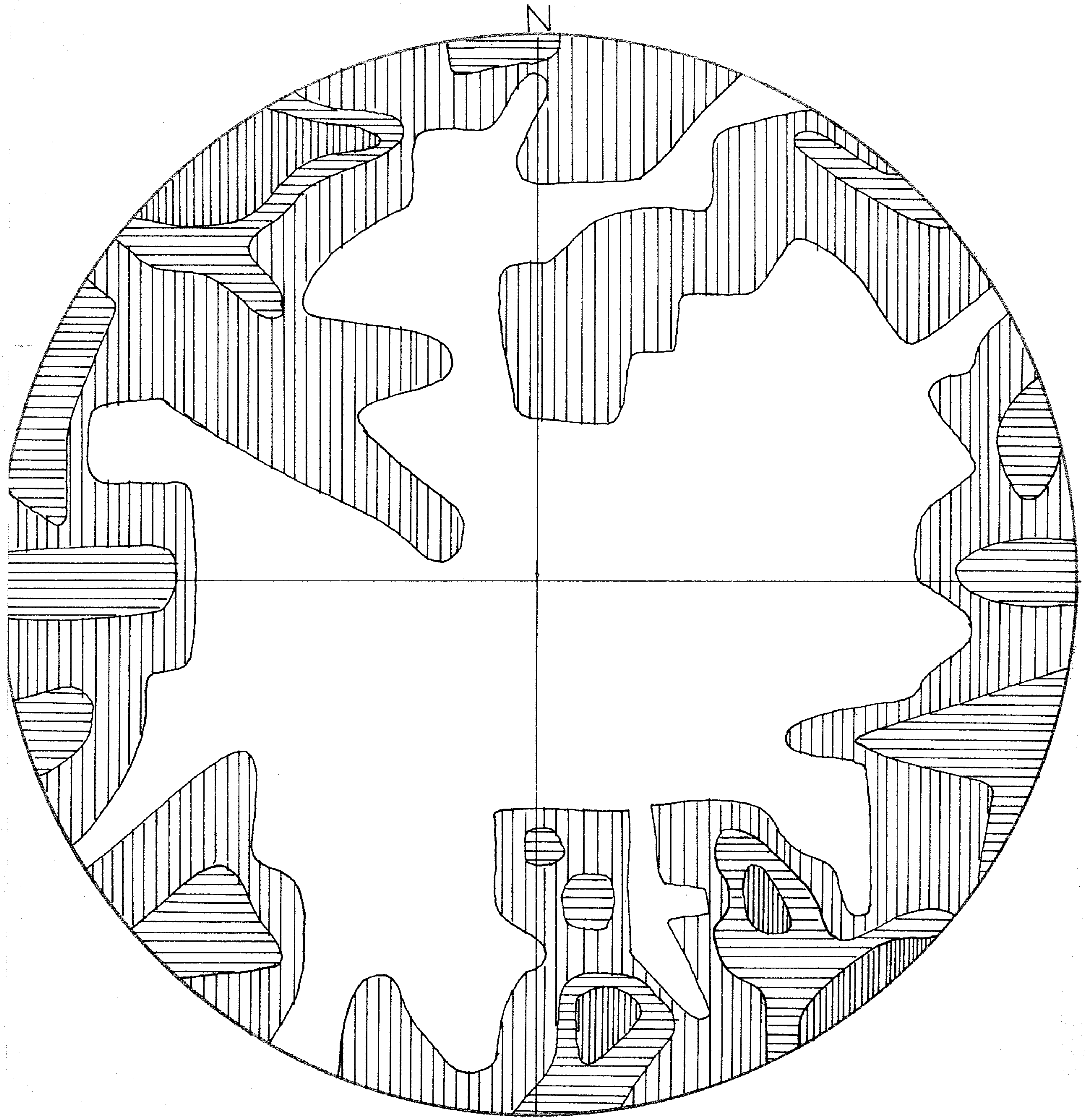

JOINT DISTRIBUTION, SUBAREA 16
LOWER HEMISPHERE EQUAL AREA PROJECTION
(100 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

Figure 26.




JOINT DISTRIBUTION, SUBAREA 17
LOWER HEMISPHERE EQUAL AREA PROJECTION
(109 POLES)
CONTOURS: 1%, 2%, 3%, 4%, AND 5%.

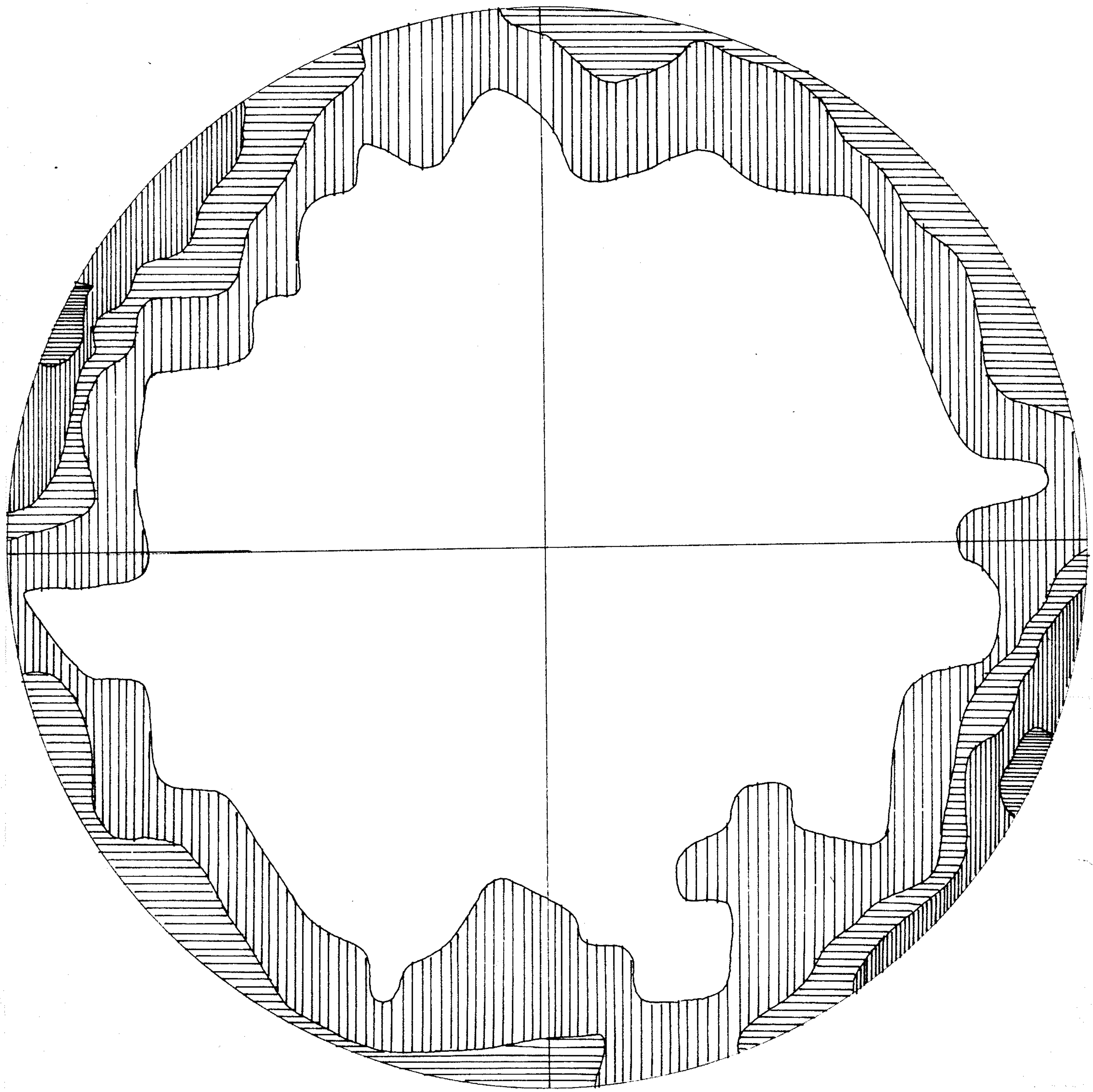
Figure 27.




JOINT DISTRIBUTION, SUBAREA 18
LOWER HEMISPHERE EQUAL AREA PROJECTION
(130 POLES)
CONTOURS: 1%, 2%, AND 3%.

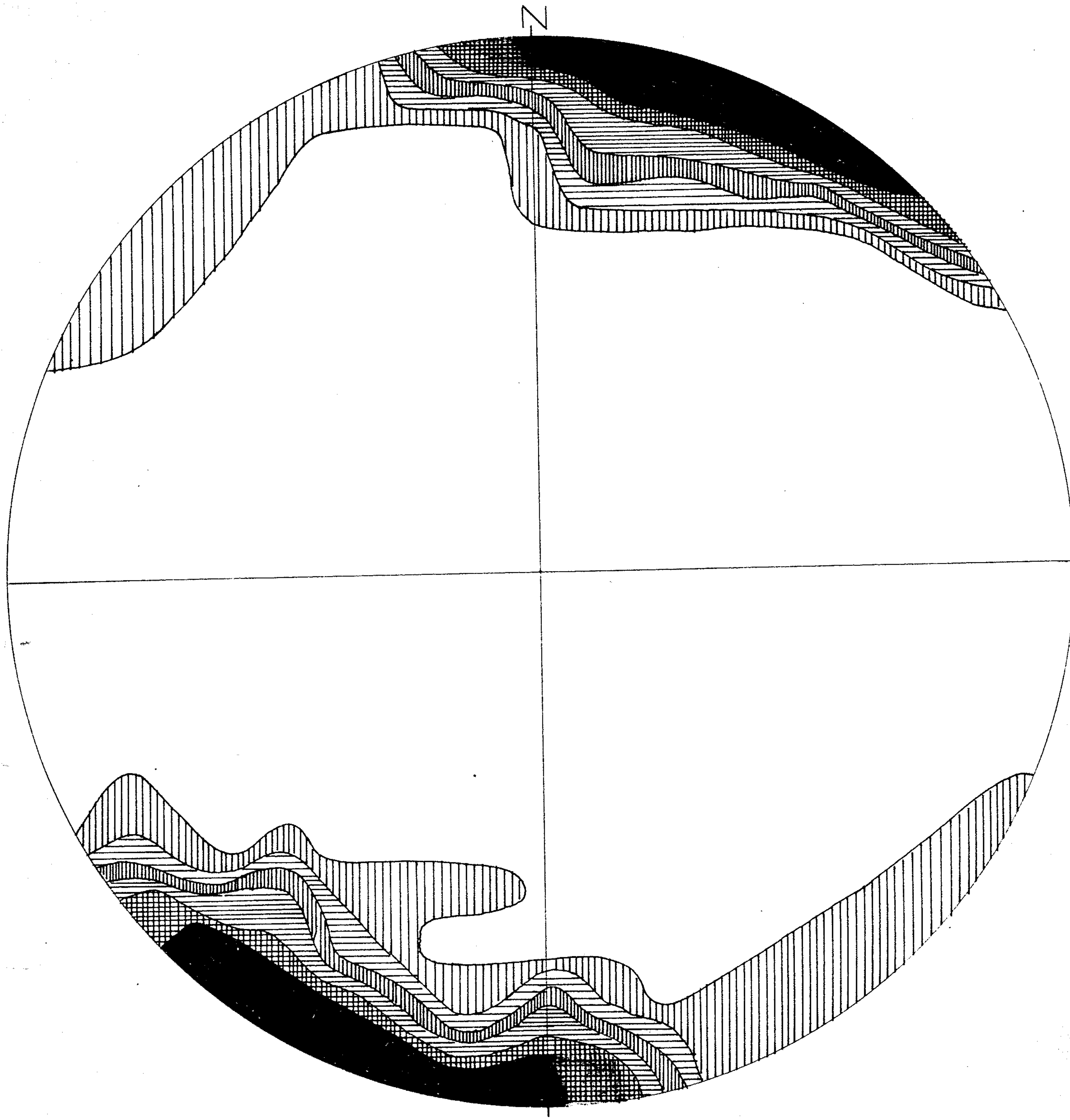
Figure 28.

N



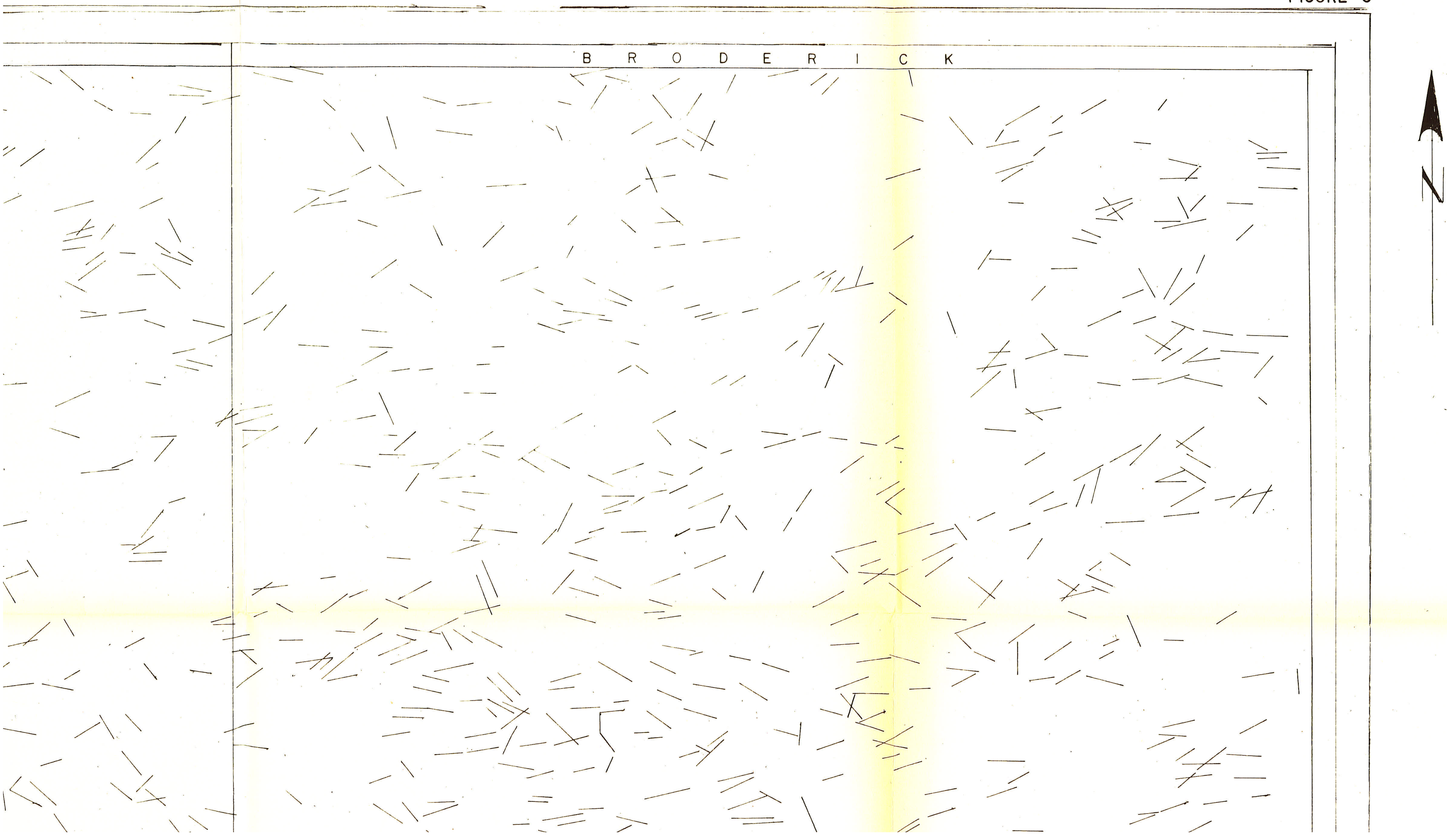
SYNOPTIC JOINT DISTRIBUTION
GUNDY AND BRODERICK TOWNSHIPS
LOWER HEMISPHERE EQUAL AREA PROJECTION
(1,178 POLES)
CONTOURS: 1%, 2%, 3%, AND 4%.

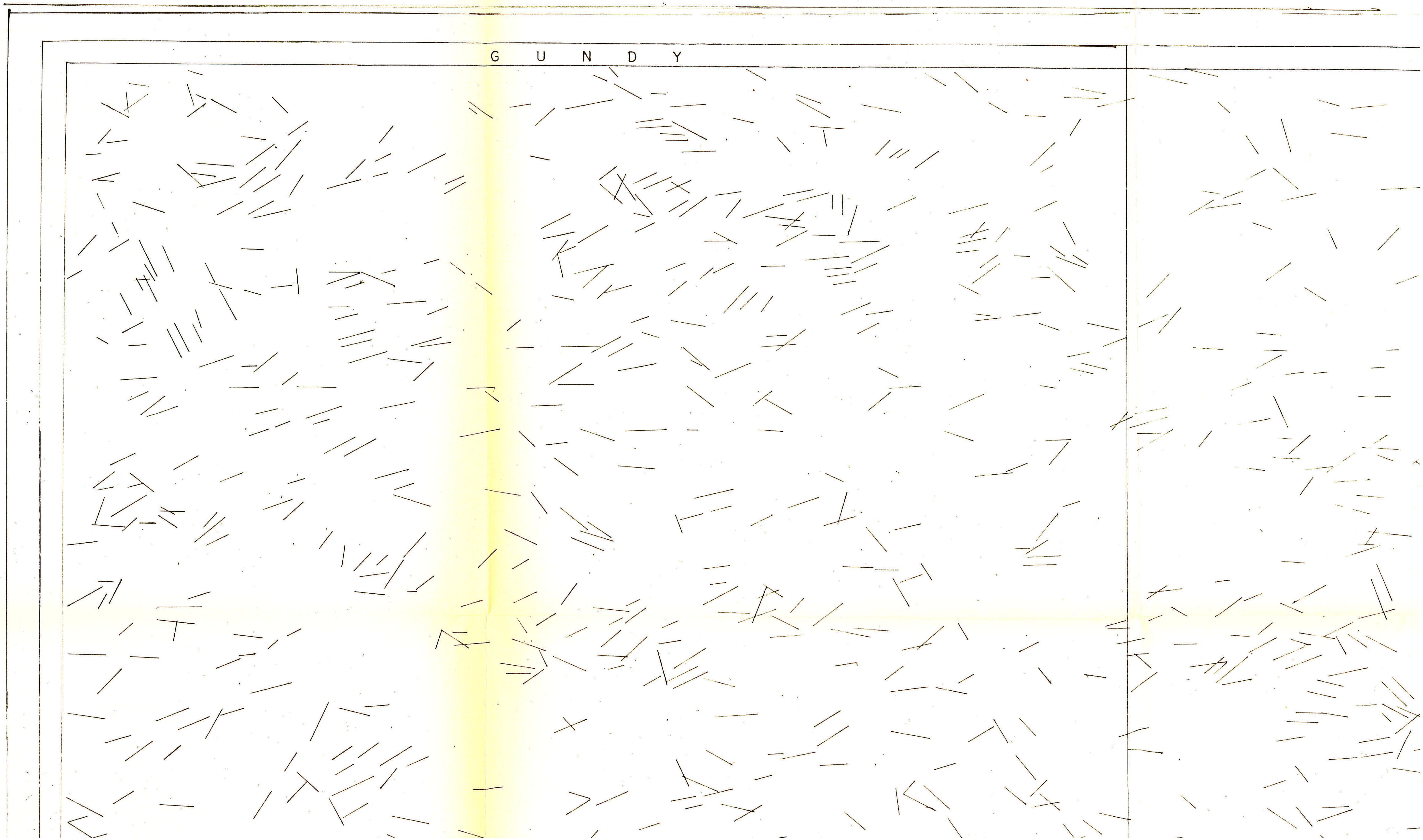
Figure 29.

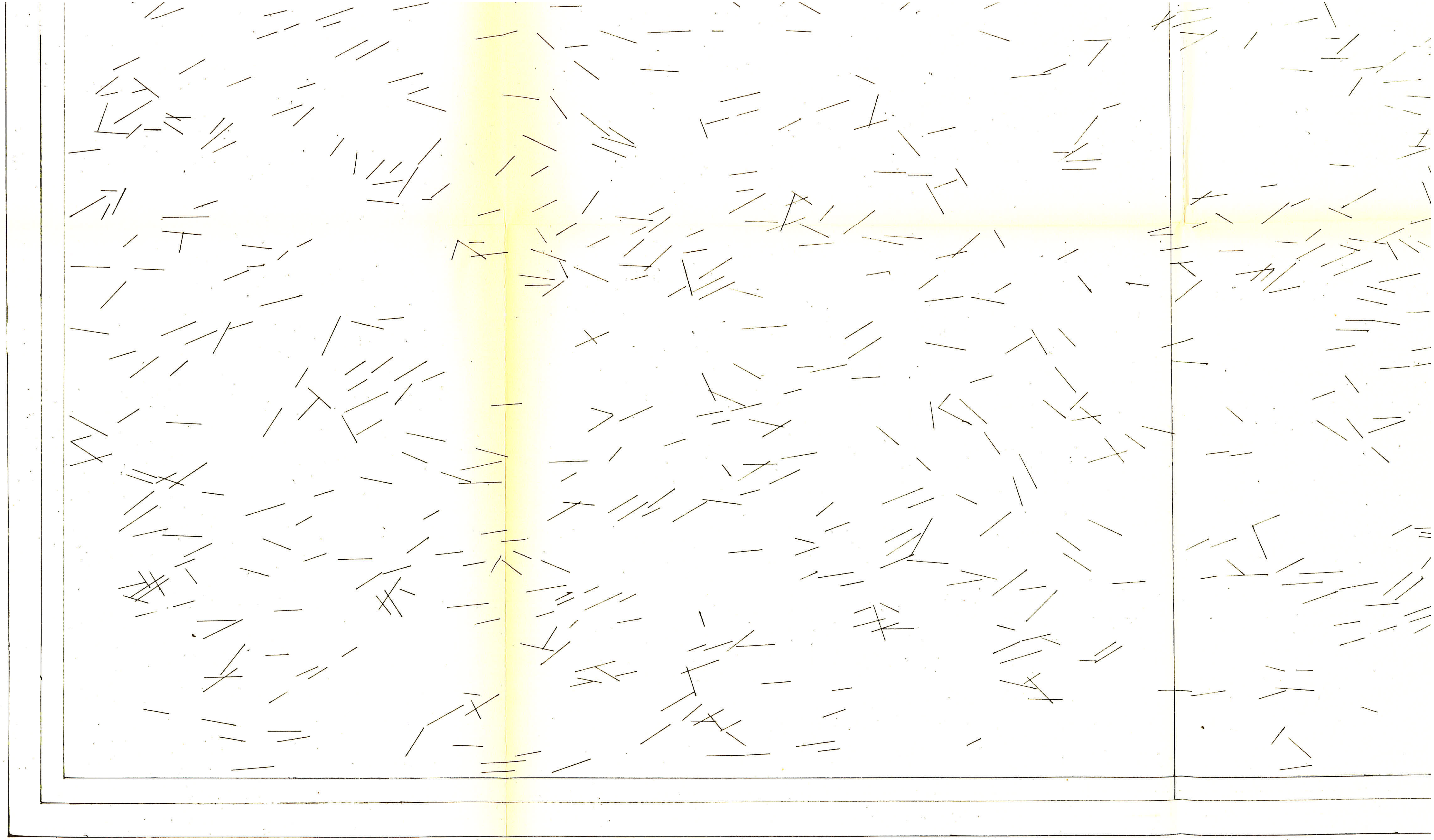



DISTRIBUTION OF GNEISSOSITY
GUNDY AND BRODERICK TOWNSHIPS
LOWER HEMISPHERE EQUAL AREA PROJECTION
(318 POLES)
CONTOURS: 1%, 2%, 3%, 4%, 5%, AND 6%.

FIGURE 3



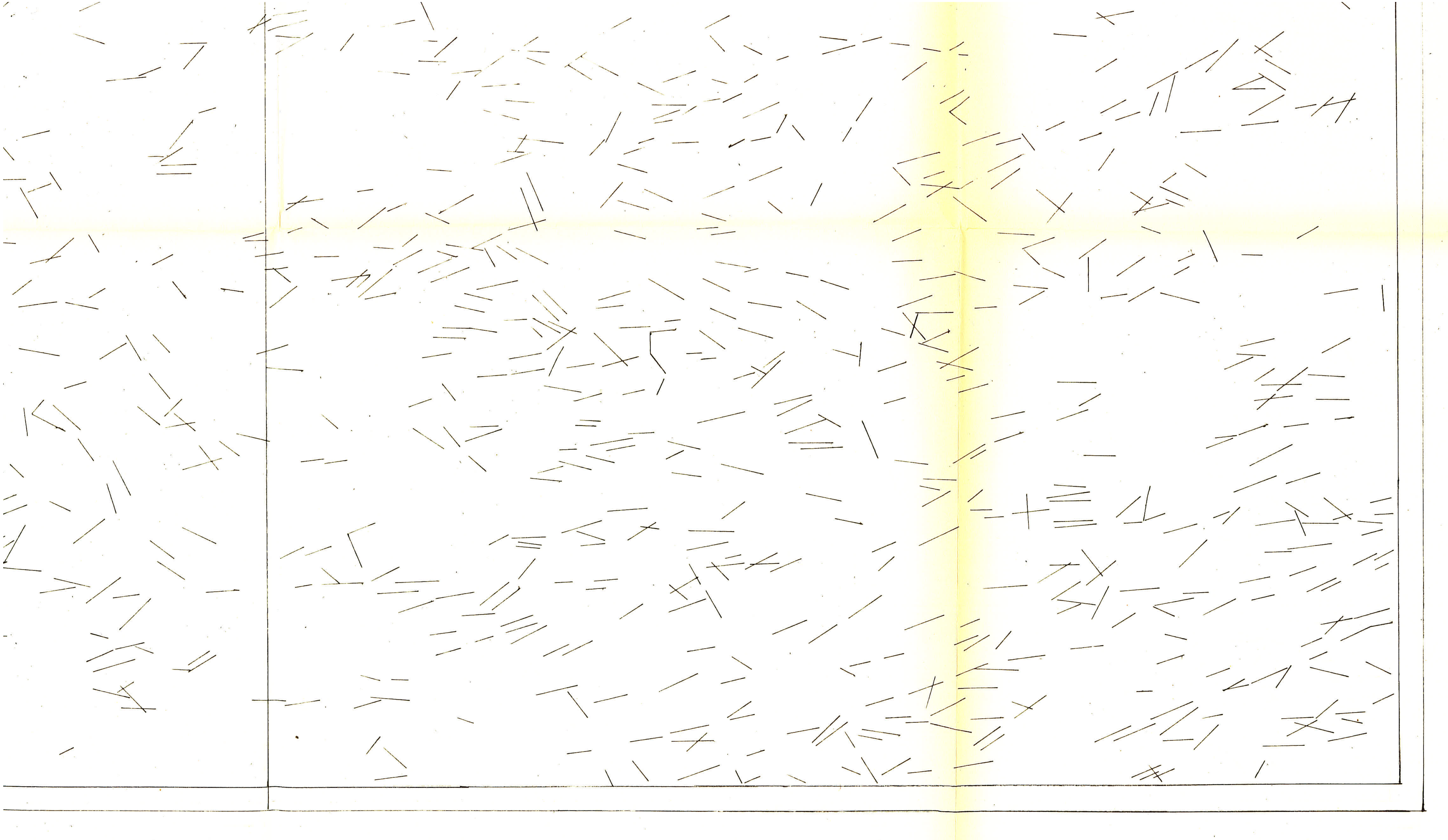

G U N D Y



SECOND ORDER AIR PHOTO LINEAMENTS IN GUNDY AND BRODERICK

KENORA DISTRICT, ONTARIO

SCALE 1 INCH = 1/2 MILE

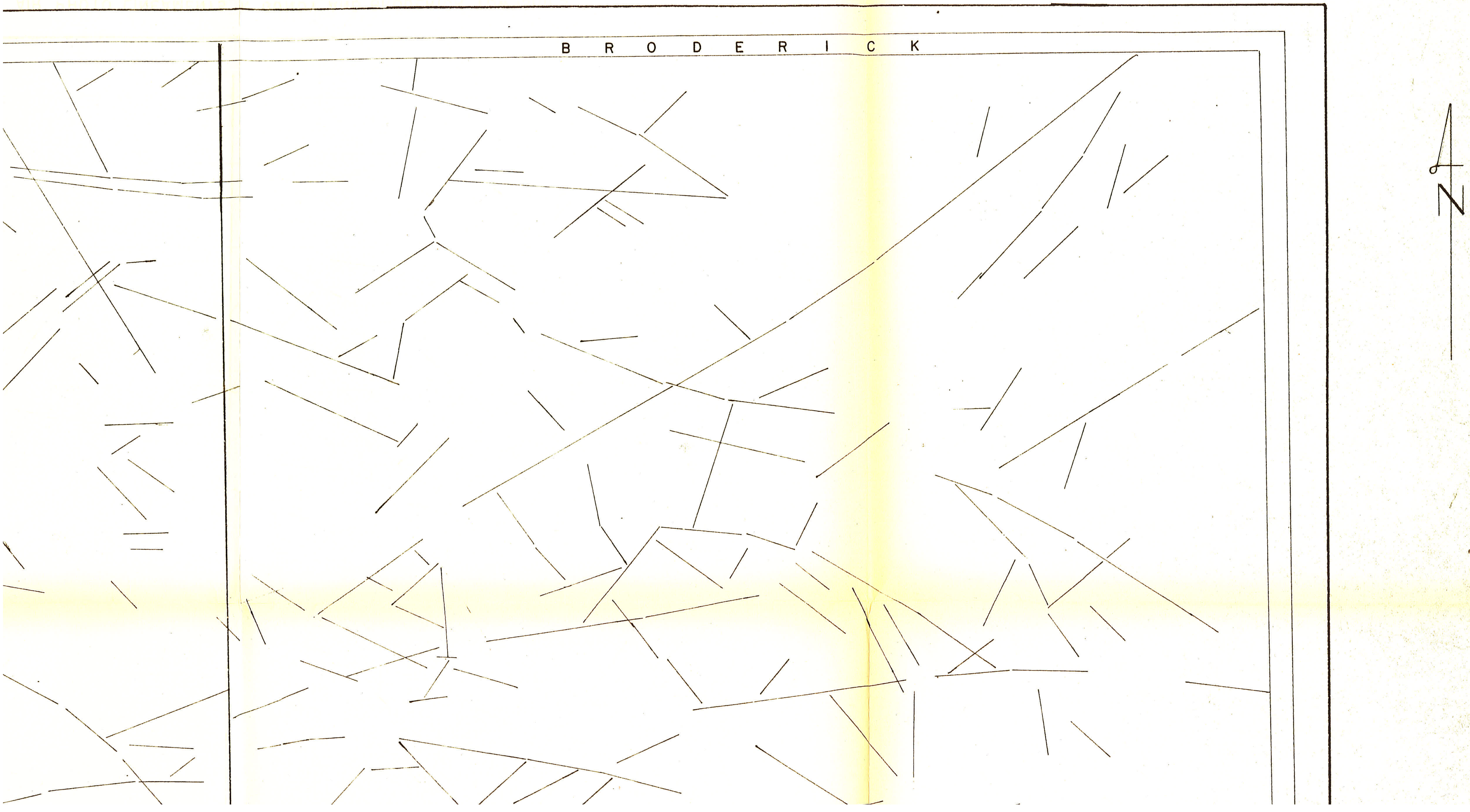


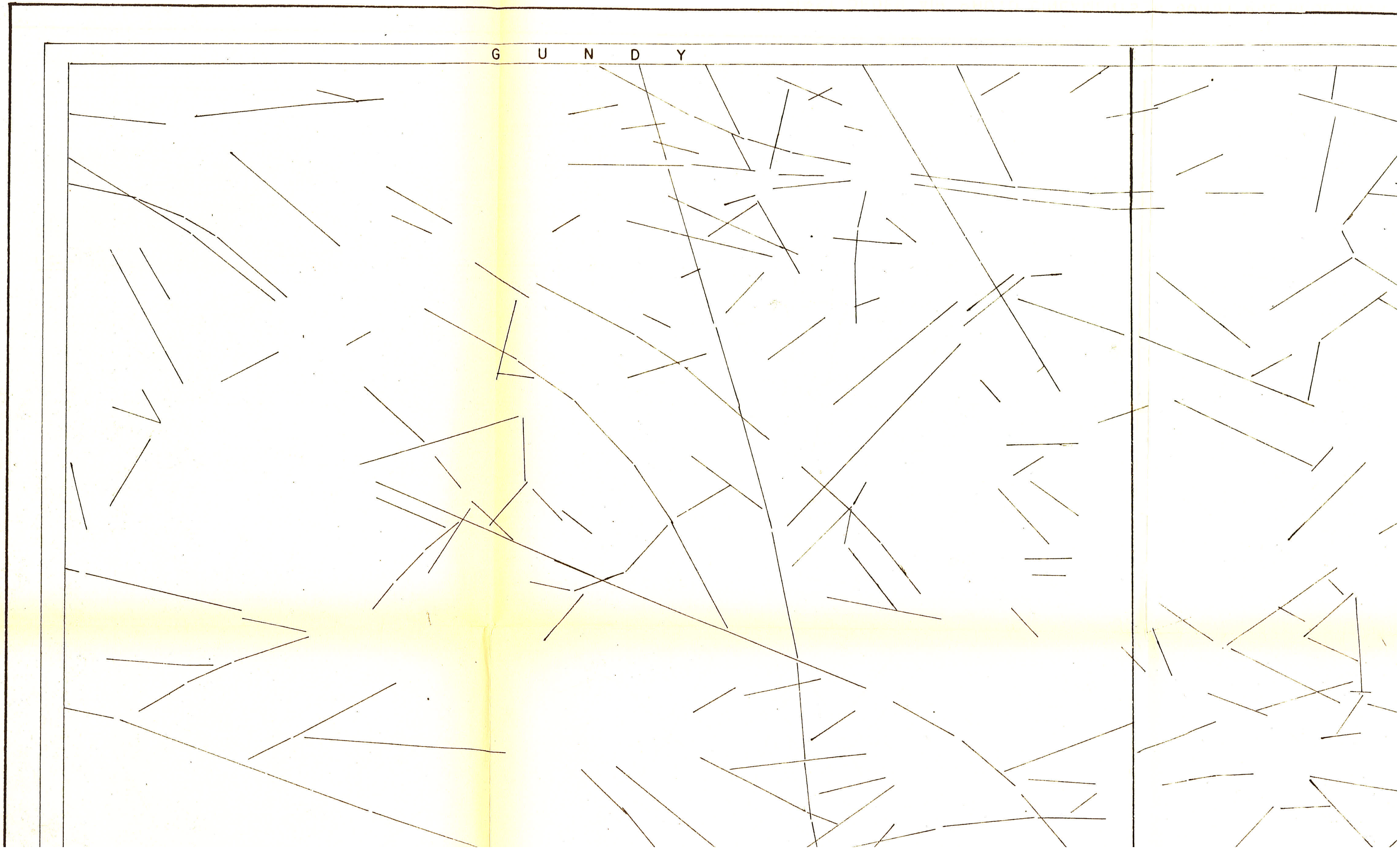
:R AIR PHOTO LINEAMENTS IN GUNDY AND BRODERICK TOWNSHIPS

KENORA DISTRICT, ONTARIO

SCALE 1 INCH = 1/2 MILE

FIGURE 2

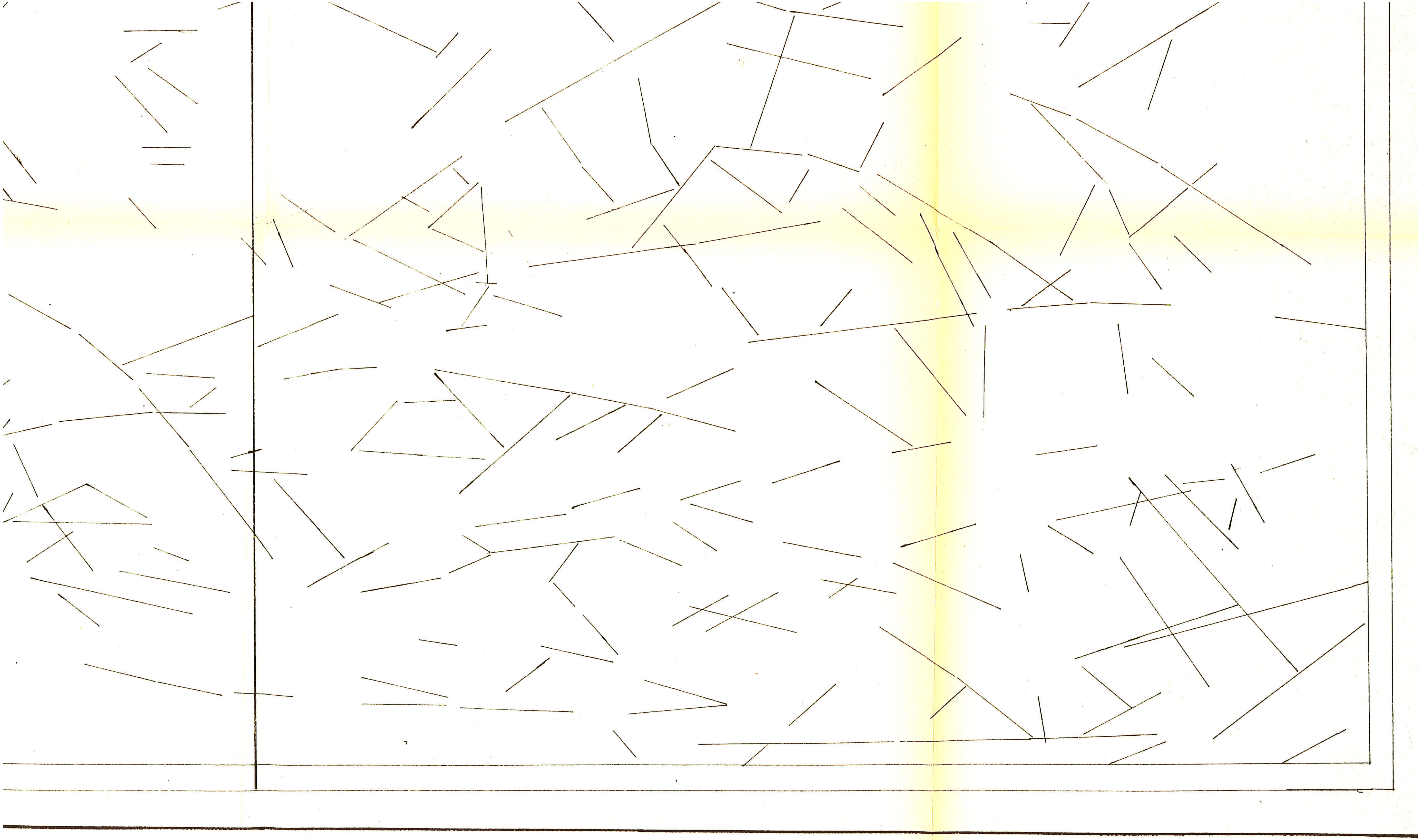



G U N D Y

FIRST ORDER AIR PHOTO LINEAMENTS IN GUNDY AND BRODERICK

KENORA DISTRICT, ONTARIO

SCALE: 1 INCH = 1/2 MILE

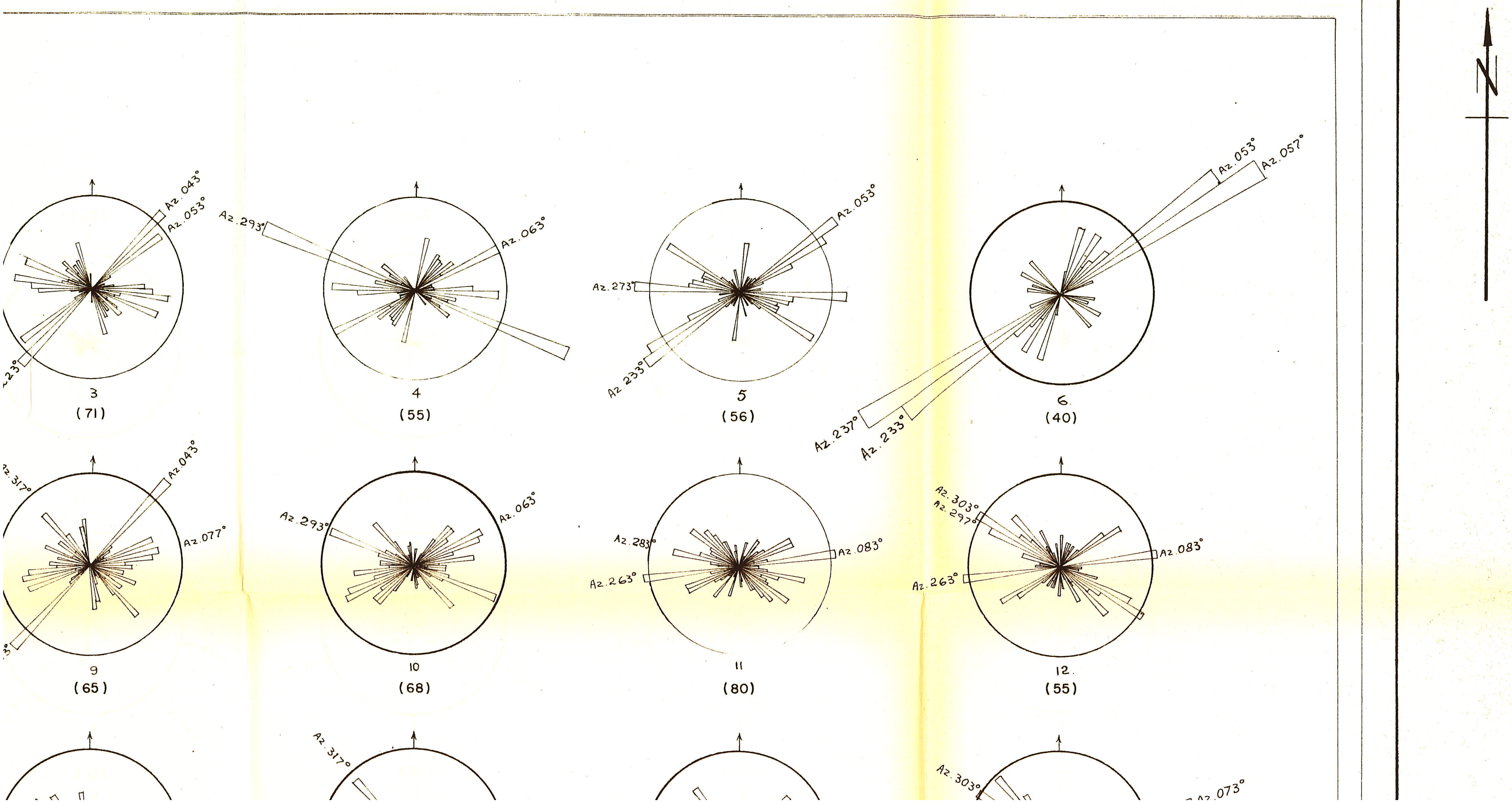


R AIR PHOTO LINEAMENTS IN GUNDY AND BRODERICK TOWNSHIPS

KENORA DISTRICT, ONTARIO

SCALE : 1 INCH = 1/2 MILE

FIGURE 5


Az. 043°
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Az. 273°
Az. 233°
Az. 053°
Az. 057°
Az. 237°
Az. 233°
3
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Az. 317°
Az. 043°
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Az. 293°
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Az. 283°
Az. 263°
Az. 083°
Az. 303°
Az. 297°
Az. 263°
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Az. 073°
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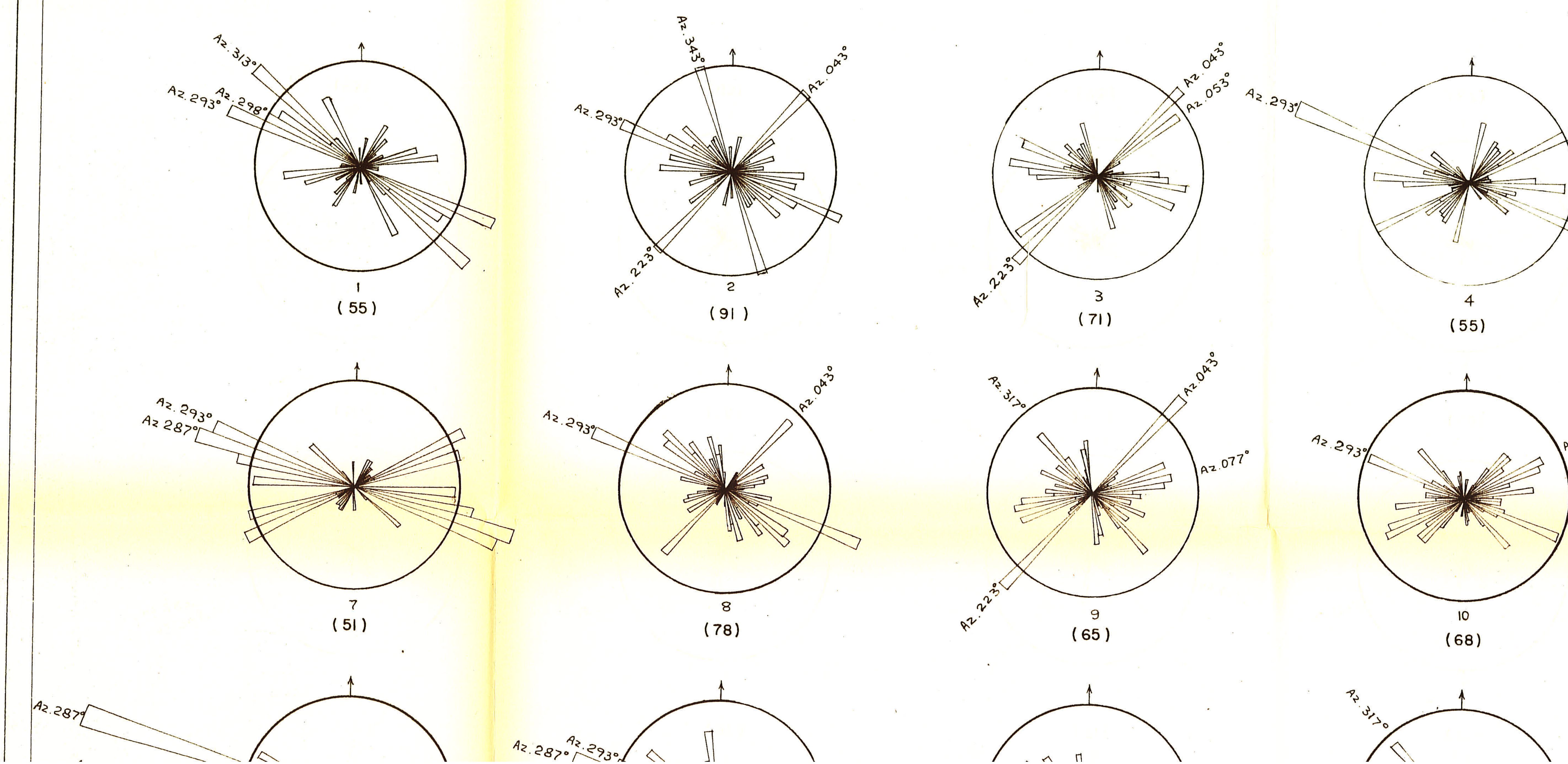

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Az. 298°
Az. 293°
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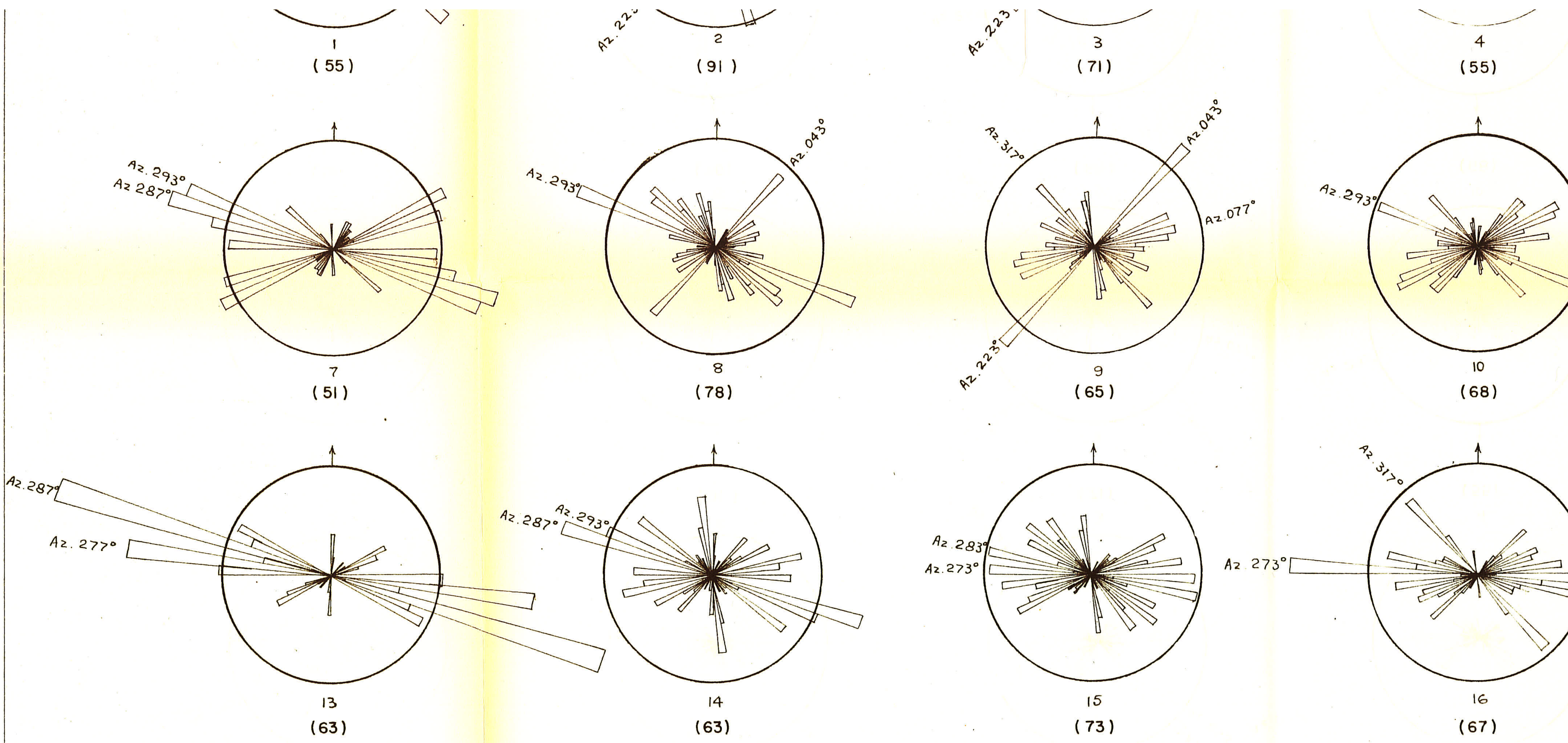
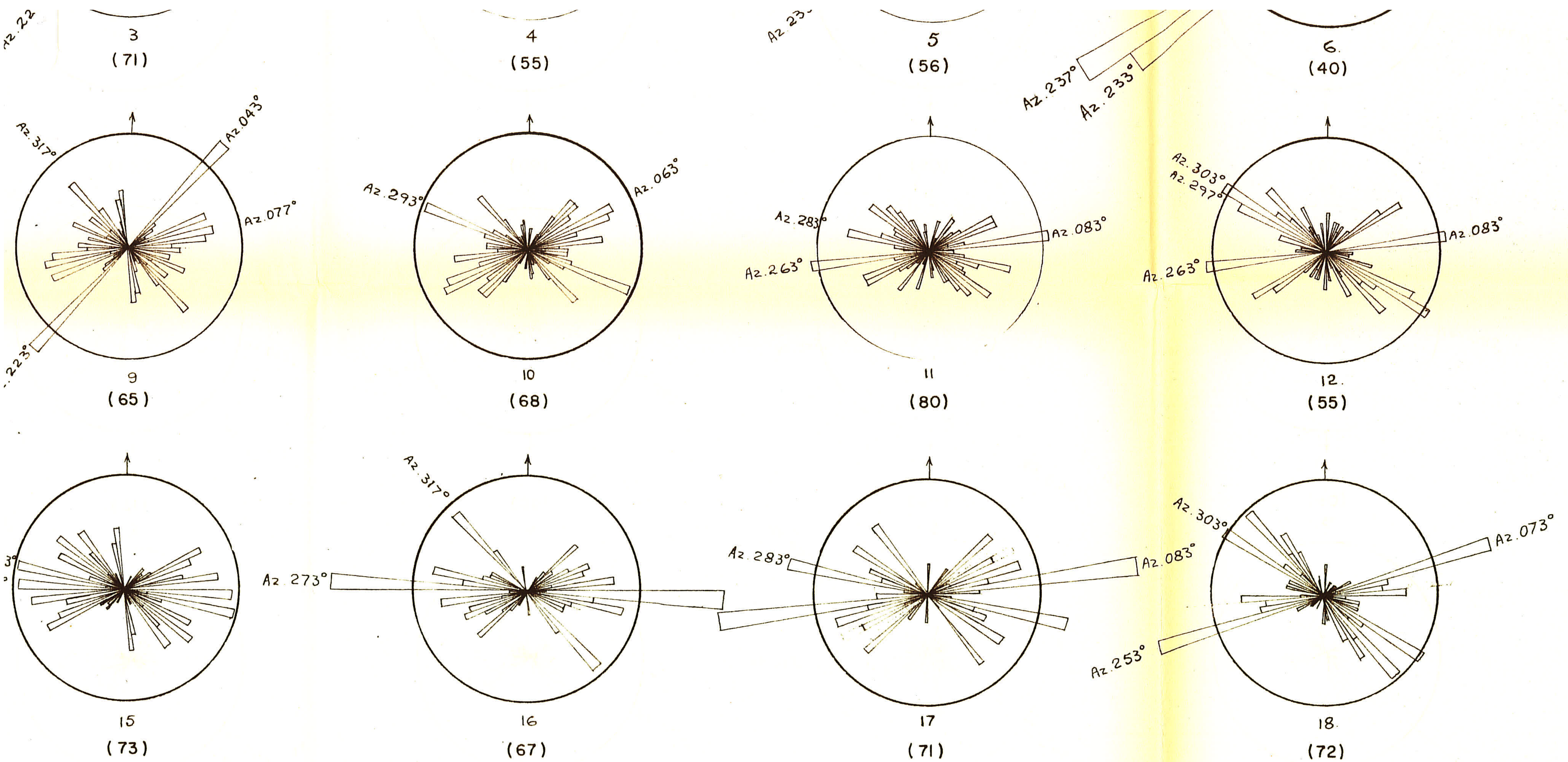



ROSETTE DIAGRAMS OF FIRST ORDER LINEAMENTS FOR EACH SUBAREA. RAD
CIRCLE REPRESENTS TEN PERCENT OF THE TOTAL NUMBER OF FIRST ORDER LINI
EACH SUBAREA. 5-DEGREE SEGMENTS.

NUMBER OF MEASUREMENTS IN EACH SUBAREA IS INDICATED IN PARENTHESES BEL
SUBAREA.

SCALE: 1 INCH = 1/2 MILE

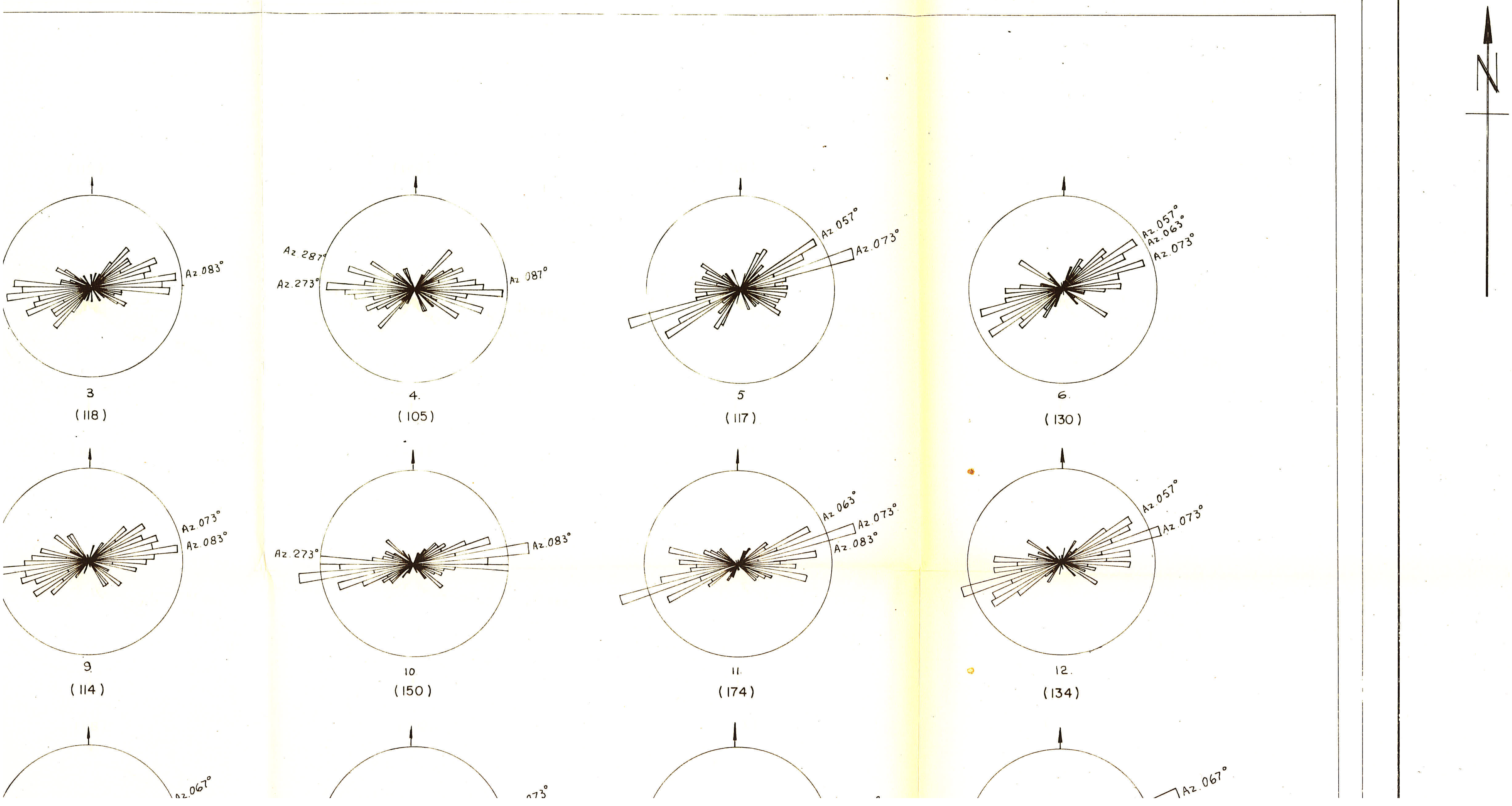



DIAGRAMS OF FIRST ORDER LINEAMENTS FOR EACH SUBAREA. RADIUS OF EACH
:SENTS TEN PERCENT OF THE TOTAL NUMBER OF FIRST ORDER LINEAMENTS IN
A. 5-DEGREE SEGMENTS.

MEASUREMENTS IN EACH SUBAREA IS INDICATED IN PARENTHESES BELOW EACH

SCALE: 1 INCH = 1/2 MILE

FIGURE 6



N
Az 083°
Az 287°
Az.273°
Az 087°
Az 057°
Az.073°
Az.057°
Az.063°
Az.073°
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(105)
5
(117)
6.
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Az 073°
Az 083°
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Az.083°
Az 063°
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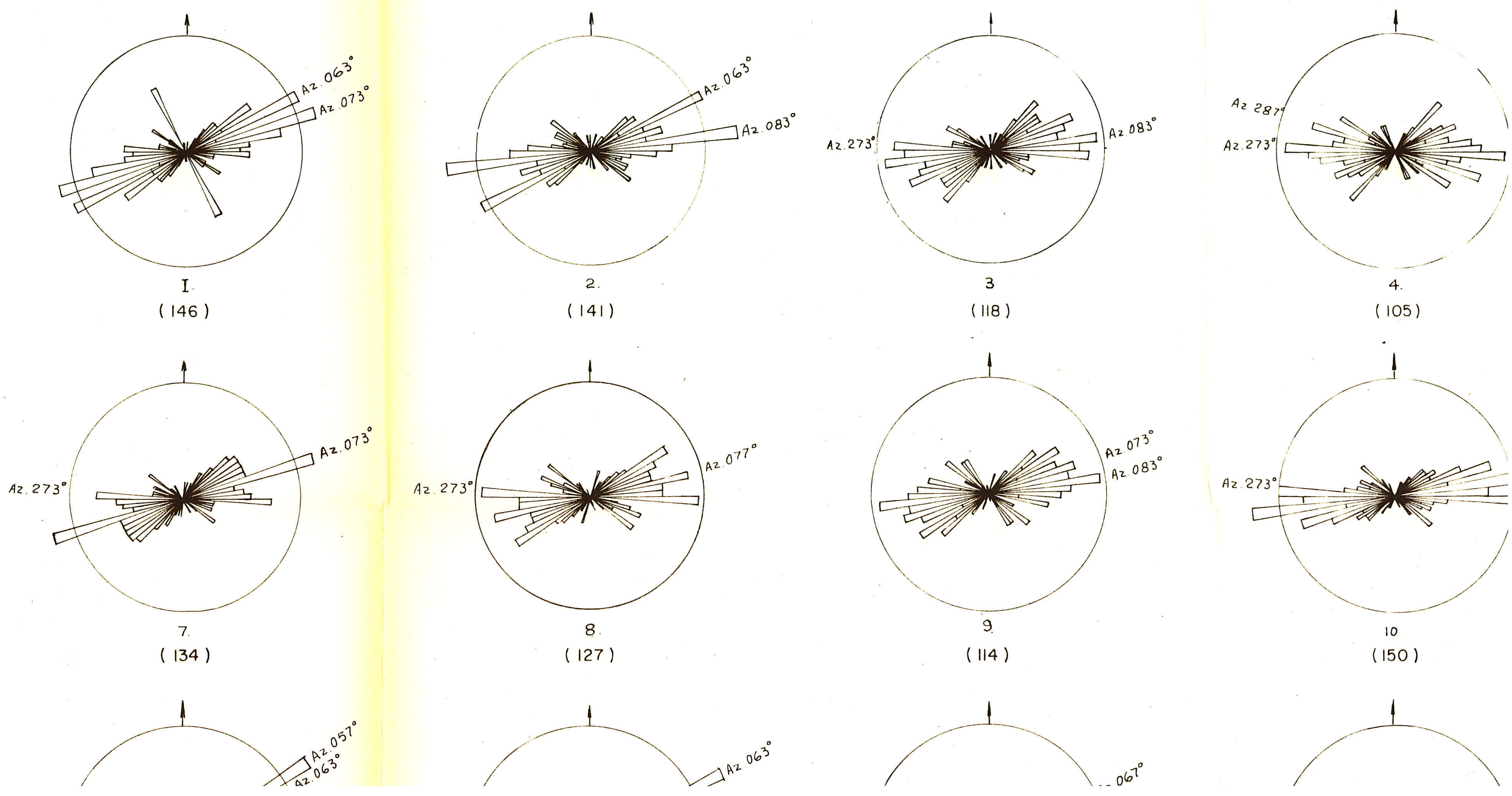

Az. 063°
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( 146 )
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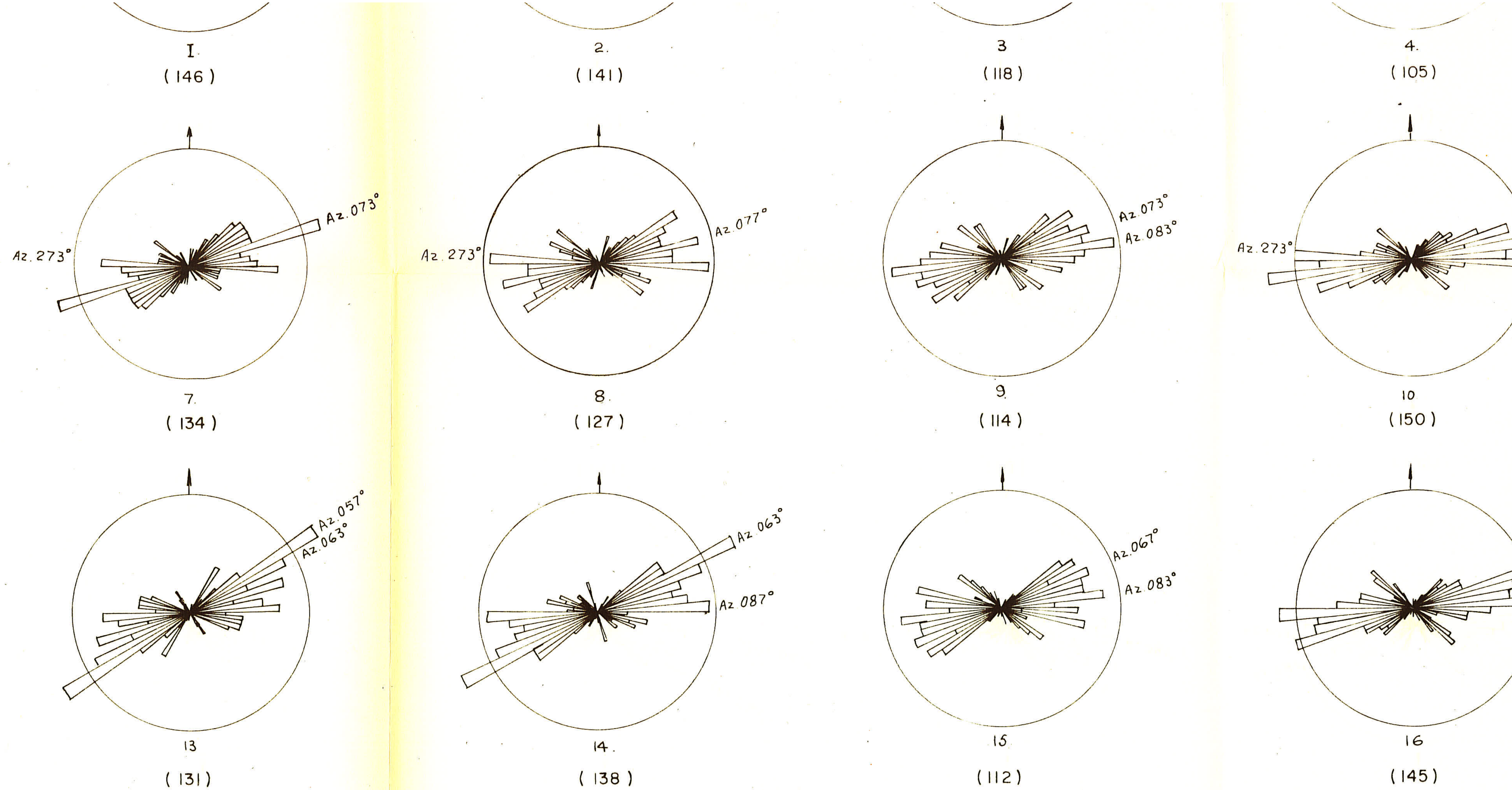
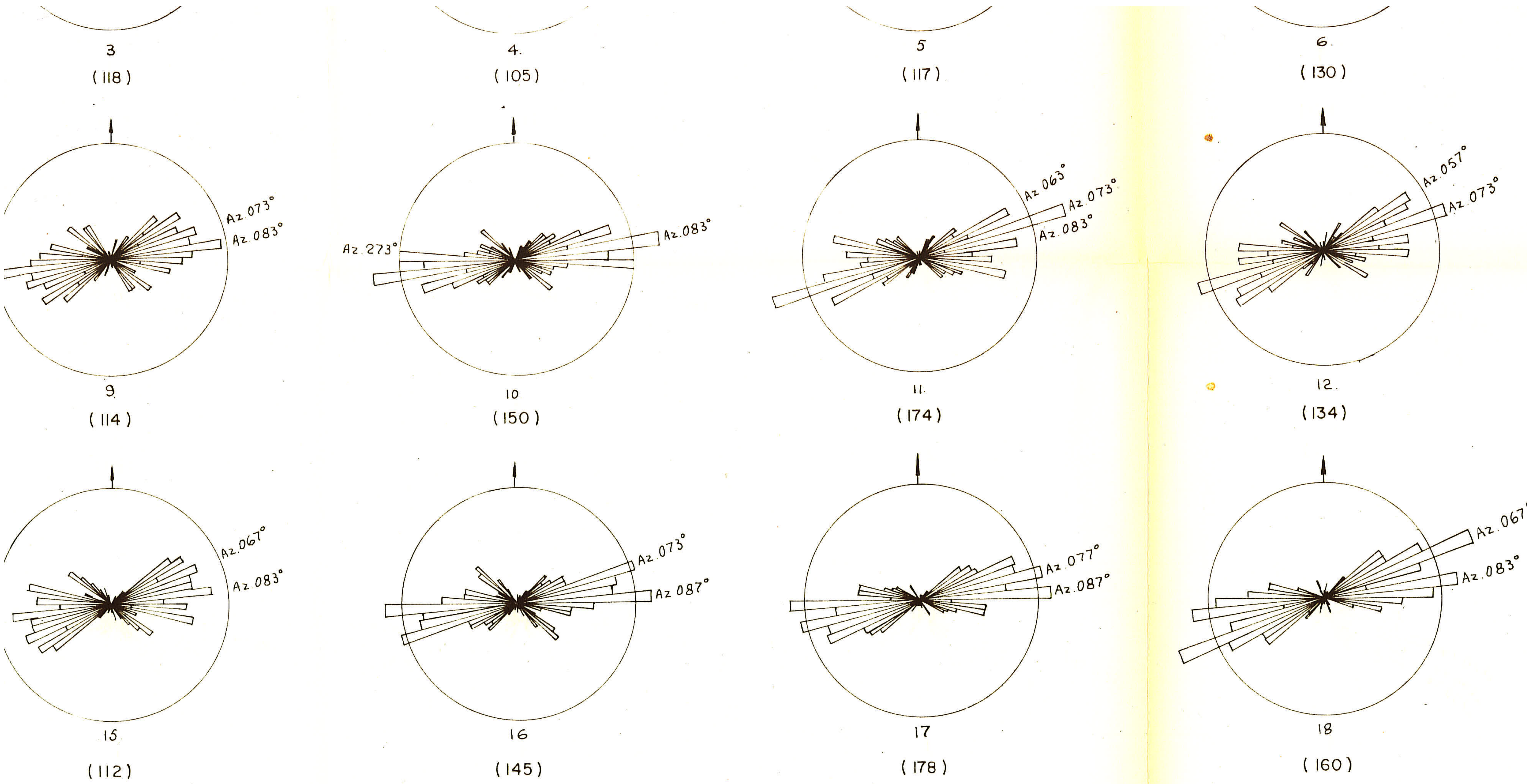



ROSETTE DIAGRAMS OF SECOND ORDER LINEAMENTS FOR EACH SUBAREA. RADI
CIRCLE REPRESENTS TEN PERCENT OF THE TOTAL NUMBER OF SECOND ORDER LI
EACH SUBAREA. 5-DEGREE SEGMENTS.

NUMBER OF MEASUREMENTS IN EACH SUBAREA IS INDICATED IN PARENTHESES BEL
SUBAREA.

SCALE: 1 INCH = 1/2 MILE

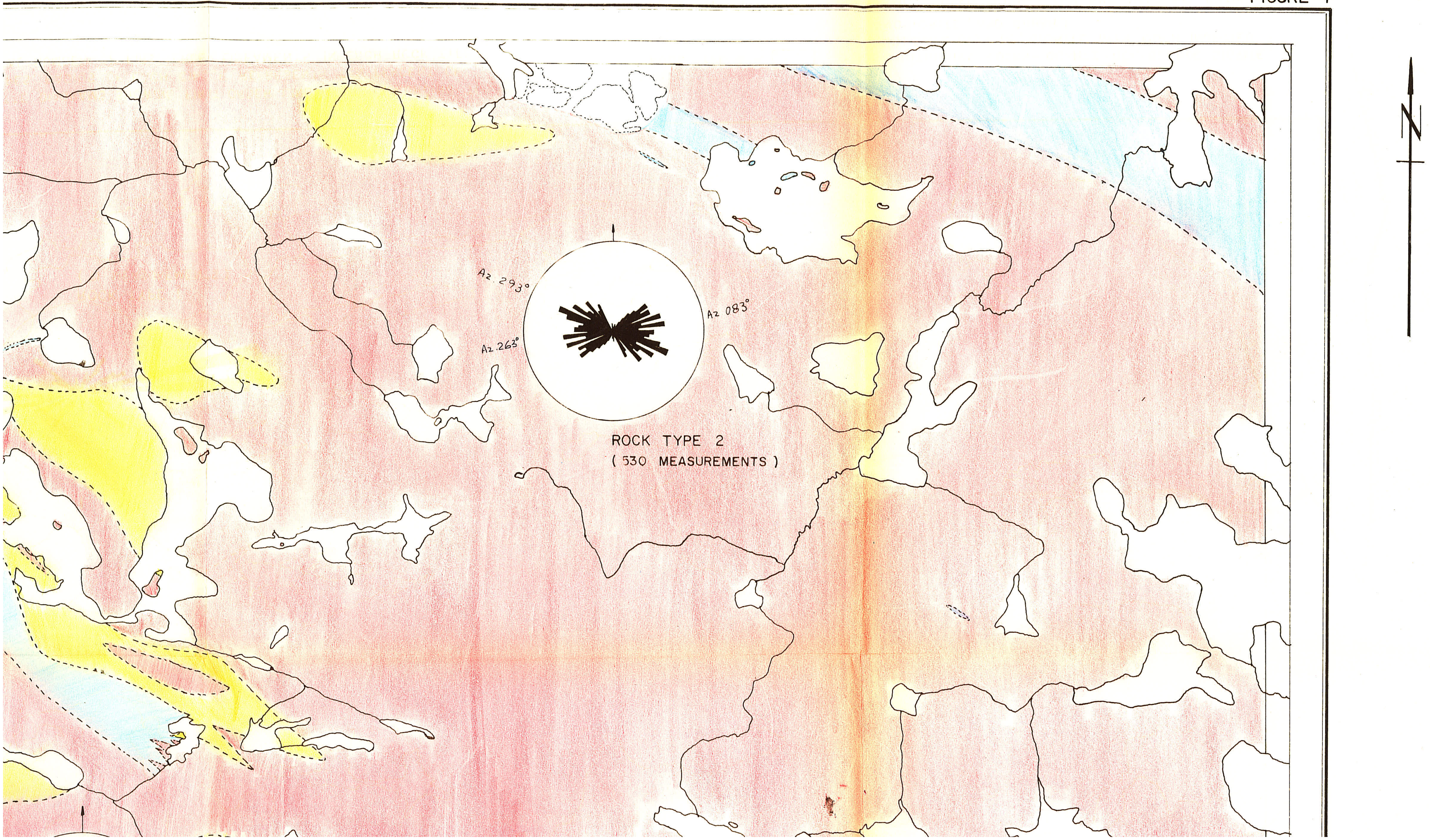


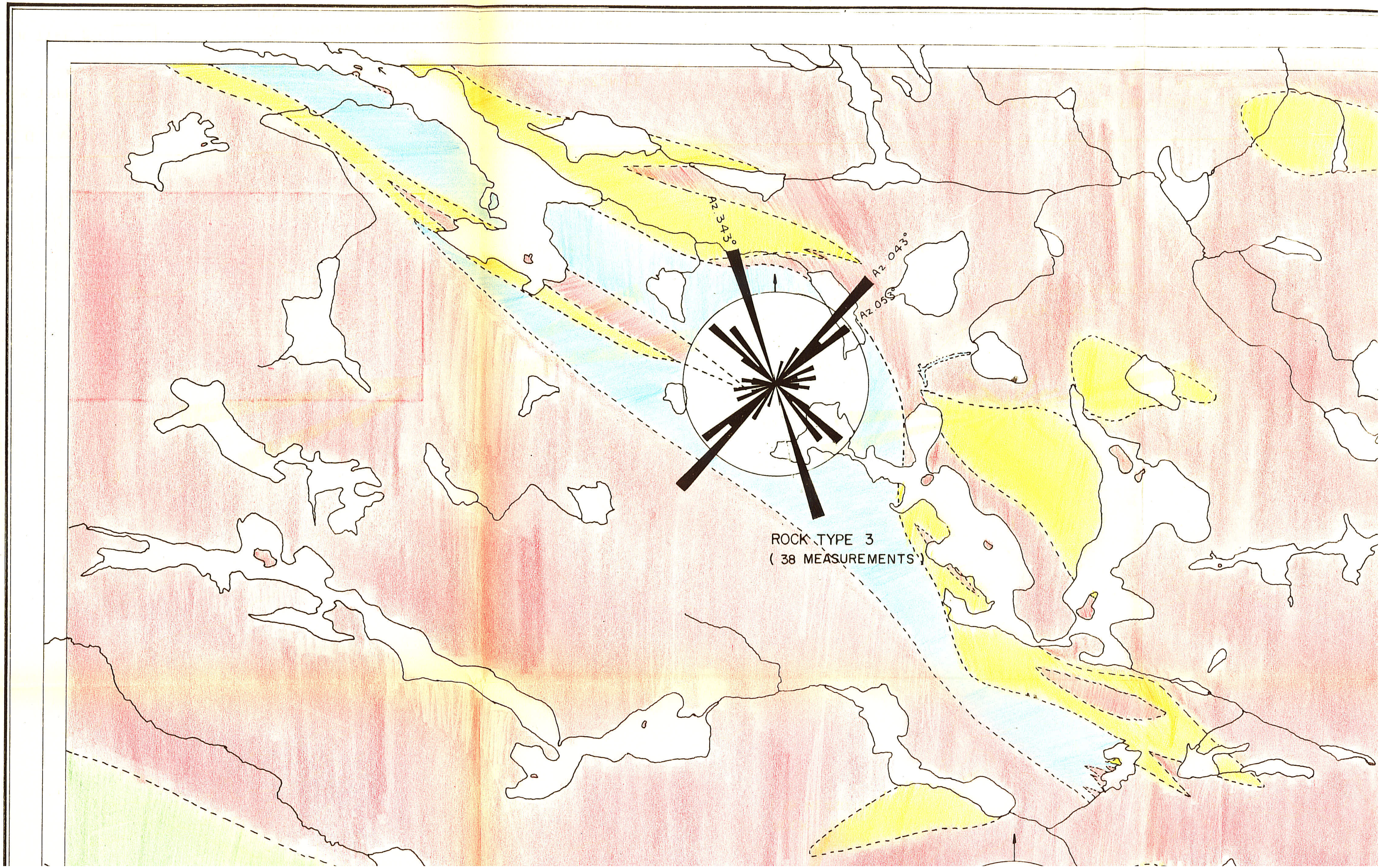

IAGRAMS OF SECOND ORDER LINEAMENTS FOR EACH SUBAREA. RADIUS OF EACH
ENTS TEN PERCENT OF THE TOTAL NUMBER OF SECOND ORDER LINEAMENTS IN
. 5-DEGREE SEGMENTS.

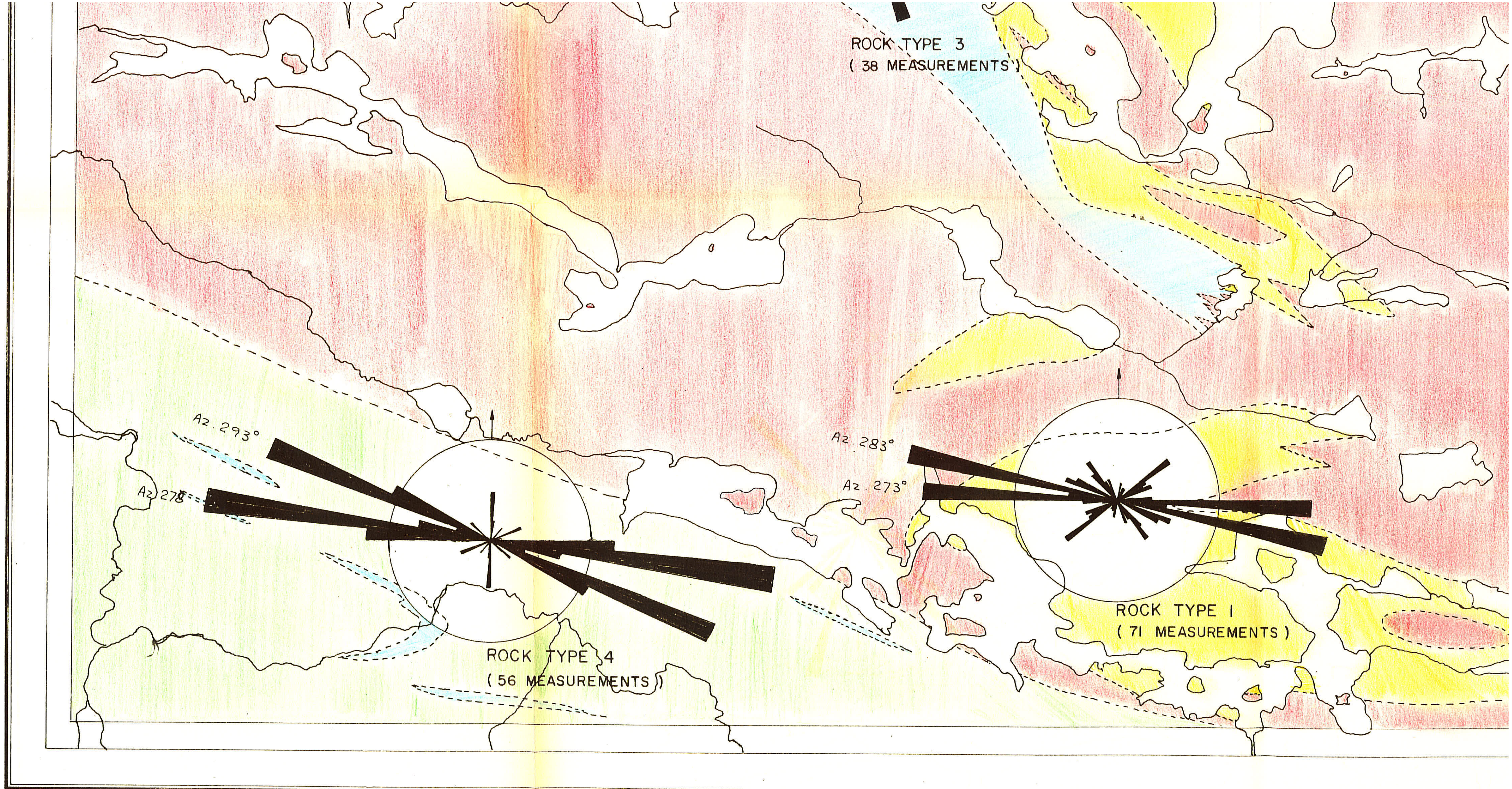
MEASUREMENTS IN EACH SUBAREA IS INDICATED IN PARENTHESES BELOW EACH

SCALE: 1 INCH = 1/2 MILE

FIGURE 7




Az 343°
Az 043°
Az 055°
ROCK TYPE 3
( 38 MEASUREMENTS )




LEGEND :

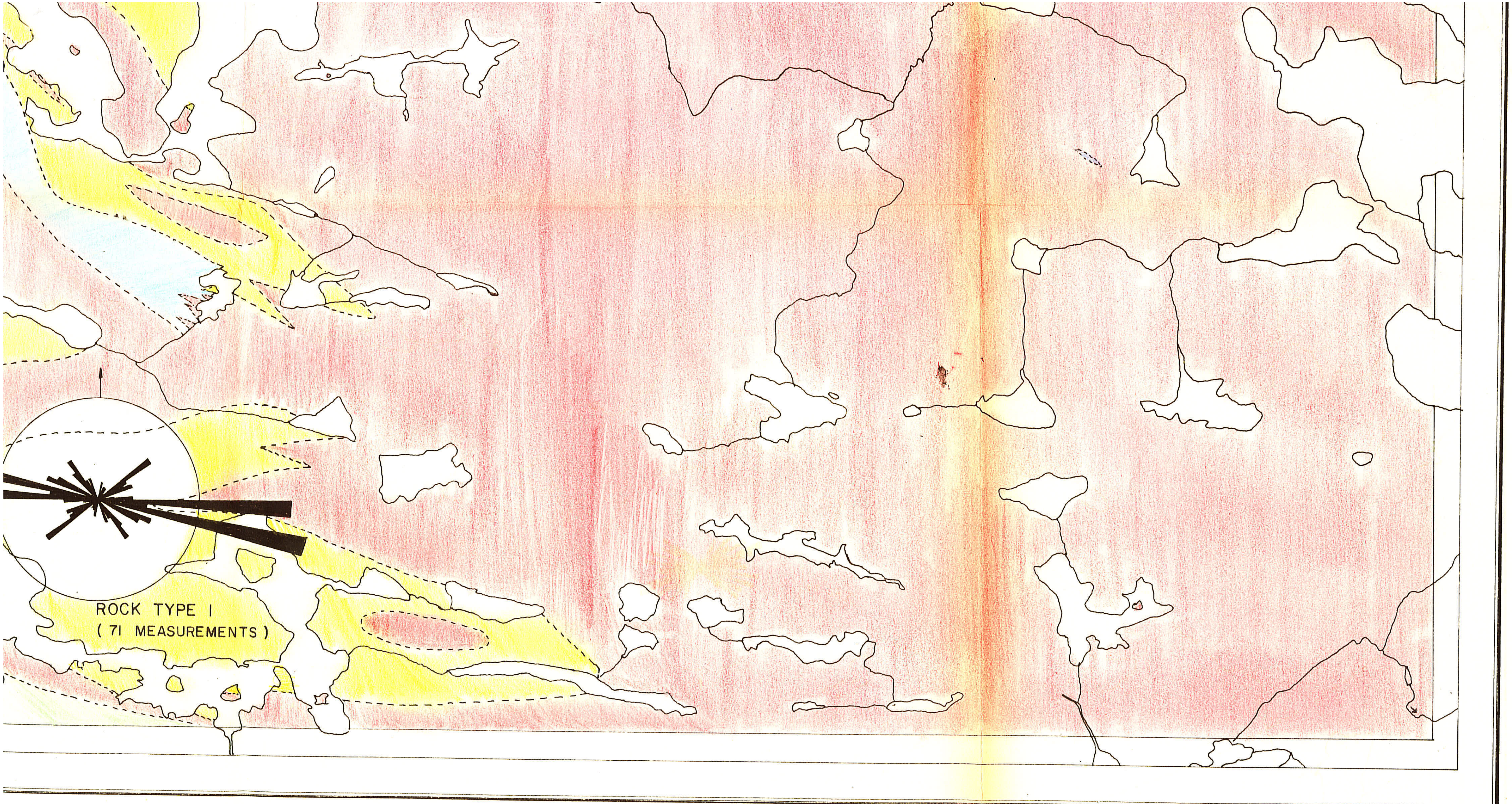
ROCK TYPE I - ACID INTRUSIVE ROCKS - PINK QUARTZ MONZONITE AND GRANODIORITE; WITH SOME GREY FOLIATED GRANODIORITE.

ROCK TYPE 2 - ACID INTRUSIVE ROCKS - QUARTZ MONZONITE; GREY GRANODIORITE; GNEISSIC HORNBLENDE-BIOTITE GRANODIORITE WITH APLITE; PEGMATITE; AND DARK INCLUSIONS; TONALITE AND DIORITE; BORDER PHASE OF HYBRID ROCKS AND LIT-PAR-LIT GNEISS; GRANODIORITE WITH LARGE FELDSPAR "EYES."

( Geology from Ontario Department Of Mines Map 2068 )

ROSETTE DIAGRAMS SHOWING FIRST ORDER LINEAMENTS ACCOR
ROCK TYPES. RADIUS OF EACH CIRCLE REPRESENTS TEN PERCEN
THE TOTAL NUMBER OF FIRST ORDER LINEAMENTS IN EACH ROC

SCALE : I INCH = I/2 MILE



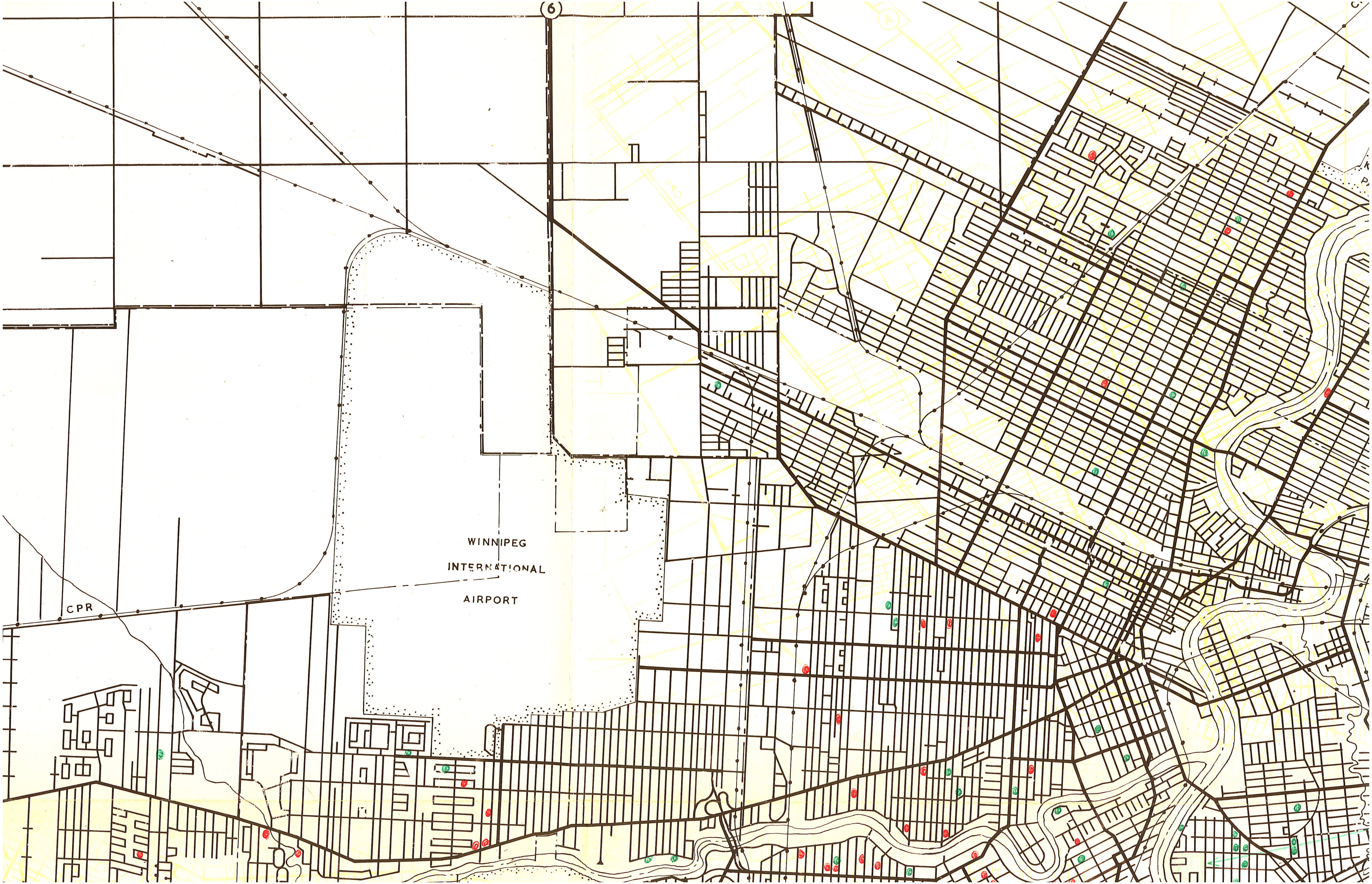

ETTE DIAGRAMS SHOWING FIRST ORDER LINEAMENTS ACCORDING TO
YPES. RADIUS OF EACH CIRCLE REPRESENTS TEN PERCENT OF
TAL NUMBER OF FIRST ORDER LINEAMENTS IN EACH ROCK TYPE.

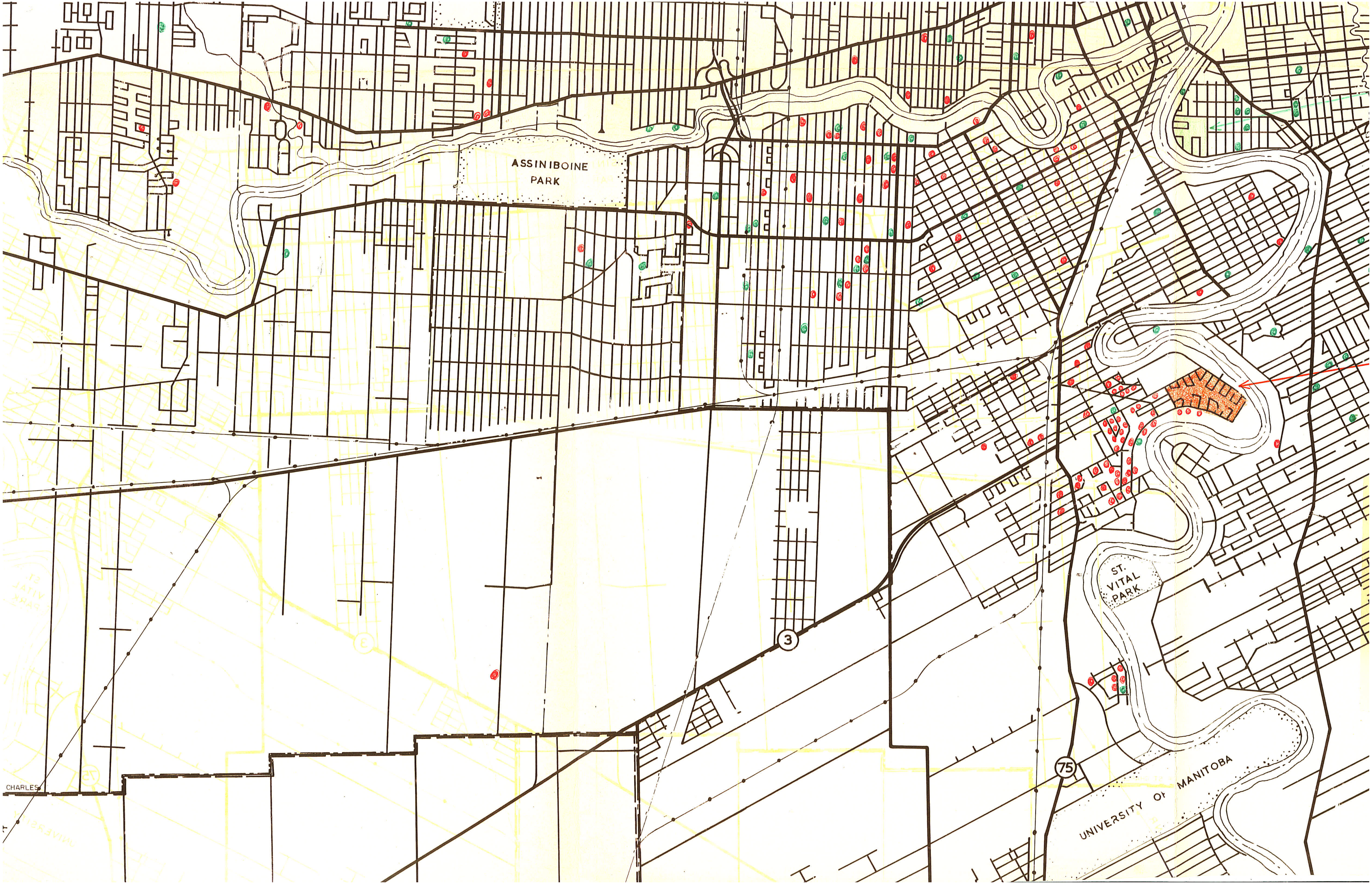
SCALE: 1 INCH = 1/2 MILE

ROCK TYPE 3 - BASIC INTRUSIVE ROCKS - QUARTZ-HORNBLENDE DIORITE; HORNBLENDE DIORITE; DIORITE WITH MUCH INJECTED GRANODIORITE; AND GABBRO.

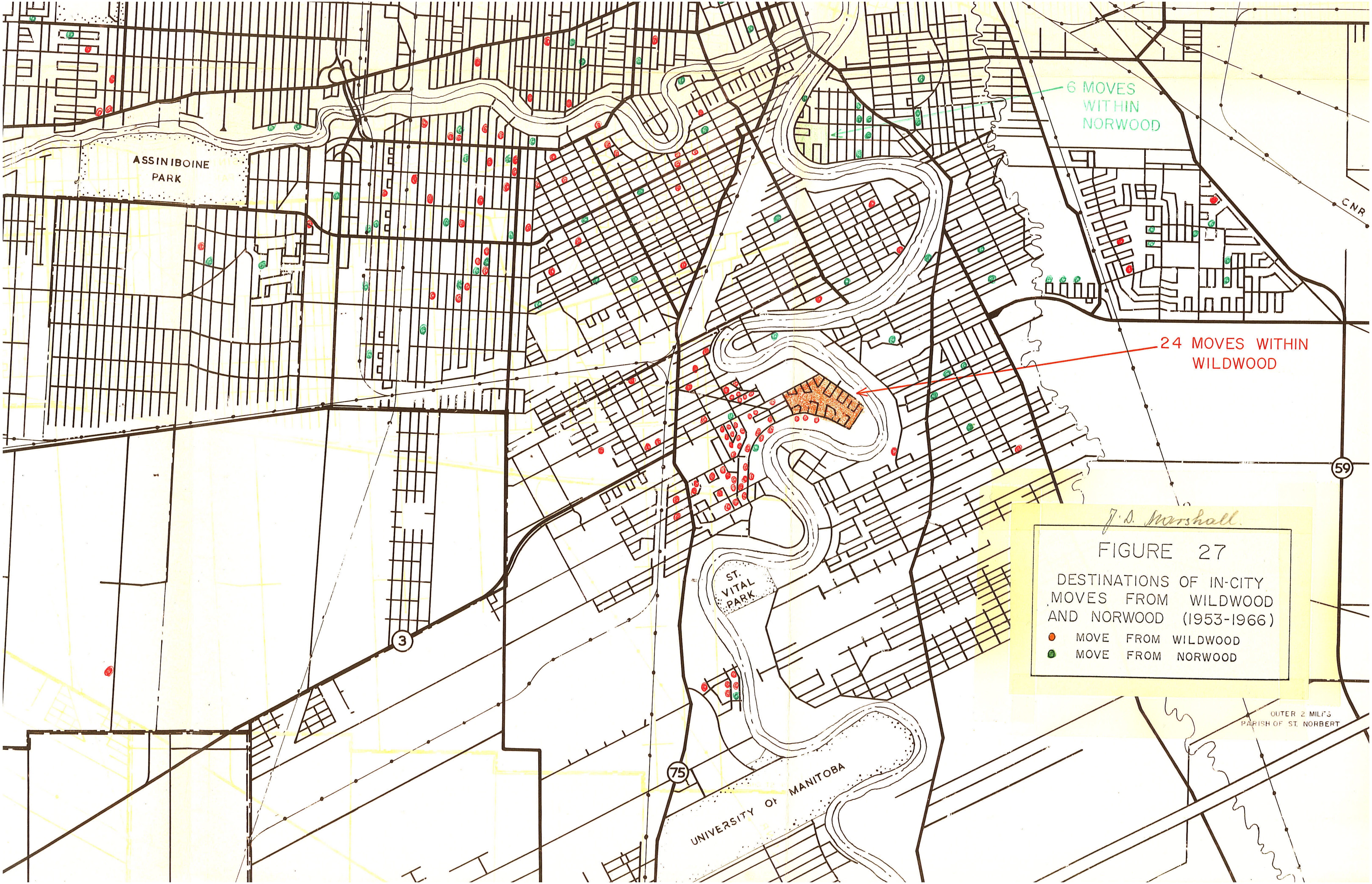
ROCK TYPE 4 - METAMORPHOSED SEDIMENTARY AND VOLCANIC EXTRUSIVE ROCKS,- ARKOSE; GREYWACKE; CONGLOMERATE; SLATE; SILICEOUS SILTSTONE; CHERTY SEDIMENTS; GARNET-RICH GREYWACKE; ANDESITE; BASALT; TUFF; AGGLOMERATE AND TUFF; INTERBANDED LENSY TUFF; FLOWS AND SEDIMENTS; HORNBLENDE-BIOTITE-PLAGIOCLASS SCHIST; GABBRO; PILLOW LAVA.


6
4
9
CPR
CPR
KILDONAN
PARK
WINNIPEG
INTERNATIONAL
AIRPORT
6 MOVES
WITHIN
NORWOOD


6
WINNIPEG
INTERNATIONAL
AIRPORT
CPR



ASSINIBOINE PARK
ST. VITAL PARK
UNIVERSITY OF MANITOBA
3
75
CHARLES


6 MOVES WITHIN NORWOOD
ASSINIBOINE PARK
CNR
24 MOVES WITHIN WILDWOOD
59
3
ST. VITAL PARK
75
UNIVERSITY OF MANITOBA
OUTER 2 MILES
PARISH OF ST. NORBERT
J. D. Marshall
FIGURE 27
DESTINATIONS OF IN-CITY MOVES FROM WILDWOOD AND NORWOOD (1953-1966)
MOVE FROM WILDWOOD
MOVE FROM NORWOOD