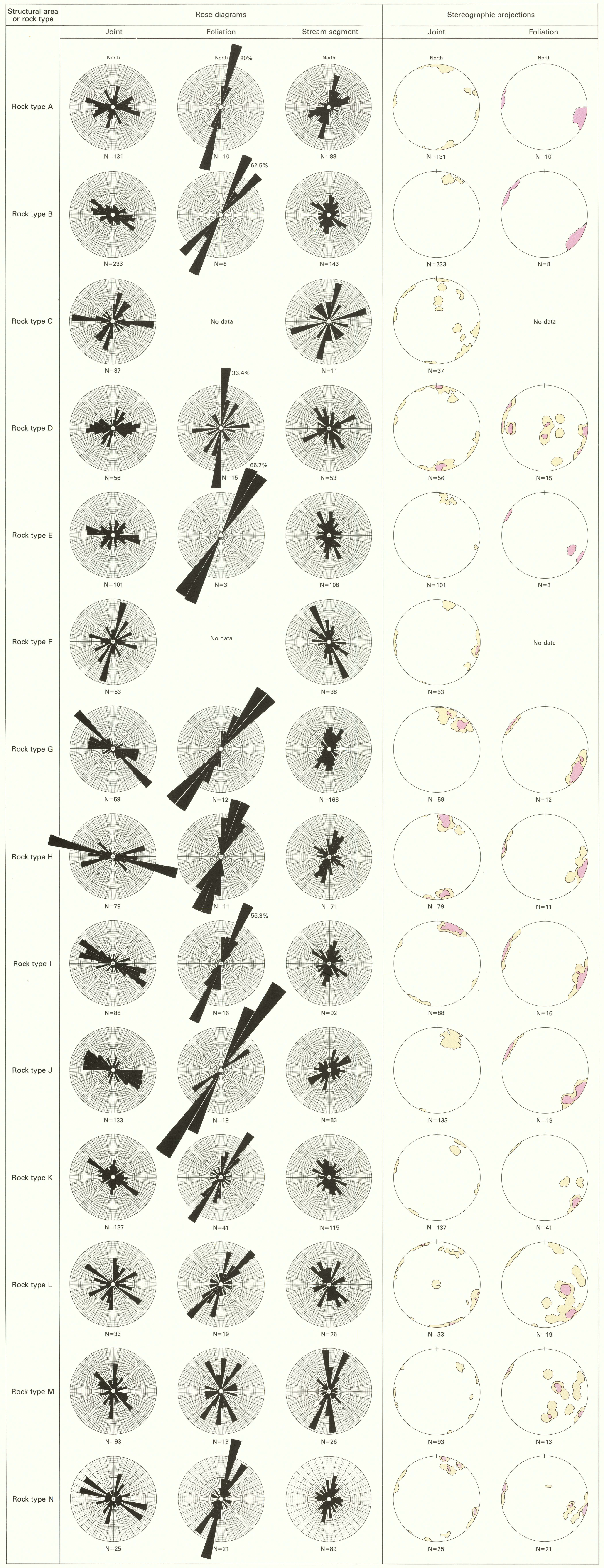


Figure 1.—Computer-generated rose diagrams and stereographic projections by structural area and rock type. Rose diagrams show trends and percentages of number of measurements in each 10° interval for joints, foliation, and stream segments; stereographic projections show poles to foliation and joint planes at a 5-percent contour interval. N=number of measurements.

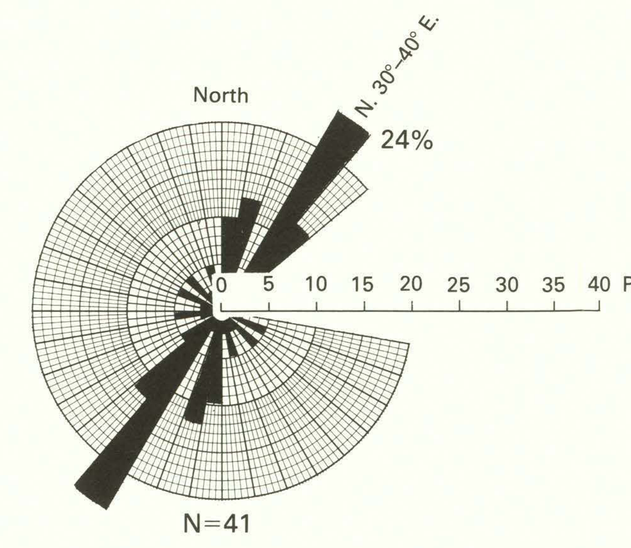
EXPLANATION

- **A** — Medium- to coarse-grained metamorphosed granite (Wier, 1977)
- **B** — Plagiogranitic granitoid and related rocks; quartz-rich meta-intrusive rocks (Pavlides, 1976, p. 6)
- **C** — Trondhjemitic granitoid rocks, allotriomorphic-granular, fine-grained, locally having granophyric texture (Pavlides, 1976, p. 4)
- **D** — Microcline granite gneiss, coarse-grained, well foliated (Pavlides, 1976, p. 4; 1980, p. 12–15)
- **E** — Metamorphosed mafic plutonic rocks, chiefly amphibolite and hornblendite (Pavlides, 1976, p. 6)
- **F** — Diamictite. Granite-like metasedimentary rocks that are massive, dark gray, nonstratified, and characterized by quartz lumps having granoblastic texture, and clasts of schist and gneiss randomly scattered in a micaceous quartz- and plagioclase-rich matrix (Pavlides, 1976, p. 7)
- **G** — Metasedimentary rocks, chiefly laminated quartzose schists (Wier, 1977)
- **H** — Mainly mafic metavolcanic rocks and small masses of metamorphosed ultramafic rocks, interlayered with phyllite, metasiltstone, and metagraywacke that are locally mylonitic (Wier, 1977)
- **I** — Schist and slate consisting mostly of fine-grained micaceous schist, green slate, slaty siltstone, and gritty to granule schist characterized by elongate quartz grains (Pavlides, 1976, p. 7)
- **J** — Chiefly metavolcanic rocks of felsic, intermediate, and mafic compositions; interlayered with lesser amounts of meta-epiclastic volcanic rocks and schist. Chopawamsic Formation of Pavlides (1976, p. 6–7)
- **K** — Black graphitic slate and phyllite to dark gray biotite-muscovite schist. In areas of increased metamorphism, occurs as fine- to medium-grained staurolitic schist and biotite-muscovite garnetiferous schist. Quantico Formation of Pavlides (1980)
- **L** — Impure quartzite occurring as thin discontinuous lenses of quartzose or feldspathic meta-arenites and metawackes within the Quantico Formation (K) and locally at its base (Pavlides, 1980)
- **M** — Hornblende-biotite quartzofeldspathic gneiss (Pavlides, 1976)
- **N** — Chiefly amphibolitic gneiss associated with conformable granitoid and pegmatoid rocks and small amounts of biotitic gneiss and schist. Ta River Metamorphic Suite of Pavlides (1980)
- **O** — Mesozoic sedimentary rocks, undivided
- **P** — Gneissoid and granitoid rocks; Po River Metamorphic Suite of Pavlides (1980)
- **g** — Small granitoid bodies intruding the major lithology; they are included in it for purposes of this study
- **CP** — Unconsolidated sediments: Coastal Plain deposits, terraces, alluvium, and upland gravels

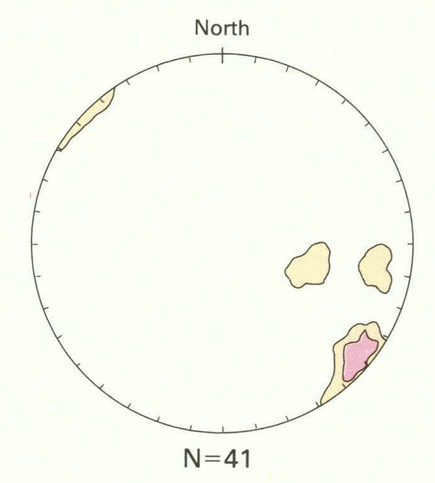
Note.—Commonly used geologic symbols are printed on the map jacket; a separately printed list is available on request from the U.S. Geological Survey.

III / IV — Structural area boundary—Areas I–IV defined by major rock types (see text)

Stream segment—Trend marked and measured for distances greater than 120 m (see text)



Rose diagram—Showing trend and percentage of number of measurements in 10° intervals. N=number of measurements. For some foliation rose diagrams, the percentage value is shown by the long arms that are not extended the appropriate length.



Stereographic projection — Contoured equal area plot showing poles to foliation and joint planes at 5-percent intervals. N=number of measurements

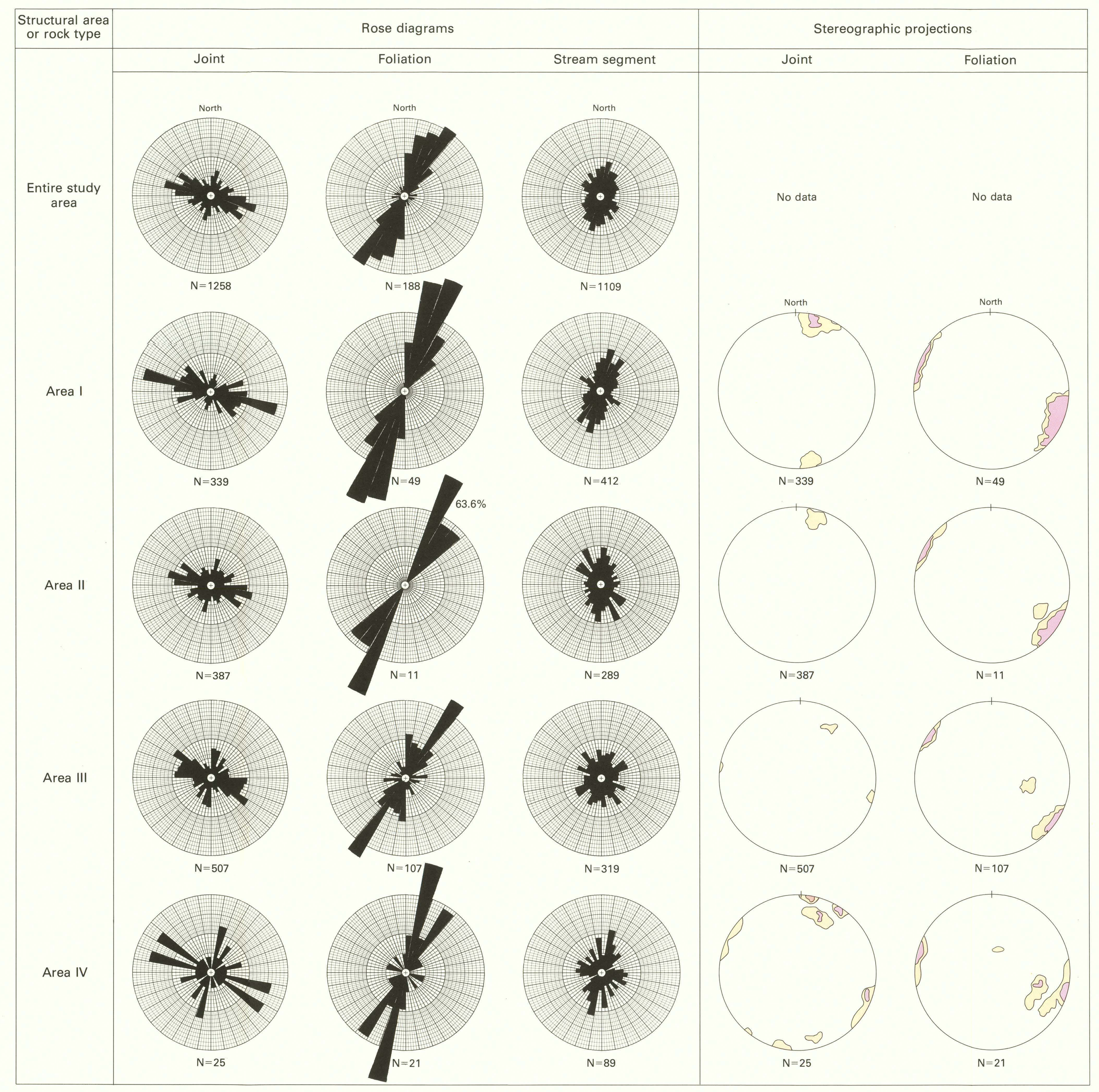
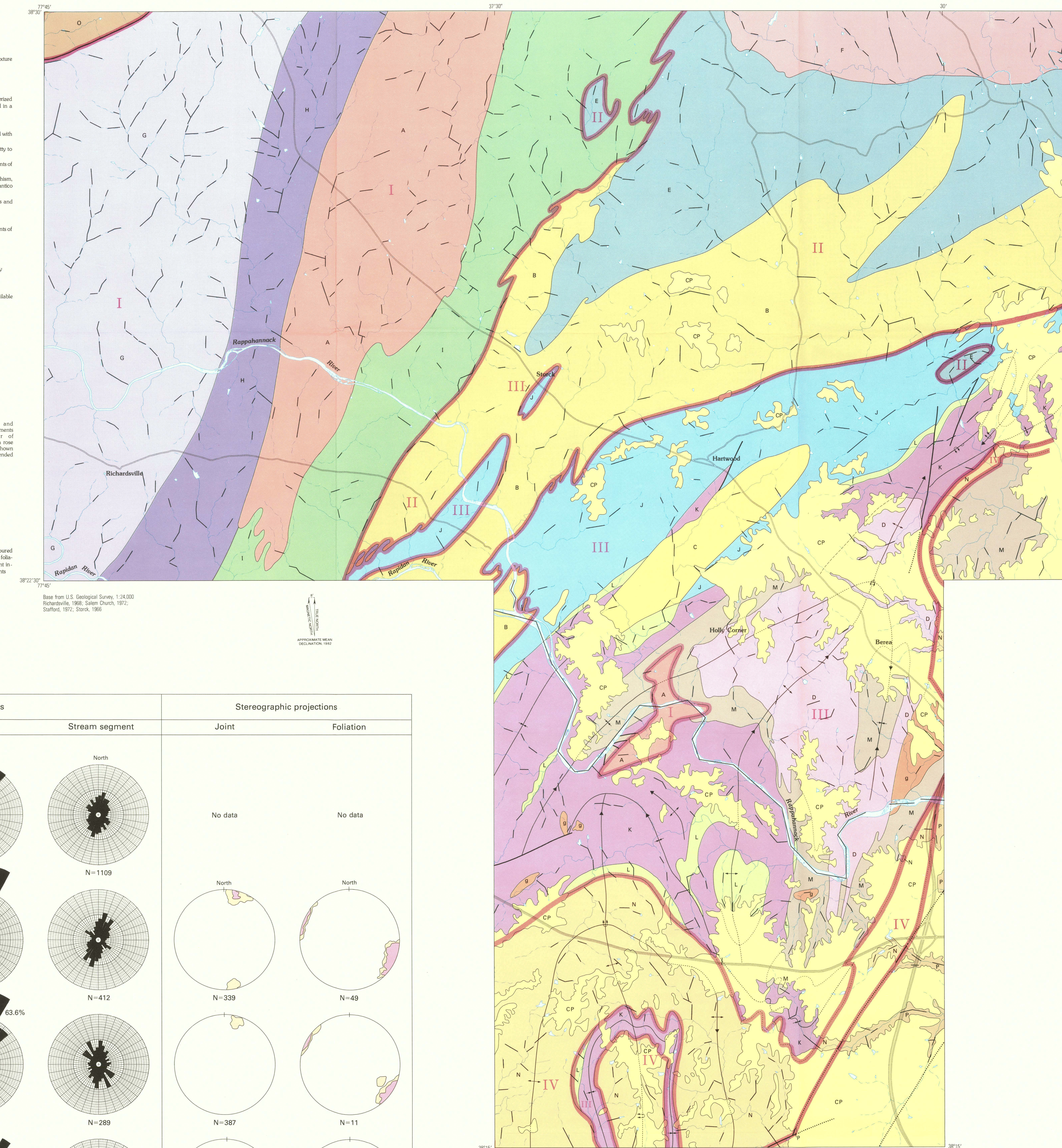


Figure 1.—Continued.



Base from U.S. Geological Survey, 1:24,000
Richardsville, 1968; Salem Church, 1972;
Stafford, 1972; Storck, 1966

8°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1982

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1982—G80234

Geology by Louis Pavlides, 1971–75;
and Karen Wier, 1974–76

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

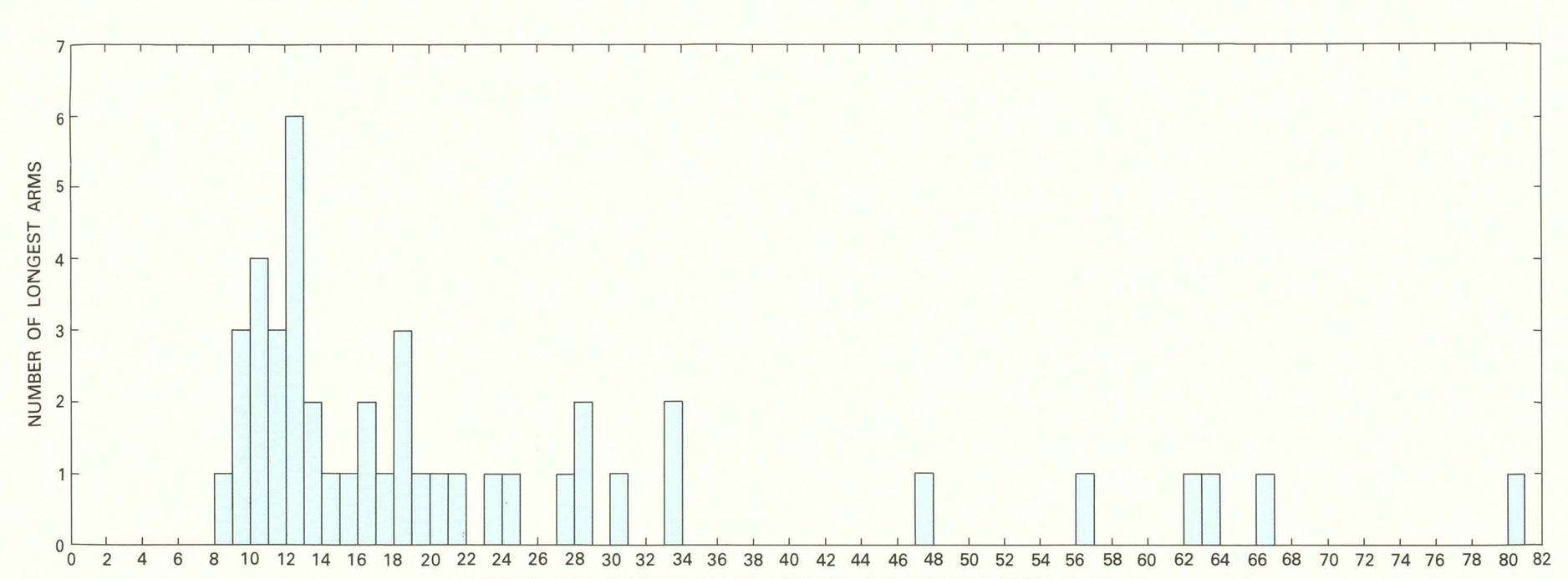


Figure 2.—Histogram of major trends from all rose diagrams plotted as cumulative number of trends in a given percentage.

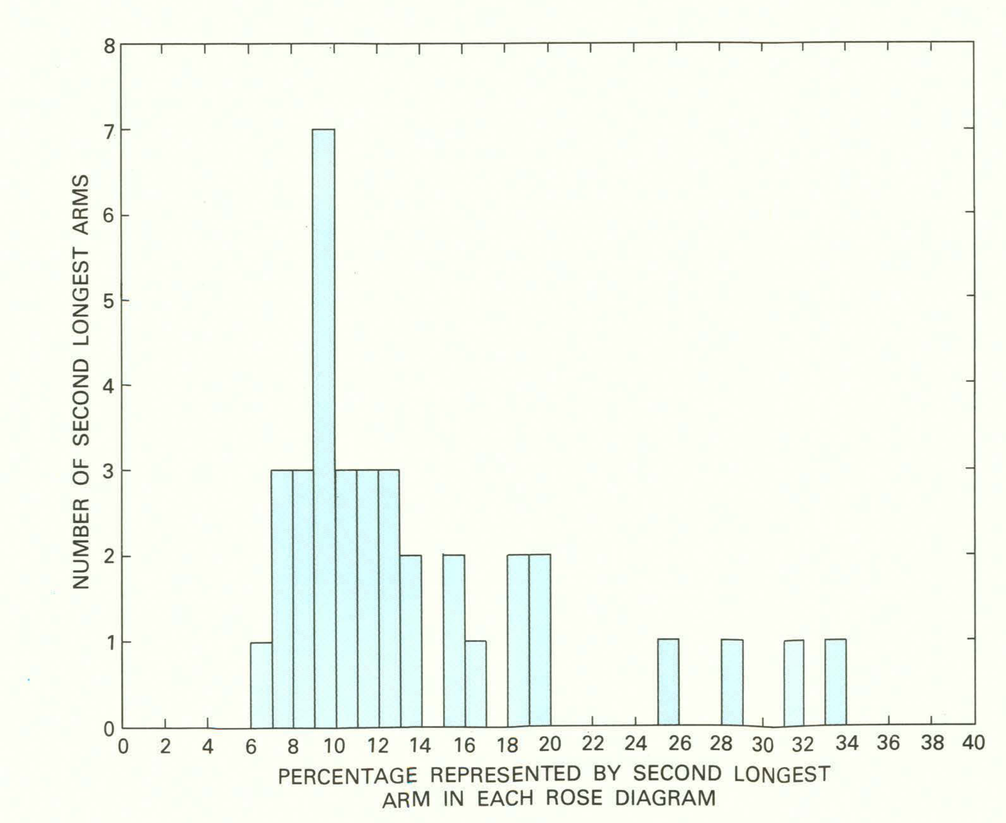
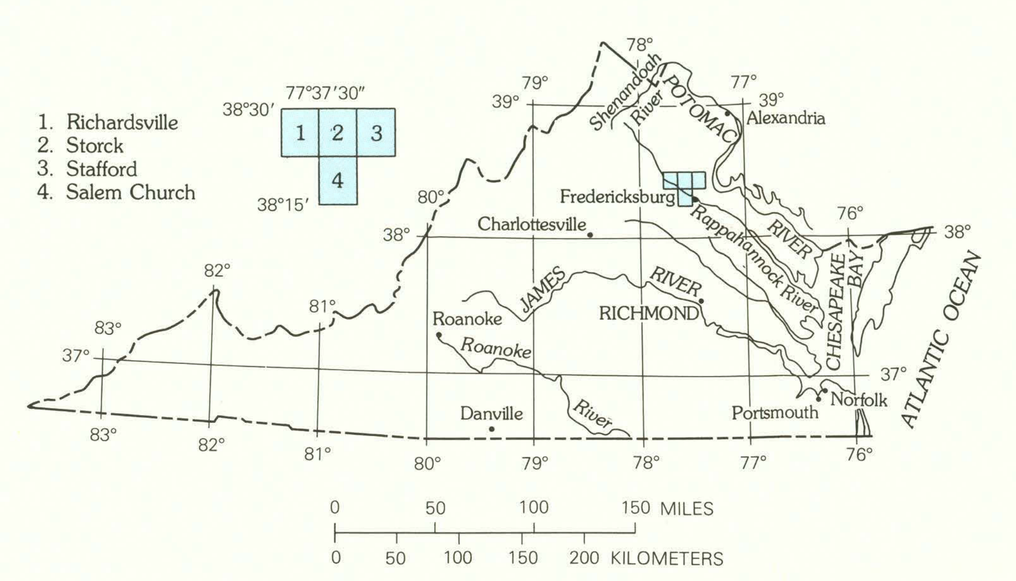


Figure 3.—Histogram of minor and major trends from all rose diagrams plotted as cumulative number of trends in a given percentage.



Index map of Virginia showing location of the four 7½-minute quadrangles composing the study area

Table 1.—Major and minor trends for joints and stream segments, and major trends for foliation for the entire area of study, Areas I–IV, and rock types A–N. See text for discussion

	Joint trends					Foliation trends			Stream segment trends				
	Major	Percentage of measurements	Minor	Percentage of measurements	Number of measurements	Major	Percentage of measurements	Number of measurements	Major	Percentage of measurements	Minor	Percentage of measurements	Number of measurements
Entire study area	N. 71°-80° W. N. 51°-60° W.	12 9.6	N. 10°-19° E. N. 70°-79° E.	6.5 6.0	1,258	N. 30°-39° E. N. 10°-19° E.	20.6 15.9	188	N. 10°-19° E.	9.1	N. 1°-10° W. N. 30°-39° E. N. 21°-30° W.	7.1 7.1 6.6	1,109
Area I	N. 71°-80° W. N. 70°-79° E. N. 41°-50° W.	17.7 8.8 8.8			339	N. 20°-29° E. N. 0°-9° E. N. 40°-49° E.	30.6 12.2 10.2	49	N. 10°-19° E. N. 30°-39° E.	10.9 9.7	N. 1°-10° W. N. 51°-60° W.	7.3 6.1	412
II	N. 71°-80° W. N. 51°-60° W.	11.1 9.1	N. 10°-19° E. N. 60°-69° E.	7.0 6.5	387	N. 20°-29° E. N. 40°-49° E.	63.6 18.2	11	N. 21°-30° W. N. 0°-9° E.	9.8 9.5	N. 41°-60° W. N. 30°-39° E.	7.4 6.3	289
III	N. 51°-60° W. N. 81°-90° W.	12.3 9.4	N. 10°-19° E. N. 30°-39° E.	7.3 6.2	507	N. 30°-39° E. N. 0°-9° E.	23.4 11.2	107	N. 31°-40° W.	8.0	N. 20°-29° E. N. 50°-69° E. N. 1°-10° W. N. 61°-70° W.	7.3 7.3 7.3 6.5	319
IV	N. 51°-60° W. N. 71°-80° W. N. 10°-19° E. N. 30°-39° E. N. 70°-79° E.	16.0 16.0 12.0 8.0 8.0			25	N. 10°-19° E. N. 30°-39° E.	28.6 19.0	21	N. 10°-19° E. N. 1°-10° W.	11.2 9.0	N. 61°-70° W. N. 81°-90° W. N. 40°-49° E. N. 21°-30° W.	6.7 6.7 6.7 6.7	89
Rock type A	N. 71°-80° W. N. 10°-19° E. N. 60°-69° E. N. 21°-30° W.	13.3 9.9 9.9 8.8			131	N. 10°-19° E.	80.0	10	N. 10°-19° E. N. 60°-69° E. N. 30°-39° E.	15.1 10.5 8.1			88
B	N. 51°-60° W. N. 71°-80° W.	12.1 10.3	N. 60°-69° E.	6.5	233	N. 20°-29° E. N. 40°-49° E.	62.5 25.0	8	N. 51°-60° W. N. 0°-9° E.	9.8 9.1	N. 30°-39° E.	7.0	143
C	N. 81°-90° W. N. 10°-19° E. N. 30°-49° E.	18.9 13.5 10.8			37	No data			N. 10°-19° E. N. 70°-79° E.	18.2 18.2	[1]		11
D	N. 80°-89° E. N. 10°-19° E. N. 30°-39° E. N. 71°-80° W.	12.5 8.9 8.9 8.9	N. 51°-60° W.	7.1	56	N. 0°-9° E.[1] N. 30°-39° E. N. 80°-89° E.	33.3 13.3 13.3	15	N. 60°-69° E. N. 31°-40° W. N. 11°-20° W.	13.2 11.3 9.4	N. 10°-19° E.	7.5	53
E	N. 71°-80° W.	12.9	N. 40°-49° E. N. 10°-19° E. N. 51°-60° W.	7.9 6.9 6.9	101	N. 20°-29° E.	66.7	3	N. 21°-30° W. N. 0°-9° E.	12.0 11.1	N. 41°-50° W. N. 30°-39° E. N. 70°-79° E.	7.4 6.5 6.3	108
F	N. 10°-19° E. N. 30°-39° E. N. 71°-80° W. N. 60°-69° E.	18.9 11.3 11.3 9.4	N. 21°-30° W.	7.5	53	No data			N. 21°-30° W. N. 51°-60° W. N. 1°-10° W.	18.4 10.5 10.5	N. 81°-90° W. N. 10°-19° E.	7.9 7.9	38
G	N. 41°-50° W. N. 61°-90° W.	23.7 11.9			59	N. 30°-49° E. N. 0°-19° E.	33.3 8.3	12	N. 30°-39° E. N. 0°-9° E.	10.8 10.2	N. 10°-19° W.	7.8	166
H	N. 71°-80° W. N. 70°-79° E. N. 41°-50° W.	30.4 15.2 8.9			79	N. 10°-29° E. N. 1°-10° W.	27.3 9.1	11	N. 10°-19° E. N. 30°-39° E. N. 1°-10° W. N. 51°-60° W.	12.7 11.3 8.5 8.5			71
I	N. 51°-60° W. N. 71°-80° W. N. 70°-79° E.	18.2 15.9 8.0			88	N. 20°-29° E.[1] N. 0°-9° E.	56.3 12.5	16	N. 10°-19° E. N. 51°-60° W.	10.9 9.8	N. 30°-39° E. N. 31°-40° W. N. 50°-59° E. N. 70°-79° E. N. 1°-10° W.	7.6 7.6 6.5 6.5 6.5	92
J	N. 51°-70° W. N. 81°-90° W.	14.6 13.8	N. 10°-19° E. N. 21°-30° W.	6.2 6.2	133	N. 30°-39° E. N. 50°-59° E.	47.4 15.8	19	N. 50°-69° E. N. 10°-19° E.	10.8 9.6	N. 30°-39° E. N. 81°-90° W. N. 51°-60° W.	7.2 7.2 6.0	83
K	N. 51°-60° W. N. 0°-9° E.	13.9 8.0	N. 81°-90° W.	6.6	137	N. 30°-39° E. N. 10°-19° E.	24.4 12.2	41	N. 31°-40° W. N. 11°-20° W. N. 61°-70° W.	9.6 8.7 8.7	N. 20°-29° E. N. 50°-59° E.	7.0 7.0	115
L	N. 51°-60° W. N. 0°-9° E. N. 60°-69° E. N. 30°-39° E. N. 71°-80° W.	15.2 12.1 12.1 9.1 9.1			33	N. 40°-49° E. N. 10°-19° E.	21.1 15.8	19	N. 20°-29° E. N. 21°-30° W. N. 41°-50° W.	11.5 11.5 11.5	N. 60°-79° E. N. 10° W.-9° E.	7.7 7.7	26
M	N. 0°-9° E. N. 41°-50° W.	12.9 11.8	N. 30°-39° E. N. 61°-70° W. N. 70°-79° E.	7.5 7.5 6.5	93	N. 0°-9° E.[1] N. 30°-39° E. N. 21°-30° W.	15.4 15.4 15.4	13	N. 20°-29° E. N. 1°-10° W.	19.2 19.2	N. 41°-50° W.	7.7	26
N	N. 51°-60° W. N. 71°-80° W. N. 10°-19° E. N. 30°-39° E. N. 70°-79° E.	16.0 16.0 12.0 8.0 8.0			25	N. 10°-19° E. N. 30°-39° E.	28.6 19.0	21	N. 10°-19° E. N. 1°-10° W.	11.2 9.0	N. 61°-70° W. N. 81°-0° W. N. 40°-49° E. N. 21°-30° W.	6.7 6.7 6.7 6.7	89

[1]Minor trends not considered because of small number of measurements.

STREAM CONTROL BY FOLIATION, JOINTS, AND FOLDS IN THE RAPPAHANNOCK RIVER DRAINAGE SYSTEM NEAR FREDERICKSBURG, VIRGINIA

By
S. L. Cranford, A. R. Bobyarchick, Louis Pavlides, and Karen Wier

1982

INTRODUCTION

In connection with a detailed geologic mapping program in the Piedmont of northeast Virginia, attitudes of foliations and joint surfaces in the crystalline rocks were measured. This report discusses possible relationships between stream orientations and these planar structures in rocks in part of the Rappahannock River drainage basin. In order to evaluate the influence these structures have in controlling stream orientations, linear stream segment trends were systematically compared to foliation and joint trends. The purpose of the study was to determine whether foliations or joints influence drainage in this area and the relative importance of these planar structures in drainage control. Highest order drainage of the river is examined in relation to folds in bedrock.

The area studied is located near Fredericksburg, Va. It consists of parts of the Richardsville, Storck, Stafford, and Salem Church 7½-min. quadrangles (see index map), through which the Rappahannock River flows to the Fall Line at Fredericksburg. In the study area, the river flows southeastward through the gently rolling, subdued terrain of the Piedmont. Coastal Plain sediments cover the Piedmont on the eastern edge of the area, a flat to gently rolling plateau incised by a dendritic drainage pattern. However the area covered by Coastal Plain sediments is excluded from this study because it was not mapped extensively.

Geologic field mapping was done by Karen Wier in the Richardsville quadrangle (Wier, 1977) and Louis Pavlides in the Storck, Stafford, and Salem Church quadrangles (Pavlides, 1976, 1980). They collected data on foliation, joints, and saprolite. Their geologic maps provide the base for this report.

Data collected by Karen Wier and Louis Pavlides were appropriated for use in this study and were not originally intended for comparison with the area's drainage. Therefore, interpretations of the data, such as joint density analysis, and more rigorous statistical tests were not made because of the inconsistency of measurement techniques.

GEOLOGY

For the purposes of this report, Piedmont metamorphic rock units have been designated alphabetically A through N. Triassic rocks in the northwestern part of the Richardsville quadrangle (rock type O), biotite gneiss of the Po River Metamorphic Suite (Pavlides, 1980) in the Salem Church quadrangle (rock type P), and unconsolidated sediments in the eastern part of the area (rock type CP) are shown on the map, but not included as part of this study. The order of letter designations bears no relationship to stratigraphic or chronologic sequences. However, the major metaplutonic units, designated A–E, are generally listed alphabetically, west to east. The other major rock units, G–N, form another general, west to east progression. Minor granitoid plutons (g) are considered too small in area to have an influence in the analysis in this report and are treated as part of the major lithology they intrude.

A preliminary geologic map of the Richardsville quadrangle has been published by Wier (1977) and the rest of the region has been described by Pavlides (1976, 1980) and Pavlides and others (1974). Only a brief description of the major geologic features, therefore, will be given in this report.

The schist, gneiss, amphibolite, and granitoid rocks that comprise the Piedmont terrane of the region have undergone a complex history of polydeformation and polymetamorphism. In general, metasedimentary rock types G, H, and I are in stratigraphic order (oldest to youngest) from west to east. Rock type J is a metavolcanic unit (Pavlides, 1976) stratigraphically above rock type I. Rock type N, an amphibolitic unit, and rock type M, a hornblende-biotite gneiss, are considered eastern, more highly metamorphosed volcaniclastic facies of rock type J (Pavlides, 1980). The youngest stratigraphic unit, rock type K, a schist, and its lenticular quartzitic members, rock type L, stratigraphically overlie rock types J and N.

The rocks of the region have been folded at least three times. Deformation by superimposed folding has formed a type II interference fold in the Salem Church quadrangle (Pavlides, 1976, p. 18–19). This refolded fold consists of a synform which has been folded about a later northeast-plunging antiform.

Most faults in the study area are not shown on the map; one is a major fault that separates rock types G and H (Wier, 1977). Minor faults also occur (Pavlides, 1976, fig. 2) and several appear on the map.

PLANAR STRUCTURES

Foliation.—As used in this report, foliation applies to planar elements, cleavage and schistosity, of metamorphic-tectonic origin in rocks. All of the major rock types discussed in this report are foliated. They have several foliations as a result of polydeformation and metamorphism. The most prevalent foliation is a steeply dipping, northeast-striking schistosity. Rocks in the area of the refolded fold also have a later, northeast-trending foliation, axial planar to the latest folds (Pavlides, 1976, p. 17–20).

Joints.—Joints are common in all types of rocks and may be found in unconsolidated sediments (Langer and Obermeier, 1978, p. 7–10). Because they are so widespread and are not restricted to any one rock type, they probably have more than one origin (Price, 1966, p. 110). They probably originated through tensional or compressional stress and commonly are related genetically to folds, faults, warps, intrusions, and other tectonic elements (Hills, 1963, p. 150). But their development in relation to tectonic processes is not well understood.

A comprehensive genetic analysis of joints requires a detailed knowledge of the structural history of the region. Due to the polydeformed nature of this part of the Piedmont, such a detailed history is not available. Therefore, joints are considered to be planar surfaces of unspecified, tectonic origin.

Joints are systematic in that they comprise more than one generally recognizable set (see fig. 1, rose diagram showing joint trends for entire study area). Joint densities range from about 0.3 joints per meter (0.1 joints per foot) to about 30 joints per meter (10 joints per foot). Although horizontal joints occur, they are sparse. Several generations of joints may be superimposed on the area, as can be deduced from the large scatter of trends in the rose diagram of all the joint trends. However, it is difficult to determine the number of generations or the precise history of joint development.

DRAINAGE

The Rappahannock River flows southeastward from its source in the Blue Ridge mountains to the tide water of the Chesapeake Bay, a total distance 225 km. Its northeast-oriented tributaries form a dendritic drainage pattern throughout the study area. The river channel meanders and varies in width; the main channel widens where the Rapidan River enters the Rappahannock at the northwest corner of the Salem Church quadrangle. Where resistant rock types B, D, J, and M are traversed by the river, a series of rapids occurs. Scarps along the Rappahannock are steep in places, reaching a maximum of 61 m in height. The river is entrenched 30–61 m below the Piedmont plateau. Large meanders of the highest order drainage in the study area are present in the Salem Church quadrangle.

Bedrock crops out in the main channel of the river and in the lower portions of its tributaries. Weathered rock is encountered further upstream along the tributaries. The lowest order tributaries flow on saprolite.

METHODS

Varying characteristics of different rocks affect joint and drainage development, therefore, the study area has been delineated by rock type. Different rock types have unequal resistance to weathering and erosion. Streams tend to become oriented to the distribution of weaker rocks or to weaker parts of rocks, such as along foliation or potential joints. Massive crystalline rocks weather primarily along joint faces, and other rocks, such as schist, weather primarily along the foliation. The degree to which each rock type has been weathered and the nature of the weathering product will also affect adjustment of the drainage. According to Hack (1978, p. 4) drainage of the Appalachians has become closely adjusted to rock type, although many areas of deviation persist. Thus, rock types having planar structure trends were chosen as data sets for comparison with stream segment trends in order to evaluate differences in drainage orientation brought about by the varying characteristics of different rocks.

Because folds or faults may generate new joint sets or reorient older ones, bedrock structure is important in a consideration of joint development. Four broad structural areas are defined based on the local geology: Area I-A, G, H, I; Area II-B, E, F; Area III-C, D, J, K, L, M; and Area IV-N. These areas are defined in relation to an antiformal structure in the Salem Church quadrangle. Area I consists of a northeast-trending belt of rocks. Area II consists of northeast-trending and more irregularly trending rocks, and lies on the northern edge of the antiformal structure. Area III encompasses the northeastern closure of the antiform, and Area IV lies along the axis of the antiform. These structural areas, outlined in red on the map, were chosen to compare possible differences in foliation and joint attitudes caused by the folding.

In order to compare the drainage patterns with foliation and joint trends, linear segments were marked off along all streams on 1:24,000 scale drainage maps for each quadrangle. Only those segments over 0.5 cm in length or 120 m at the map scale were considered, and are shown on this composite map at 1:48,000 scale.

The strikes and dips of foliations were measured in the field. Then representative measurements were chosen by visual inspection of these field data compiled on 1:24,000 scale maps. This produced a data set of average strikes and dips which gave a general picture of major foliation attitudes for comparison with stream segment data (see fig. 1). The strikes and dips of as many as three joint sets at each outcrop were measured in the field wherever possible. Approximate joint density was recorded where determinable but was excluded from the final computer analysis.

Foliation and joint attitudes and stream segment trends were stored in computer files and manipulated to test the relationship between the planar rock structures and the stream segments. The data base consisted of 188 representative foliation measurements, 1,258 joint measurements, and 1,109 stream segments (see table 1). Data sets used to create separate files for analysis were as follows: (1) rock types, A–N, (2) Areas, I–IV, and (3) total area of study. Rose diagrams were plotted for each of these sets using a Fortran program written for this purpose. Another Fortran program written by Jeran and Mashey (1970), modified by M. H. Podwysocki for interactive use on the Honeywell MULTICS[1] system, was used to plot stereographic projections of foliations and joints. Contoured equal area plots of poles to foliation and joint planes were produced for each category using a 5-percent contour interval. The rose diagrams and stereographic projections obtained are shown in figure 1.

DISCUSSION OF DATA

Major and minor trends for stream segments and joints and major trends for foliation for the entire area of study, Areas I–IV, and rock types A–N are listed in table 1. Minor foliation trends are not included because the small number of selected measurements within each area or rock type produced minor trends only in rock types D, I, and M. Trends were classified as major or minor based on the distribution of the number of maximum percentages of measurements in all rose diagrams (see figs. 2 and 3). These histograms show distributions of the largest and second largest percentages of any given rose diagram. The maximum percentages are greater than or equal to 8 percent (fig. 2), therefore, major trends are classified as greater than or equal to 8 percent. The second largest percentages are greater than or equal to 6 percent (fig. 3), therefore, minor trends are classified as greater than or equal to 6 percent and less than 8 percent. The separation between any two trends listed for the same diagram is at least 10 degrees.

The predominant stream segment trend is northeast. Exceptions are rock types E, F, K, and L in which the predominant stream segment trend is northwest. In rock types A, J, and N streams are primarily alined along the northeast trend of the regional foliation. Also major stream segment trends in these rocks coincide with either major or minor joint trends.

Data for most rock types show joints trending northwest. Exceptions to this are rock types F, K, L, and M (see accompanying diagrams) where joints trend more nearly north or northeast. Locally, major or minor stream segment trends approximately parallel joint trends. The best example of this is a trend at N. 10°–19° E. for which stream segments correspond to joints in six different rock types (A, C, D, F, J, and N). The rose diagrams for rock type C show a correspondence between the stream segment trends and the joint trends. The diagram for the stream segment trends, however, is based on a small sample size (11 segments). A major stream segment and joint trend for rock type B also coincide. Visual inspection of field maps shows alinement of streams with generally northwest trending joints for 6 percent of the total number of streams in the area, or 23 percent of the total number of streams along which measurements were made.

Stereographic diagrams show that foliations in the area are consistently northeast-trending and commonly steeply dipping. Rock types A, B, E, G, H, I, J, and K have steeply dipping, northeast-striking foliations. The exceptions are rock types D, L, M, and N which show a wider dip range. Of 10 rose diagrams showing foliation trends (B and E deleted due to small sample size), major stream segment trends coincide with foliation trends in seven rock types (A, G, H, I, J, M, and N). Major stream segment trends follow a N. 10°–19° E. foliation trend in rock types A, H, and N. There are no foliation data for rock types C and F.

Rose diagrams and stereographic projections for the four structural areas do not indicate variations in foliation and joint attitudes with folding. The attitudes of these planar structures do not change noticeably from Area I to Area IV in these plots. Nor do the rose diagrams suggest varying stream orientation with folding across these areas. The trend of the stream segments from these plots is generally northeast or north. The trend of the foliation is consistently northeast; the trends of the joints are northwest.

CONCLUSION

Most tributaries to the Rappahannock River in the Richardsville, Storck, Stafford, and Salem Church quadrangles follow the prevalent northeast-trending foliation in the area. Joints are of secondary importance, locally controlling northwest flowing, bedrock incising streams. The course of the Rappahannock River is modified by large folds in the Salem Church quadrangle where the channel is deflected around more resistant rocks in two synforms of a refolded fold.

Strike of the stream segments and foliations is generally northeast, whereas joints strike northwest. In a comparison of major stream segment trends with foliation trends in 10 rose diagrams, 7 diagrams indicate that streams follow the northeast-trending foliation (rose diagrams for rock types A, G, H, I, J, M, and N). Foliated rocks tend to be less resistant to erosion and to weathering than massive, crystalline rocks. Foliation may act as a control on drainage because it provides a path of weakness for erosion and weathering, and least resistance for the development of stream channels. Some stream segment trends coincide with major and minor joint trends, as well as major foliation trends suggesting that joints may locally reinforce foliation in controlling stream orientation.

Locally, where bedrock crops out along stream channels, the direction of stream flow can be related visually to direction of joint trends. Inspection of field maps shows that about 23 percent of all measured streams follow the northwest trend of the joints. This relationship, because of its localized nature, is not apparent from the analyses in this study. Apparently, it is obscured by the measurements used in different groupings. The saprolite in much of the upland areas also may negate the influence that foliation and joints have upon the drainage in these areas. Whereas, joints provide a means of ground-water circulation in crystalline rocks and foliation provides a direction of weakness for erosion, saprolite acts as a good reservoir for ground-water storage (Cleaves, Fisher, and Bricker, 1974, p. 439). Streams in the part of the area covered by saprolite may not be alined along foliation and joint trends. The drainage is no longer confined to natural channels, but may be dispersed throughout the porous, weathered rock.

Large meanders of the Rappahannock in the Salem Church quadrangle, compared to the refolded fold, suggest structural control of the river course. The river flows southeastward as it enters the northwest corner of the quadrangle until it reaches the northwest limb of the interference fold. Here the river bends convex to the southwest around a northeast-plunging synform. The course is slightly convex to the northeast where it meanders across the axial region of the antiform before becoming convex to the southwest again where it crosses another northeast-plunging synform. Where the river crosses the Fall Line into the Coastal Plain at Fredericksburg, it once again flows to the southeast (Pavlides, 1976, fig. 2). Only the highest order drainage shows obvious control by folding. Structural influence is not reflected by the rose diagrams and stereographic projections for the four areas. The abundance of northeast-trending foliations in the data obscures the effect of folding and is thus not seen in the four area foliation plots. The type II interference fold, however, does control the river channel just as the foliation and, to a lesser degree, the joints control the tributaries.

[1]The use of commercial trade names is for descriptive purposes only and does not constitute endorsement of these products by the U.S. Geological Survey.

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