A PALEOCURRENT STUDY OF THE OUTER CONGLOMERATE ALONG THE MONTREAL RIVER, GOGEBIC COUNTY, MICHIGAN

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Clarence Star

1959

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ALONG THE MONTREAL RIVER, GOGEBIC

COUNTY, MICHIGAN

By

CLARENCE STAR

AN ABSTRACT

Submitted to the College of Science and Arts of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
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MASTER OF SCIENCE

Department of Geology

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Approved ____

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The Outer Conglomerate Study was made in order to define the source area and direction of sedimentation.

The field study consisted of mapping exposures and collecting samples along the river. Laboratory work consisted of pebble orientation and identification. Petrographic work of the matrix and associated sand lenses was also accomplished.

The composition of the pebbles and matrix indicates a source from the Keweenawan series and the Animikie series. Petrofabric studies indicate a source direction from the southeast.

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I wish to express my appreciation to Dr. J. W. Trow for his suggestions as to the field work procedure and for his guidance during the course of this work.

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MAP

Montreal River Area . . . . Pocket

INTRODUCTION

The Outer Conglomerate Paleocurrent Study was made in conjunction with a similar thesis problem submitted by Gordon Smale in 1958, who studied the Freda formation.

The Montreal River section is located approximately 16 miles north and west of Ironwood, Michigan. Geographically the area is in the Lake Superior Lowland Province. The area studied is located in Iron County, Wisconsin and Gogebic County, Michigan, as the Montreal River provides the geographic boundary between the states in the locale. Sections 19, 20, 29, and 30 T. 47N. R. 1E, in Wisconsin, and sections 13, 23, 24, and 26 T. 48N. R. 49W., in Michigan, were studied. The area was limited to the northern contact with the Nonesuch shale and limited to the southern contact with the Eagle River Group (Figure 1 and map).

A three-week field study was made in the summer of 1958 in order to obtain samples and to record sedimentary features of the Outer conglomerate.

Laboratory work consisted of petrofabric, petrographic and sedimentary analyses.

The Outer conglomerate forms a prominent ridge in the area. Along the river it forms cliffs 100 to 150 feet high. The river and region are youthful in their geomorphic cycle. A few intermittent streams dissect the area and flow not into the Montreal River, but directly into Lake Superior. The elevation is in excess of 1100 feet. The approximate mean lake elevation is 600 feet giving a total relief in the area of 500 feet.

Wisconsin State Highway 122 and Iron County Highway B give ready access to the area. Two dams and two bridges are located along the river. One is about one half mile upstream and the other is downstream one and one half miles from the Outer conglomerate.

Most of the foliage is second growth aspen and birch with the exception of a few virgin white pines which were not removed because of the inaccessibility of the area. Underbrush is present but not prominent.

The climate is of a humid continental classification, with an average annual rainfall of 36.79 inches. Temperatures vary widely but the mean for January is 14.5° and for July is 68.6°.

Previous work by Irving in 1883, consisted mainly of a regional study during the summers of 1873, 1876, and 1877 with accompanying petrographic work.

Lane in the early 1900's corroborated most of Irving's work, but he made some changes in stratigraphy and structural interpretation.

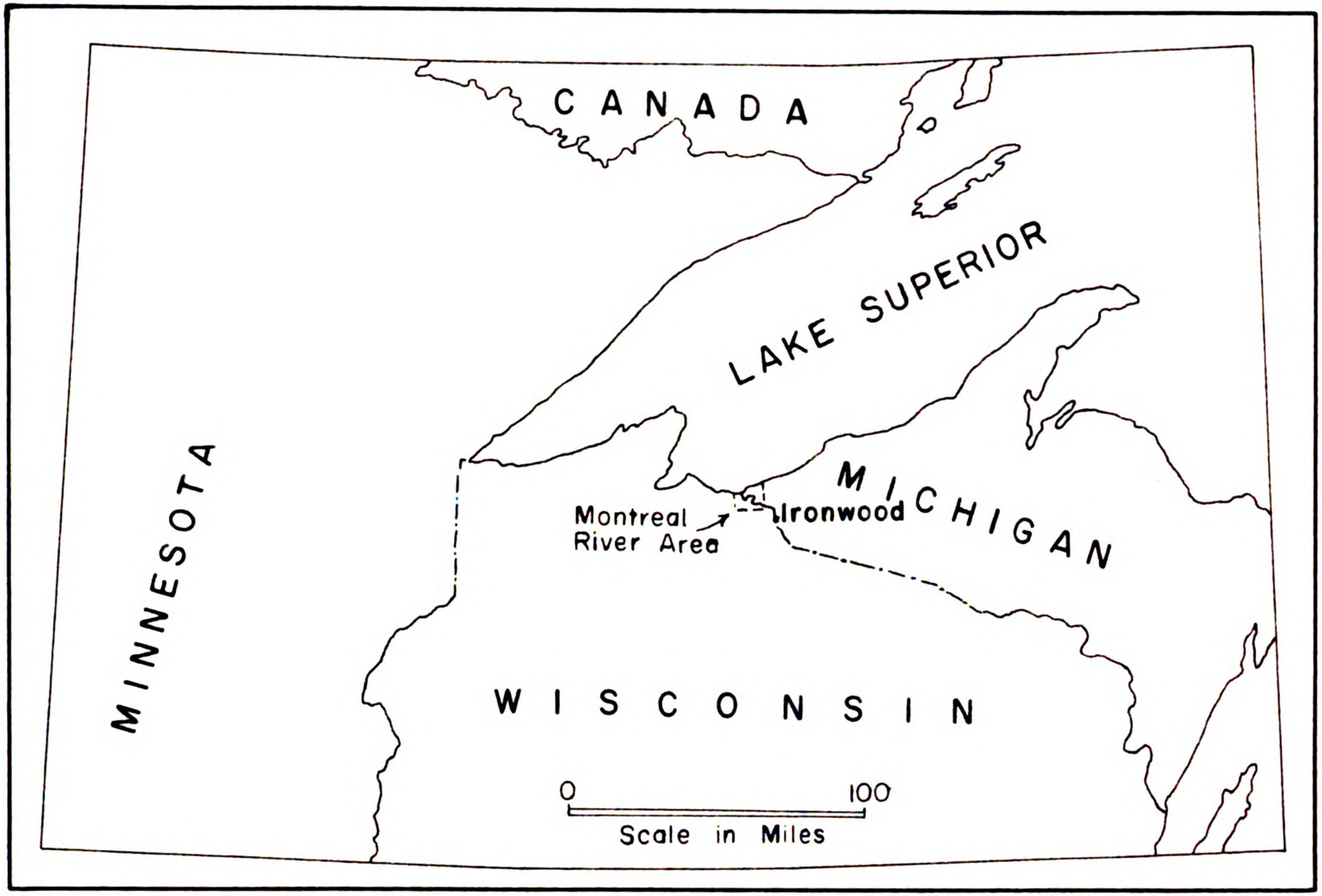

CANADA
LAKE SUPERIOR
MINNESOTA
MICHIGAN
Ironwood
Montreal River Area
WISCONSIN
0
100
Scale in Miles

Figure 1

Thwaites in 1912 mentions the exposures of Keweenawan rocks along the Montreal River, but it is doubtful whether he studied the area at this time.

There has been no extensive published study of the Montreal River area following Lane's work. The Keweenawan strata were studied in other areas, but as for the Montreal River area one is referred to Irving or Lane.

Gordon in 1906 did extensive field work on the Black River which is approximately 15 miles east of the Montreal River. He found the Outer conglomerate to be dominantly felsitic and 5,000 feet thick.

STRATIGRAPHY

The Montreal River area traverses a column from the Lower Precambrian, Archean Keewatin series, to the Upper Precambrian, Upper Keweenawan series, the latter being exposed near the mouth of the Montreal River.

The exposed Keweenawan rocks constitute an area of approximately 15,000 square miles within a total area of 41,000 square miles (Irving, 1911). The region of exposure extends from 120 miles northwest of Lake Superior, southwest to St. Paul and vicinity, within 12 miles of the south shore of Lake Superior, and on islands and the mainland at the extreme east end of the lake.

Most authors have divided the Keweenawan into three divisions. The lower division comprises conglomerates, sandstones, dolomitic sandstones, shales and marls. The middle division is comprised of extrusive and intrusive igneous rocks with interbedded sandstones and conglomerates. The upper Keweenawan contains conglomerates, shales and sandstones.

Following is a generalized column for the Montreal River area (modified after Butler and Burbank, 1929).

Precambrian

Upper Precambrian (Algonkian)

Keweenawan		
	Upper	Freda sandstone Nonesuch shale Outer conglomerate
	Middle	Eagle River group Ashbed group Central Mine group
	Lower	Bohemian Range group

----------- Unconformity ----------------

Middle Precambrian (Algonkian)

Animikie series (Huronian)		
	Upper	Tyler Ironwood iron formation Palms slate quartzite
	Lower	Bad River dolomite

The Upper Precambrian Lower Keweenawan lies directly above the Middle Precambrian Tyler slate. The lower Keweenawan consists of conglomerates, arkoses and quartzites north of Bessemer, Michigan, and a few miles west of the state boundary. The aggregate thickness is not over 100 feet at the most. The conglomerate contains pebbles of quartz, quartzite, slate and granular iron formation.

The middle Keweenawan is a period of combined igneous and sedimentary activity. The deposition of sediments characteristic of the lower Keweenawan was interrupted by the outpouring of basic lavas. The source was probably from the north as indicated by the slant of the pipe amygdules observed in some flows. There is an alternation of lavas and sediments indicating intermittent vulcanism. The individual flows vary in thickness from a few feet to 100 or more feet. The combined thickness probably exceeds 20,000 feet along the Montreal River.

The igneous rocks include basic, intermediate and acidic varieties with the basic varieties dominating. The rock types found are gabbro, basalt, diorite, anorthosite, rhyolite, granite, and syenite, plus varieties of these (Irving, 1883).

The sedimentary rocks of the middle Keweenawan are dominantly conglomerates, sandstones and a fewshales. The coarse detritus of the conglomerates is largely felsitic.

The upper Keweenawan is comprised of the Outer conglomerate at the base, above which is found the Nonesuch shale and then the Freda sandstone.

The Nonesuch shale makes a sharp contact with the Outer conglomerate. Within the Montreal River area it is found to be approximately 300 feet thick. This formation is chiefly shale although it has interstratified sandstone layers. Here is found a change in the character of the material of the Keweenawan sediments. The older material was largely acidic, however the material in the Nonesuch sands is dominantly basic igneous rocks.

While the contact between the Outer conglomerate and the Nonesuch shale is sharp, the contact between the Nonesuch shale and Freda sandstone is gradational.

The Freda sandstone is the highest stratigraphic formation, in the Keweenawan, exposed along the Montreal River. Irving estimates that the thickness exposed exceeds 12,000 feet. The characteristic feature of the sandstone is that quartz is subordinate and the detritus is dominantly from basic igneous rocks.

The most complete section of the Upper Keweenawan has been studied by Thwaites (1912). This section is located west of the Montreal River area. Following is the section that he gives:

	Feet
Upper Keweenawan	
Bayfield group (Jacobsville of Michigan)	
Chequamegon sandstone	1,000
Devils Island sandstone	300
Orienta sandstone	3,000
Oronto group	
Amnicon formation	5,000
Eileen sandstone	2,000
Freda sandstone	12,000
Nonesuch shale	350
Outer conglomerate	1,200

Field observations indicate that the Outer conglomerate along the Montreal River is merged with the Great conglomerate as there is no trace of the Lake Shore traps. The Outer conglomerate in this vicinity lies directly on the Eagle River group of which the uppermost member is a red sandy shale. There are twenty-six members of the Eagle River group found along the Montreal River (Lane, 1909). Its total thickness is 1,212 feet. Of the twenty-six beds, six are sediments and only one is conglomeratic. The rest of the sedimentary beds are red sandstones and shales.

The Outer conglomerate has a thickness of 1,800 feet, in the Montreal River area, but thins to 800 feet to the west at the Potato River (Thwaites, 1912). To the east, on the Black River, the Outer conglomerate attains a thickness of 5,000 feet (Gorden, 1906) and further east in the Porcupine Mountains it attains a thickness of 3000 feet (Irving, 1883).

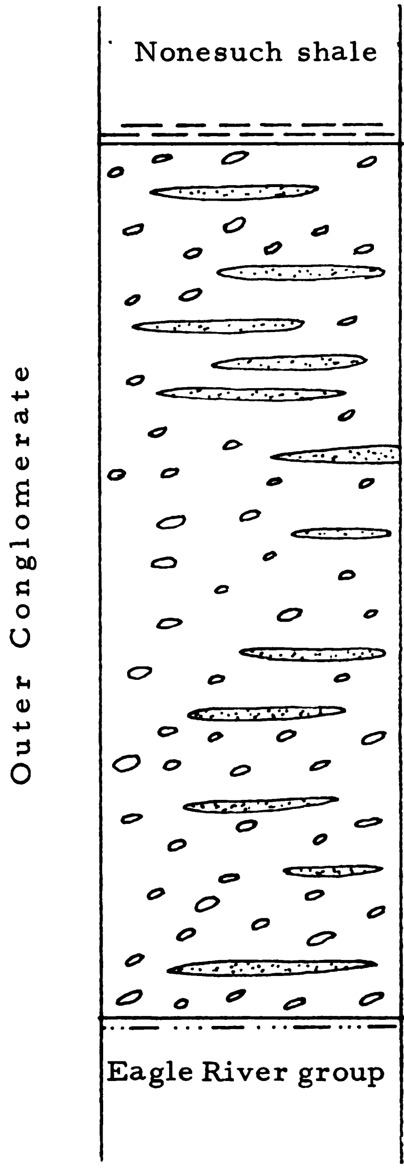
According to Gordon the Outer conglomerate from top to bottom is: sandstone, sandstone and conglomerate phases, mixed sandstone and conglomerate, conglomerate and sandstone phases, and a basal conglomerate. This sequence can be observed to the east at the Black River and into Keweenaw Point. However, this sequence was not found along the Montreal River. There is a definite lack of sandstone phases. Bedding planes are made obvious only by the intercalated sandstone seams. Many such seams occur, but none of them are more than 6 feet thick. They are lens like, as observed along the cliffs. The average size sandstone lens is 3 feet thick, the length cannot be determined. A few are fifty feet in length but this figure is not the average length.

The component grains of the sandstone lenses are quite uniform in size, however some lenses show graded bedding, particularly around sample number 28 (map). A few lenses near sample 17 and 21 show cross bedding.

Only by means of the lenses is the strike and dip of the Outer conglomerate determinable. There was of course variation in the measurements, but the average strike is N. 42° E. and the average dip is 71° N. W.

Following is a stratigraphic section of the Outer conglomerate:

Stratigraphic Cross Section of the
Outer Conglomerate



Sample Number	Ratio of the Felsitic - Mafic Material	
	Felsitic	Mafic
29	66	34
5	67	33
17	65	35
20	68	32
28	71	29
26	62	38
27	70	30
19	75	25
25		
22	93	7
18	92	8

Jointing occurs along the entire course of the stream. No movement was found to have occurred along any of the joints. Because of the lithification of the conglomerate many joints cut through the pebbles rather than around them. There are many minor breaks also cutting the pebbles. Slippage was not observed on any of these breaks.

The pebbles in the Outer conglomerate are dominantly rhyolite. This rhyolite is thought to be Keweenawan in age and contemporaneous with the mafic lavas. The local percentages of 445 pebbles are as follows:

rhyolite	55%	granite	4%
gabbro-diabase	17%	graywacke	3%
quartzite	10%	jasper	1%
vesicular and amygdoloidal basalt	9%	syenite	1%

Sample 18 at the base of the formation is dominantly rhyolite with an occasional pebble of quartzite and basalt. Graywacke first appears near sample 19. Stratigraphically, half way between samples 19 and 20 jasper pebbles first appear with also an increase in the basic pebble content.

These percentages may not correspond to pebble composition at other localities along the strike of the Outer conglomerate. It appears certain however that the Outer conglomerate is dominantly rhyolite conglomerate.

The pebbles were studied megascopically. Following is a description of some of the pebbles.

rhyolite: Reddish brown color. Very fine grained ground mass with phenocrysts of quartz and orthoclase. Phenocrysts of orthoclase vary in size from less than

1 mm. to 4 mm. The quartz is generally smaller. Either may dominate in the various pebbles.

granite: Pink in color. Composed of orthoclase, quartz, and hornblende. A few varieties of graphic granite were observed.

amygdoloidal and/or vesicular basalt: Brown to black groundmass. Amygdules of calcite, quartz, epidote, and chlorite present. Calcite dominates. A few of the pebbles contain hair-like crystals of feldspar.

diabase and/or gabbro: Brown to black, fine grained. An occasional small crystal of plagioclase, possibly labradorite.

graywacke: Gray to black. Quartz, orthoclase and plagioclase predominate with minor amounts of hornblende and/or augite.

jasper: Banded, red and hard.

quartzite: Brownish to white in color. Impure quartzite.

syenite: Brown to red in color. Chief mineral is orthoclase. Quartz is conspicuously absent.

The majority of the pebbles are fresh in appearance showing little or no weathering.

Roundness and sphericity were determined visually, by arranging the pebbles so that their maximum projection area was visible. (See figure 2.)

The roundness and sphericity percentages were found to be as follows:

Roundness	Sphericity
0.9 - 45%	0.9 - 2%
0.8 - 29%	0.8 - 12%
0.7 - 21%	0.7 - 34%
0.6 - 4%	0.6 - 28%
0.5 - 1%	0.5 - 20%
	0.4 - 4%

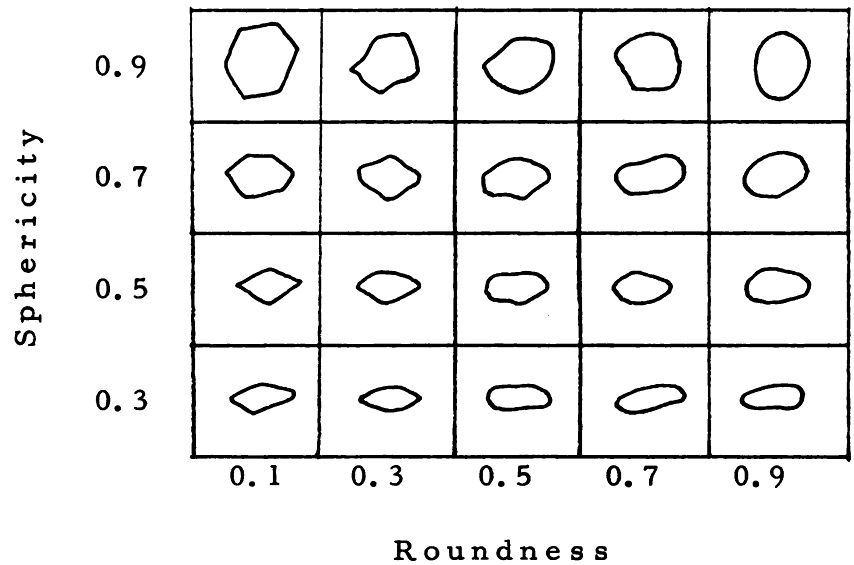


Figure 2. Visual chart for estimating roundness and sphericity of sand grains (After Krumbein and Sloss, 1958, p. 81).

The percentages given on page 12 were for all samples. The values showed no significant trend other than that there is a high degree of rounding. This was also noticed by Gordon in his study of the Black River section. He observed that the pebbles are water worn and rounded with angular fragments difficult to find (Gordon, 1906, p. 427).

Using the roundness classes of Pettijohn (1957, p. 59), namely: Rounded (0.40 - 0.60) and Well-rounded (0.60 - 1.00), the samples showed the following percentages:

	Rounded	Well-rounded
Sample 5	-	100%
Sample 17	-	100%
Sample 18	11%	89%
Sample 19	3%	97%
Sample 20	1%	99%
All samples	3%	97%

Sample 18, which is at the base of the formation, showed a decrease in the number of well-rounded pebbles present. Samples 5 and 17 near the top of the formation contain only the well-rounded class of pebbles.

Roundness indicates the abrasive history of a sediment. In traction transportation, particles are in direct contact with each other and the underlying surface, and the larger particles may become rounded to a relatively high degree. Experimental and field studies have shown that a well rounded gravel can be the result of a comparatively short transport (Pettijohn, 1957). One might be able to estimate the distances the pebbles traveled, if a down dip study were conducted. However, the study of the Outer conglomerate was from the base to the top of the formation and not down dip.

Roundness is correlated with maturity. If this index is used, the base of the Outer conglomerate is less mature than the top of the formation. Other evidence for this is that the pebbles at the base of the formation show a higher degree of weathering than do the pebbles at the top of the formation.

Sphericity reflects the conditions of deposition at the moment of accumulation. In general, abrasive action during transport is not marked and the original shape seems to persist even by prolonged transport.

IMBRICATION

Particles having two large dimensions and one small dimension tend to come to rest in some stable position with reference to the direction of flow. The position of stability is attained when the down-current side of the particle is lower than the up-current side. In this position the current strikes the upper surface and has no lifting ability. This position is known as imbricate arrangement.

Figure 3 is a sketch taken from Pettijohn (1957, p. 78) showing imbricate arrangement of pebbles.

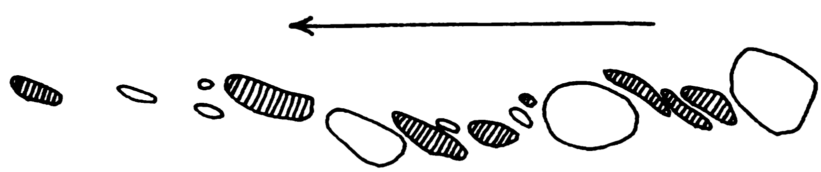


Figure 3. Sketch showing the imbricate arrangement of pebbles.

A study of the pebble orientation, long axes and maximum projection area, was made. The pebble fabric was studied on the basis of a technique described by Karlstrom (1952). The method is as follows: (1) The spatial attitudes of pebbles were marked in the outcrop before the pebbles were removed, (2) They were reoriented in the laboratory and the long axes and the face poles to the maximum projection areas were measured and plotted on equal area projections, (3) The parameters were then contoured.

The long axes of the pebbles have a strong tendency to be inclined slightly upstream. Pettijohn (1957, p. 80) states that, according to Cailleux, river deposits showed a notably uniform imbrication whereas marine formations were somewhat variable in direction. Also, in fluvial deposits the mean upstream inclination is 15 to 30 degrees whereas marine deposits showed an inclination of 2 to 12 degrees.

Figures 4 through 18 show the long axes orientation of the pebbles sampled. Samples 17, 18, and 19 represented by figures 7 through 15 show a concentration lying on a southeast-northwest line, while figures 4 and 16 show a concentration in almost a north-south line. It is possible that currents effected by some obstacle controlled the imbrication at these two localities.

Figure 34 is a composite diagram of all long axes of the pebbles sampled. The maximum concentration is in a southeast-northwest direction while the almost north-south direction is minor.

The maximum projection area was plotted by using the azimuth and angle of dip of the face pole of the maximum projection area. Figures 19 through 33 show the concentration of the face poles.

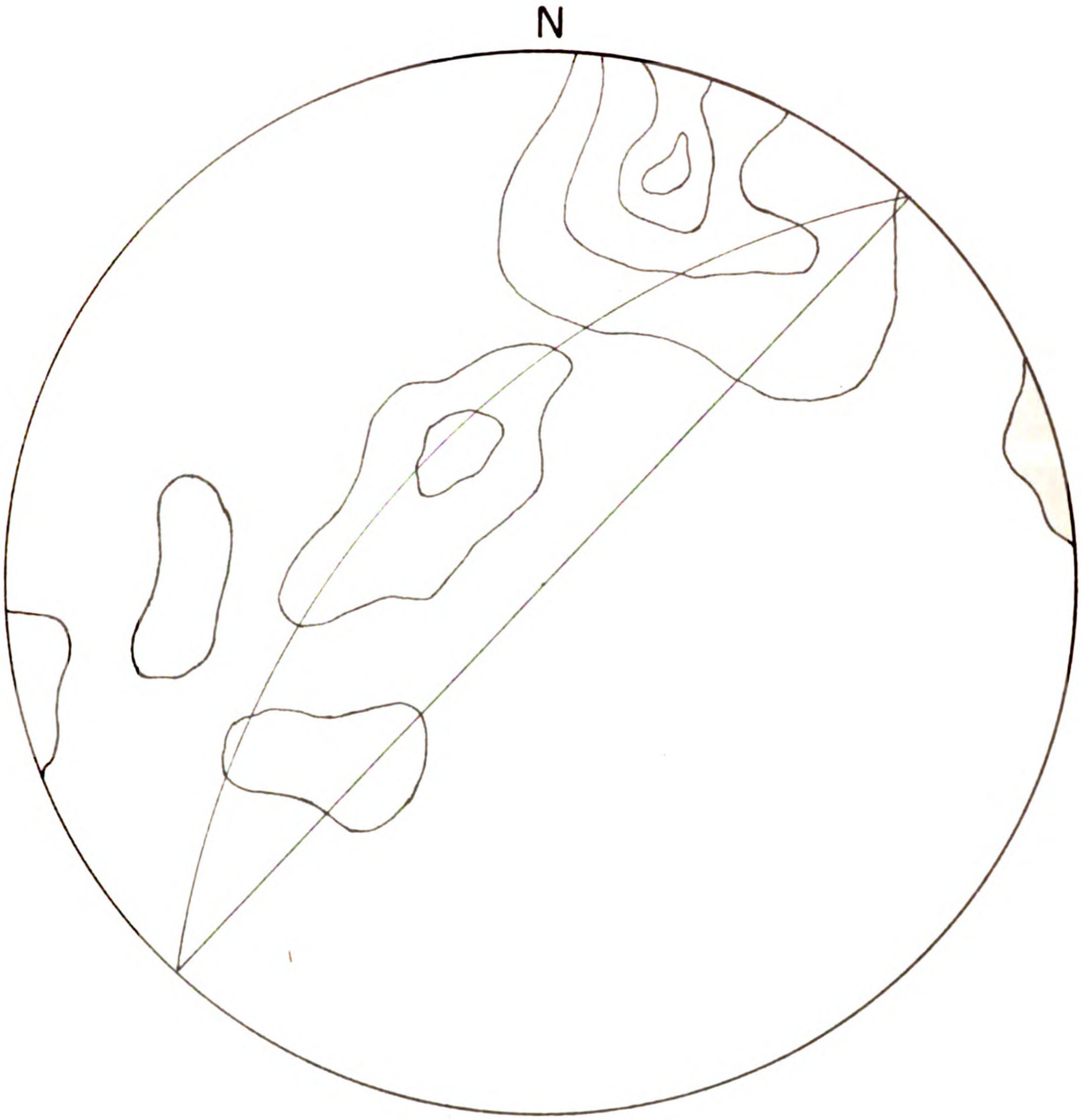


Figure 4. Sample 5 long axes.
Contours 1-2-3-4 per cent.

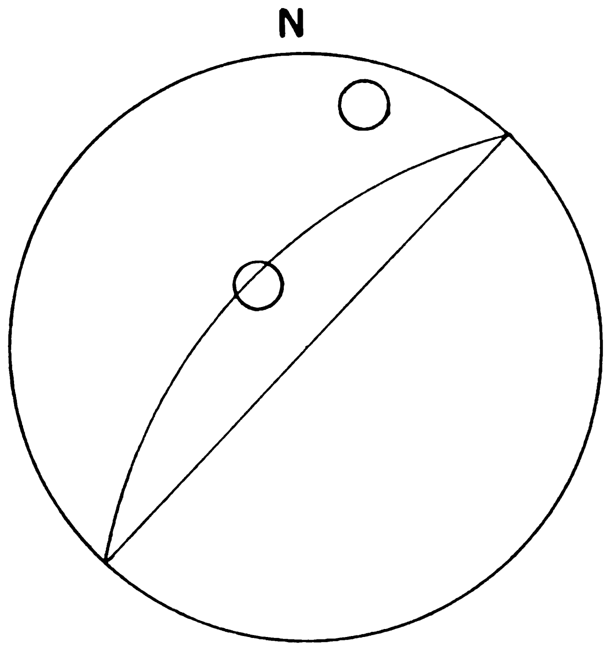


Figure 5. Generalized diagram of Figure 4 (post-tectonic, dip 71° N.W.).

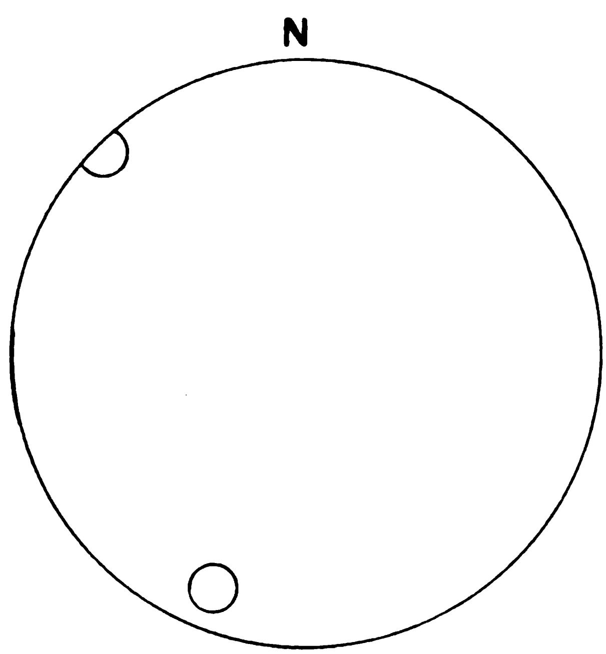


Figure 6. Generalized diagram showing Figure 4 reoriented to pre-tectonic attitude, 0° dip.

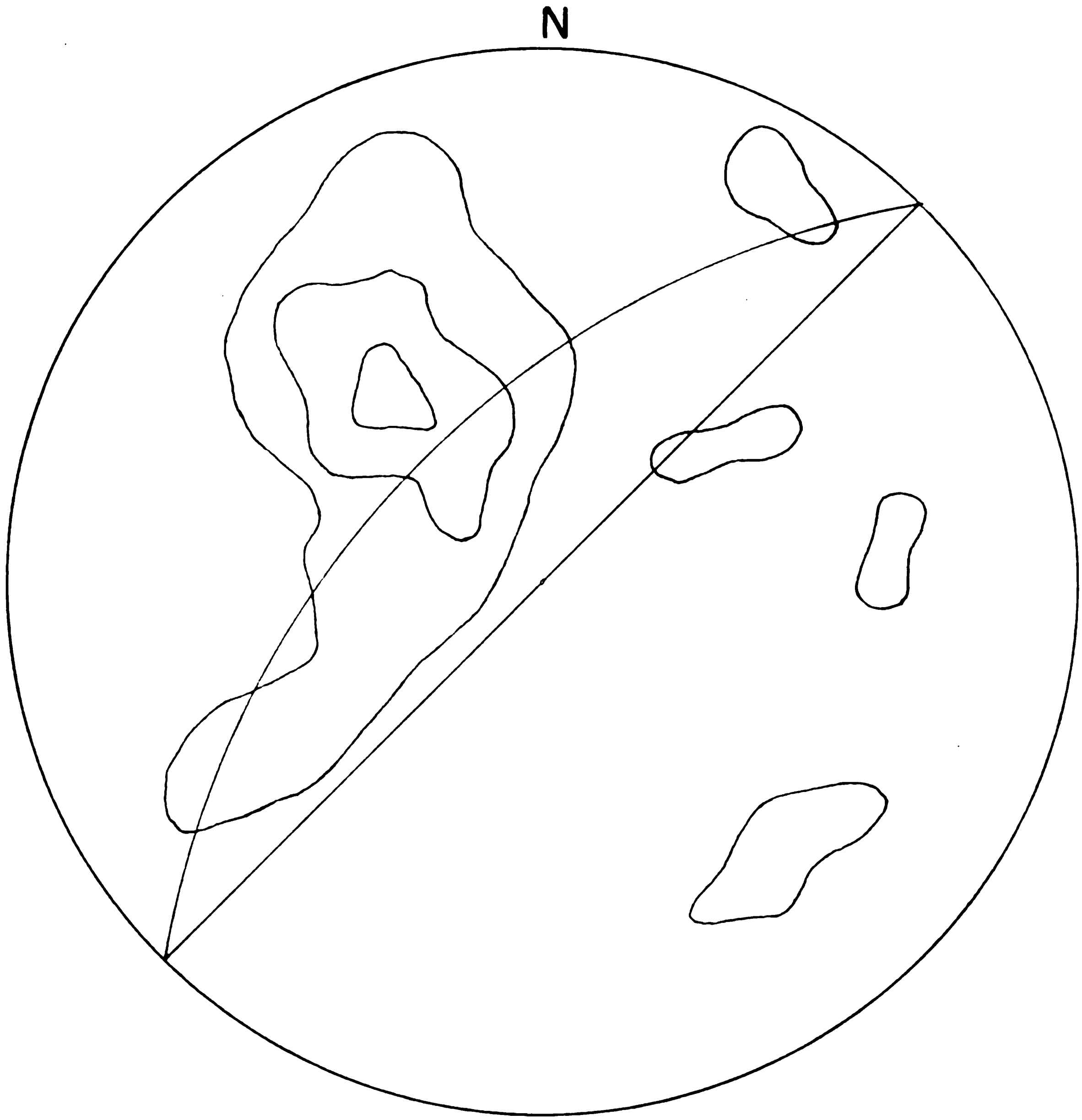


Figure 7. Sample 17 long axes.
Contours 1-2-3-per cent.

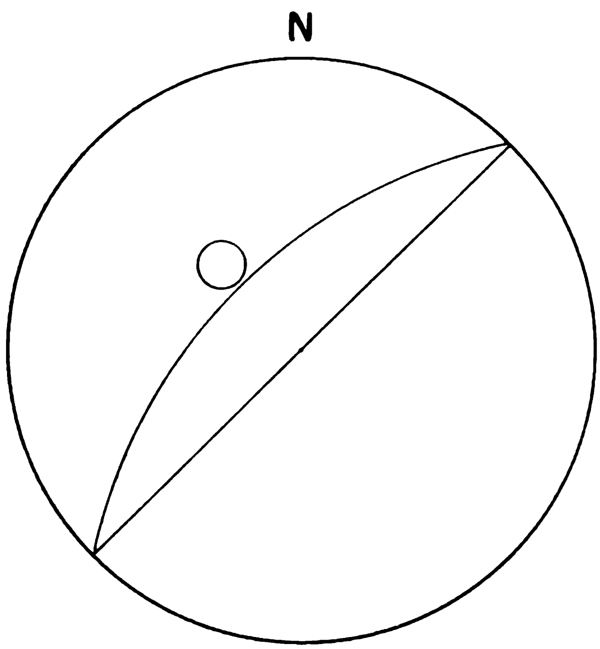


Figure 8. Generalized diagram of Figure 7 (post-tectonic dip 71° N.W.).

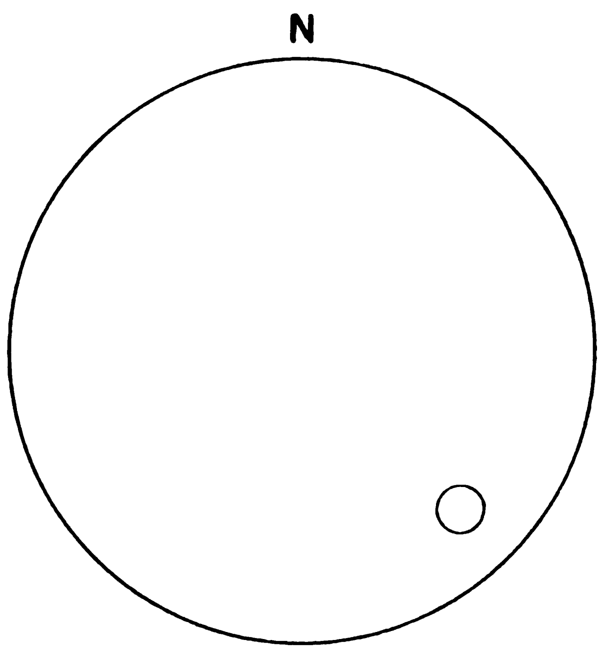


Figure 9. Generalized diagram showing Figure 7 reoriented to pre-tectonic attitude, 0° dip.

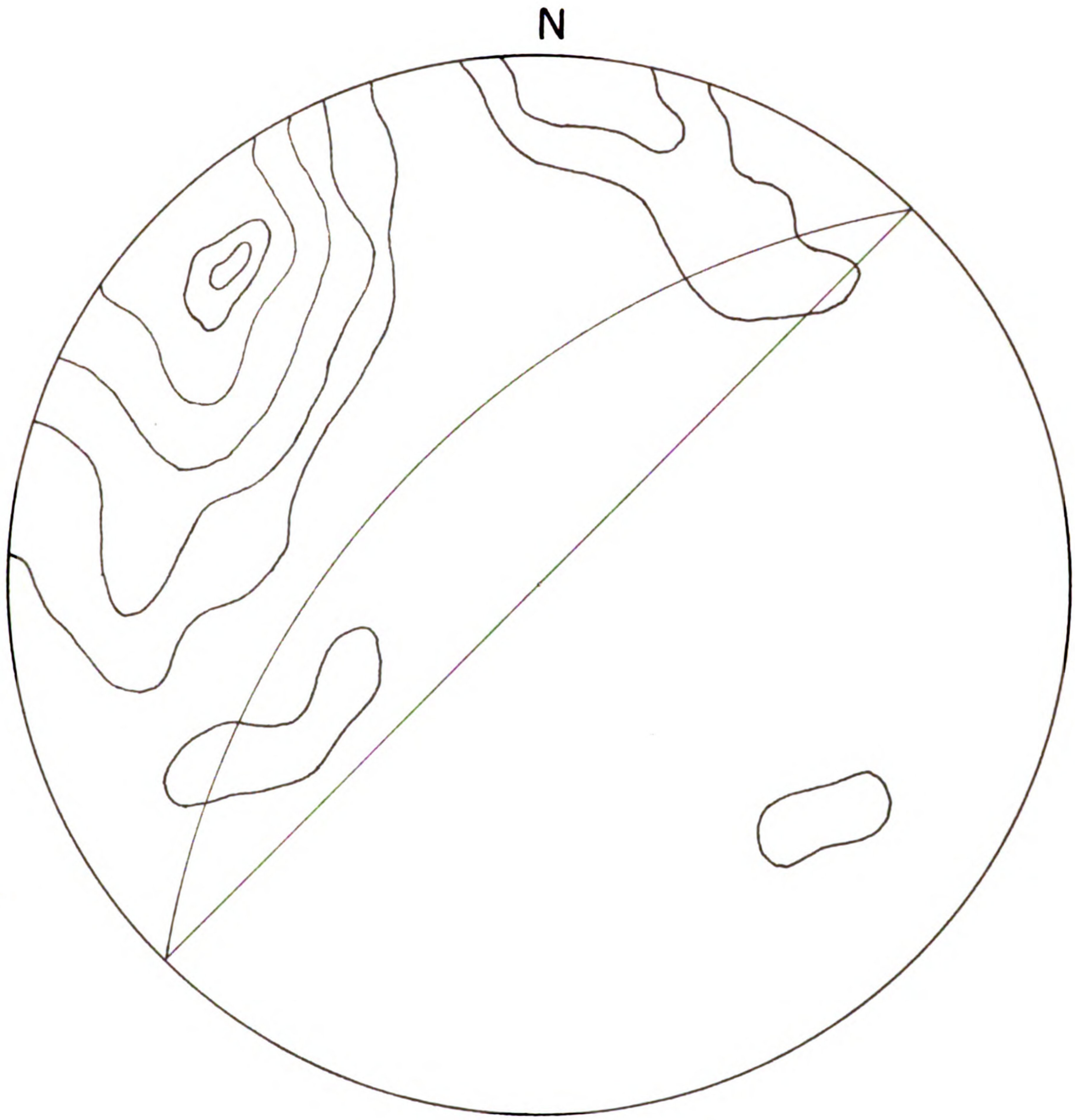


Figure 10. Sample 18 long axes.
Contours 1-2-3-4-5-6 per cent.

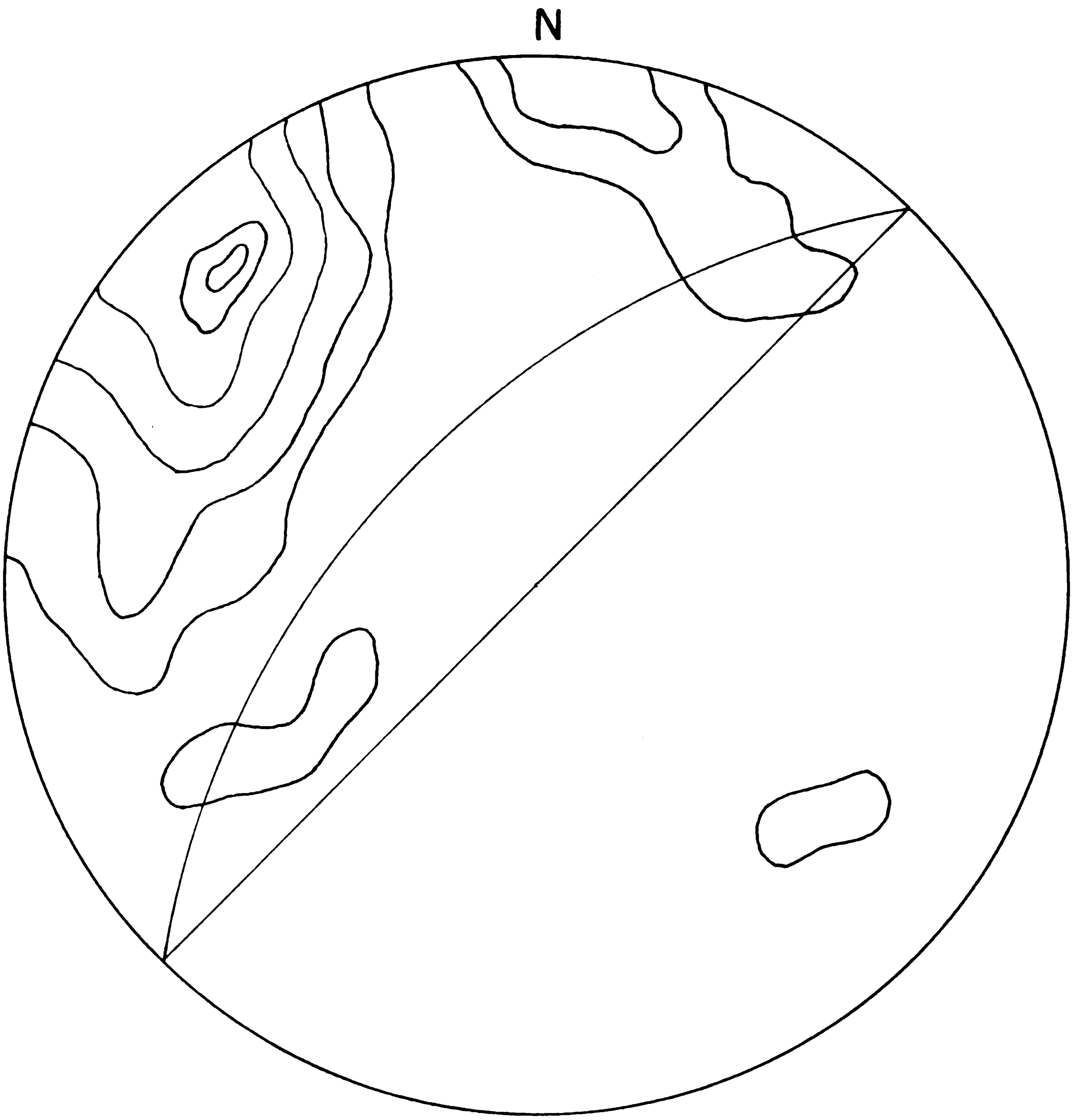


Figure 10. Sample 18 long axes.
Contours 1-2-3-4-5-6 per cent.

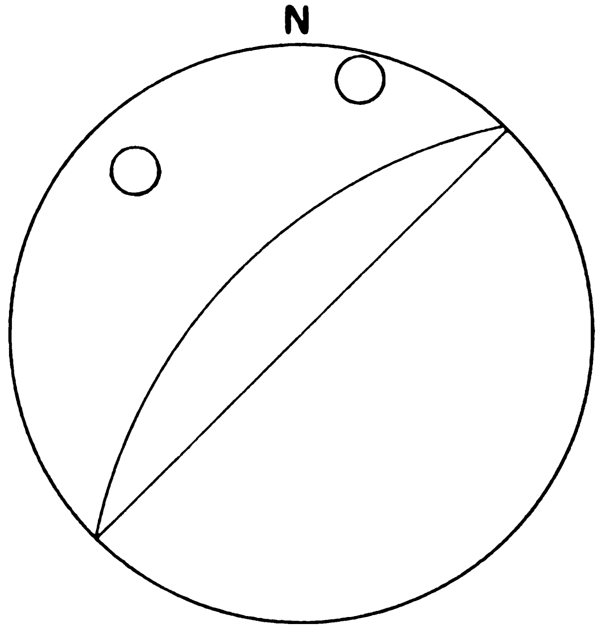


Figure 11. Generalized diagram of Figure 10 (post-tectonic, dip 71° N.W.).

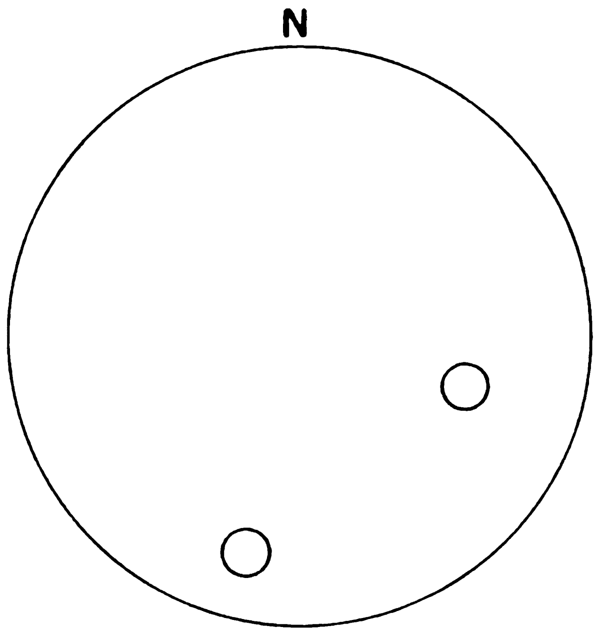


Figure 12. Generalized diagram showing Figure 10 reoriented to pre-tectonic attitude, 0° dip.

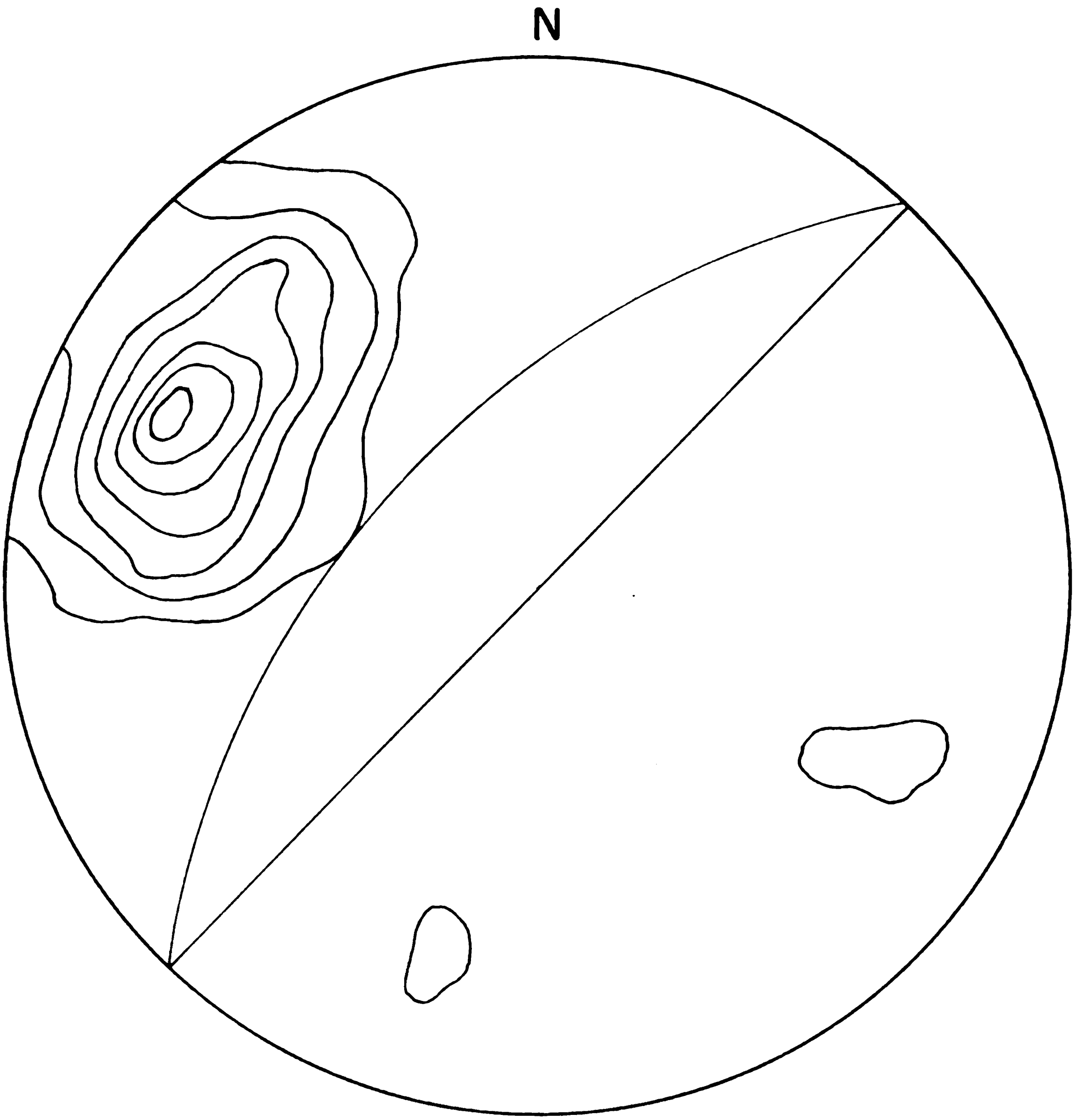


Figure 13. Sample 19 long axes.
Contours 1-2-3-4-5-6-7 per cent.

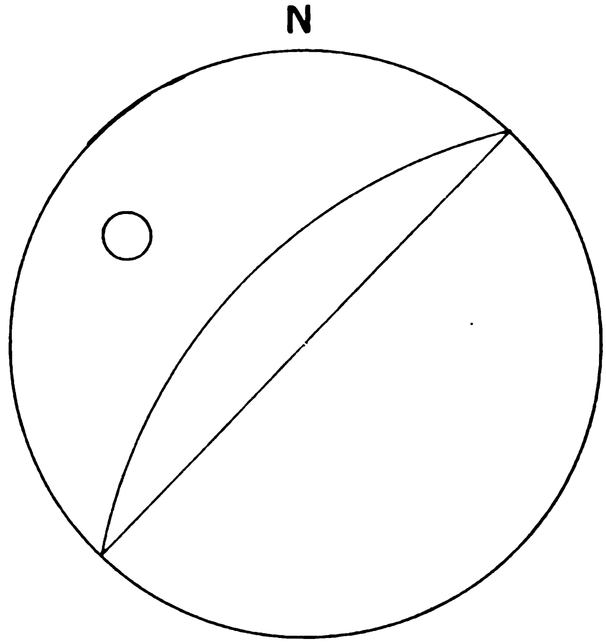


Figure 14. Generalized diagram of Figure 13 (post-tectonic, dip 71° N.W.).

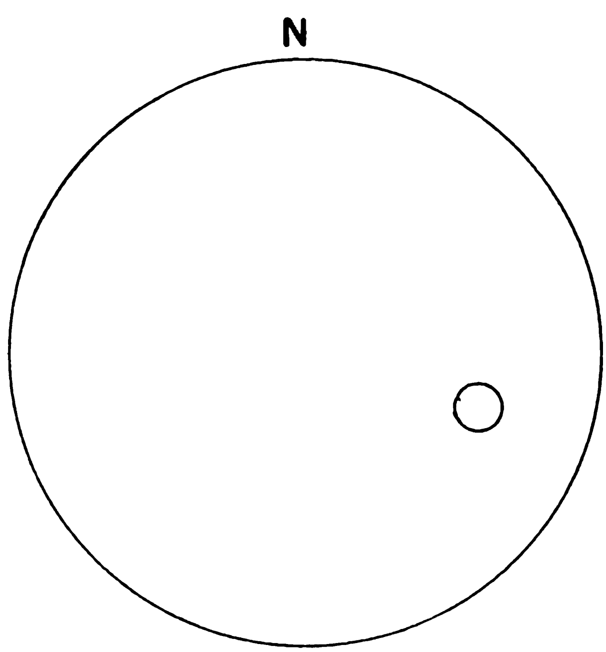


Figure 15. Generalized diagram showing Figure 13 reoriented to pre-tectonic attitude, 0° dip.

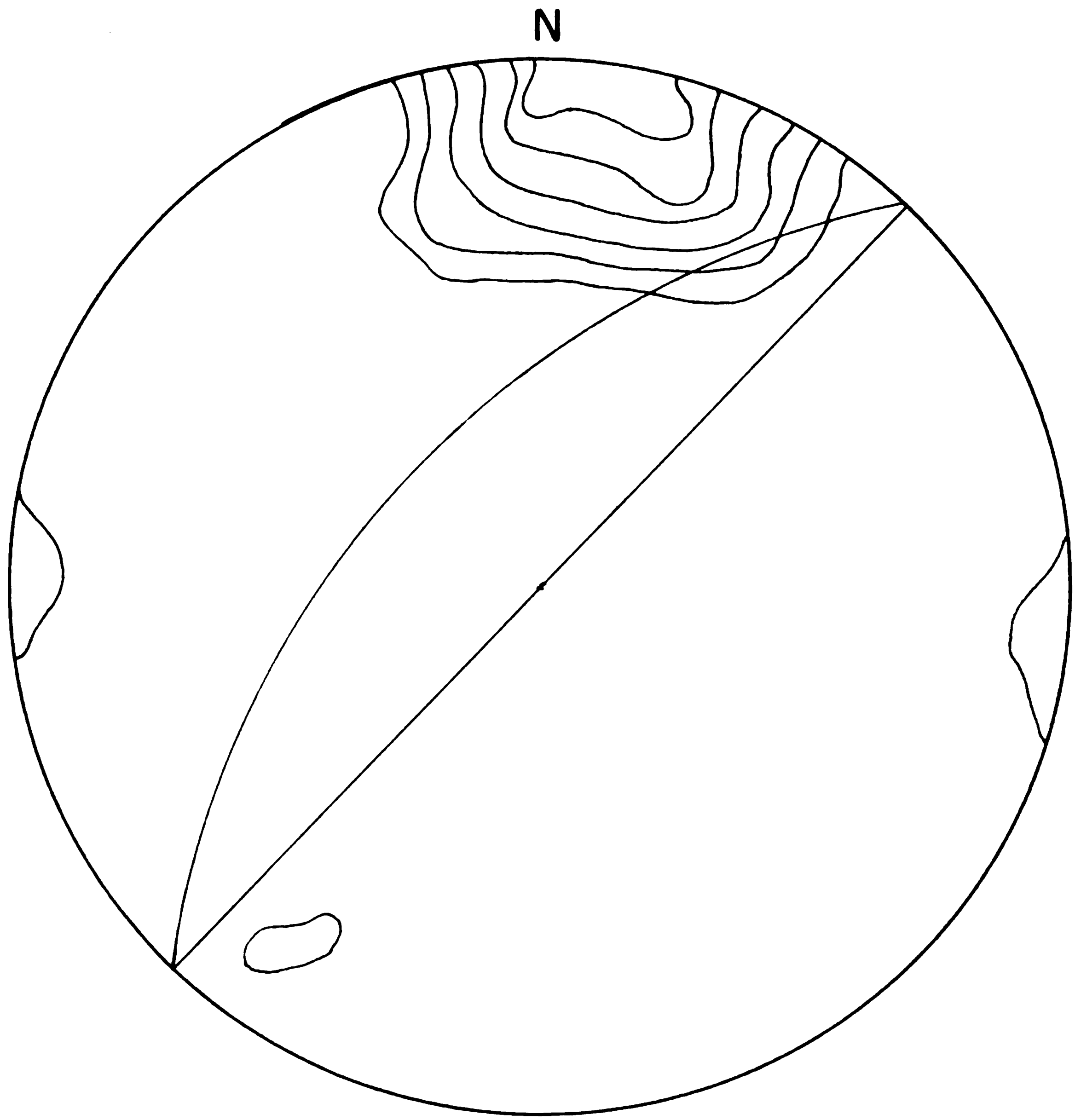


Figure 16. Sample 20 long axes.
Contours 1-2-3-4-5-6 per cent.

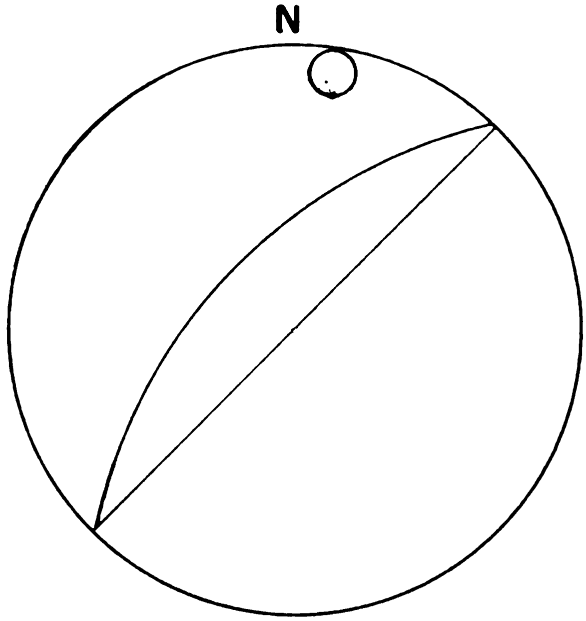


Figure 17. Generalized diagram of Figure 16 (post-tectonic, dip 71° N.W.).

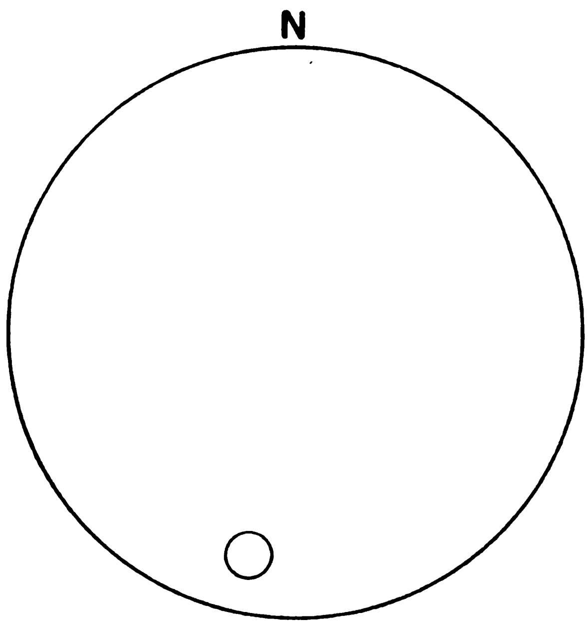


Figure 18. Generalized diagram showing Figure 16 reoriented to pre-tectonic attitude, 0° dip.

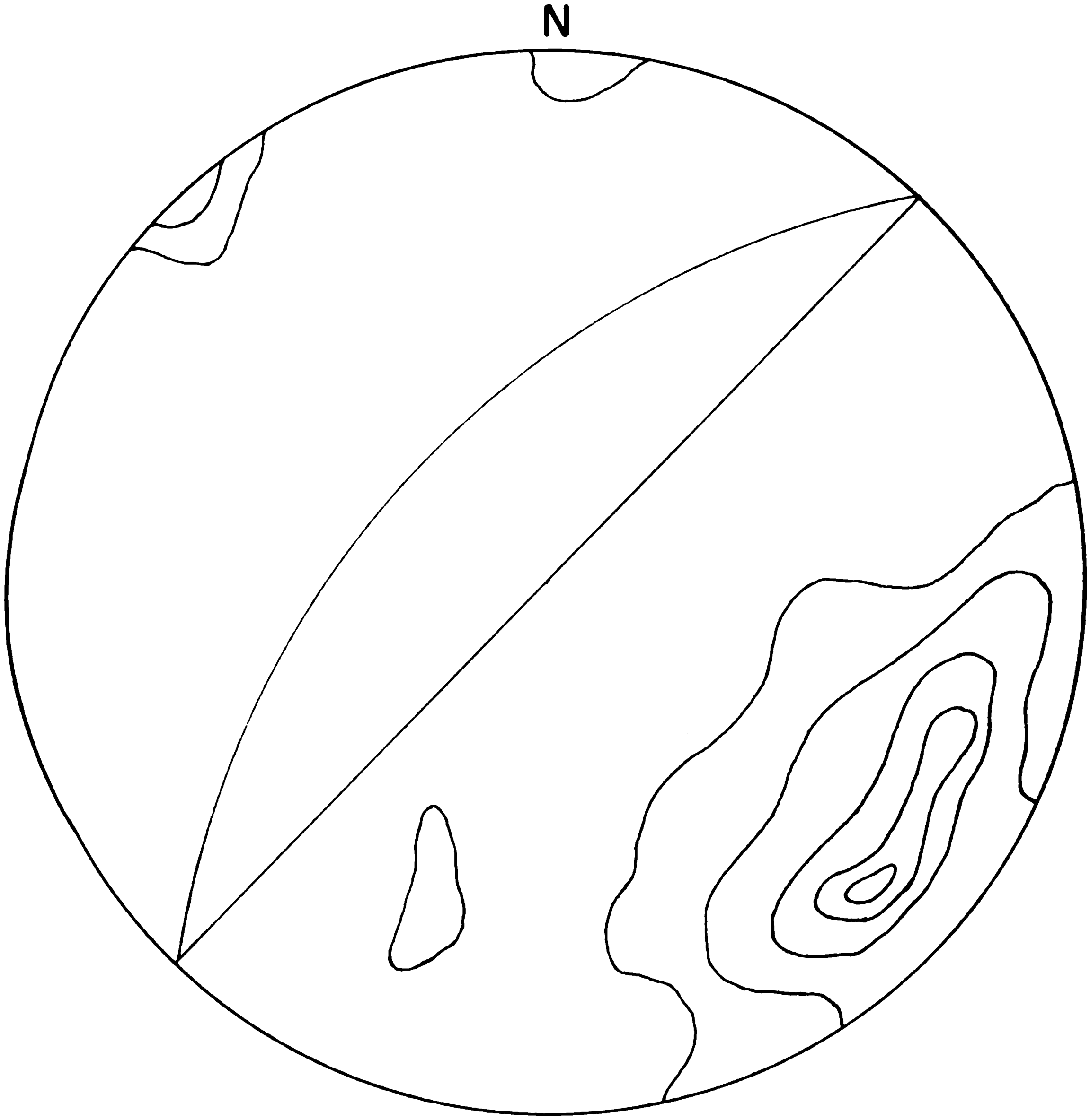


Figure 19. Sample 5 maximum projection area.
Contours 1-2-3-4-5 percent.

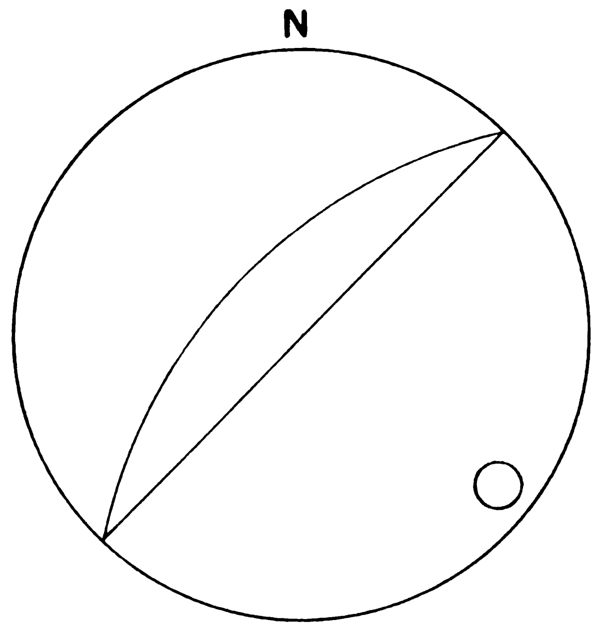


Figure 20. Generalized diagram of Figure 19 (post-tectonic, dip 71° N.W.).

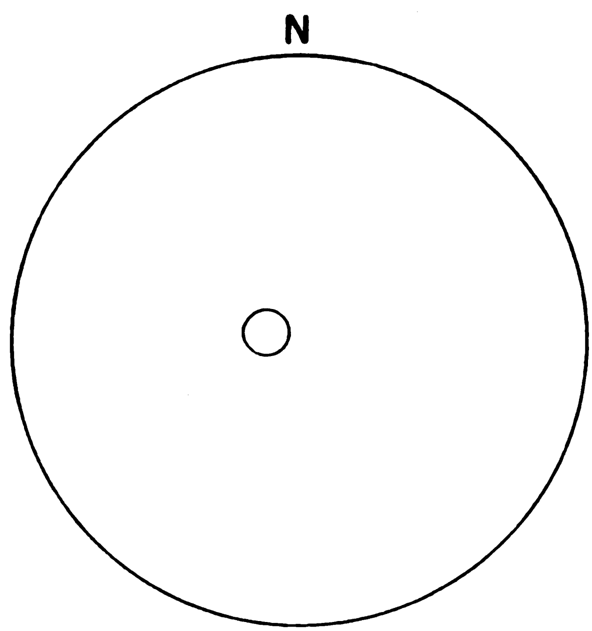


Figure 21. Generalized diagram of Figure 19 reoriented to pre-tectonic attitude, 0° dip.

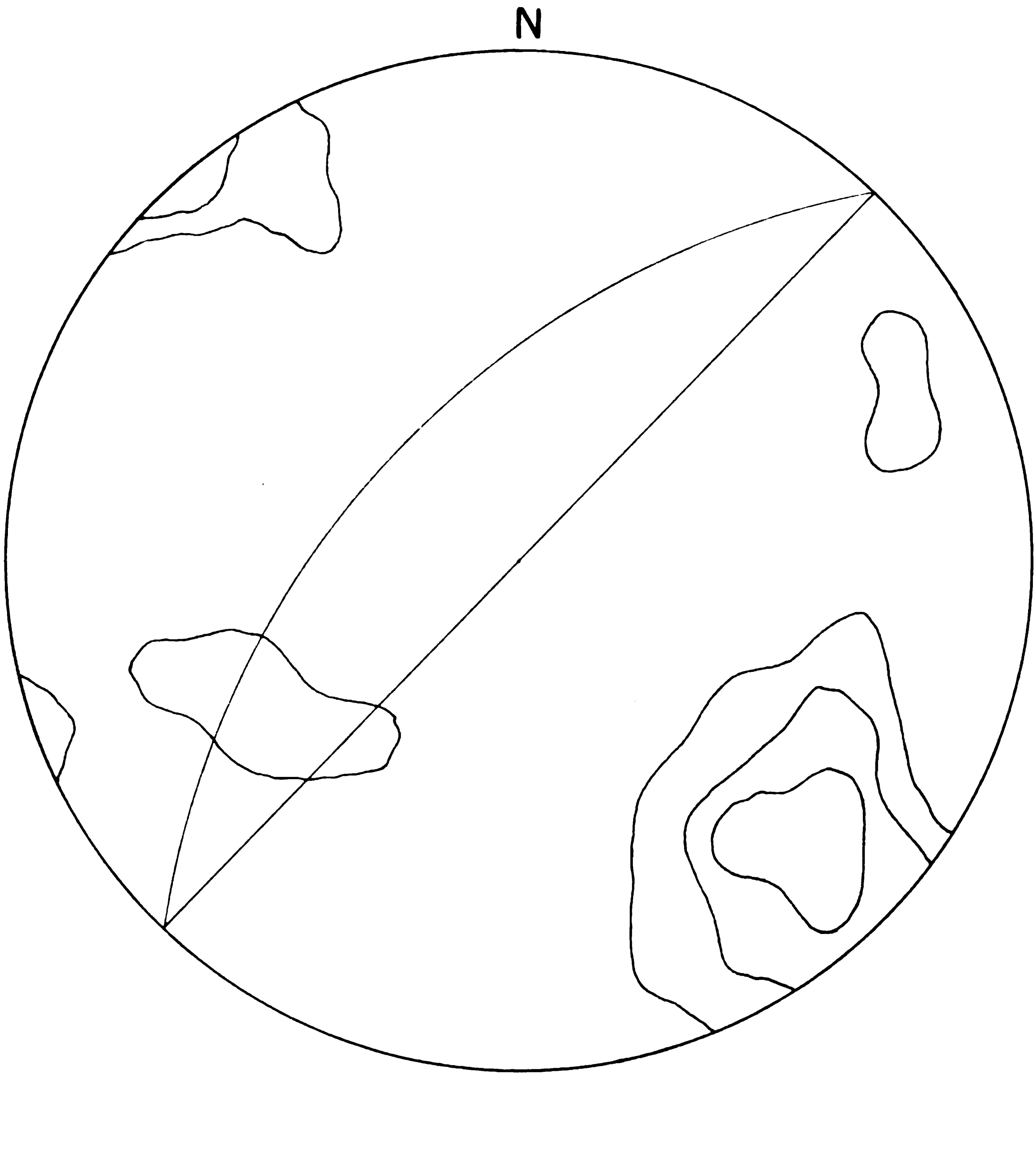


Figure 22. Sample 17 maximum projection area.
Contours 1-2-3 per cent.

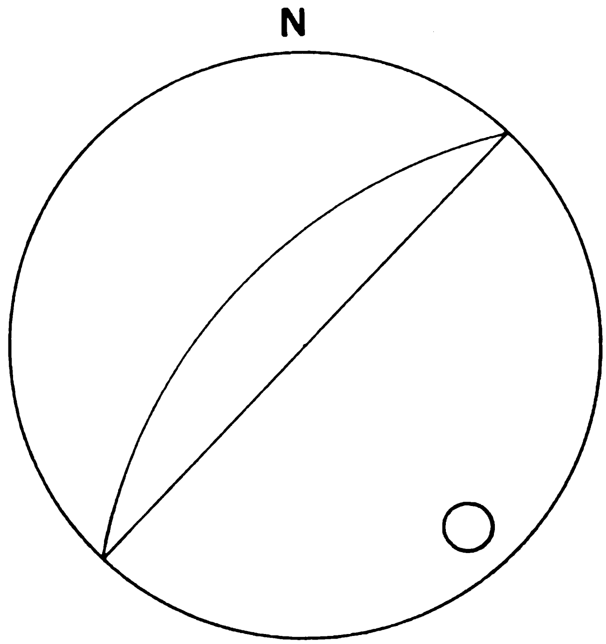


Figure 23. Generalized diagram of Figure 22 (post-tectonic, dip 71° N.W.).

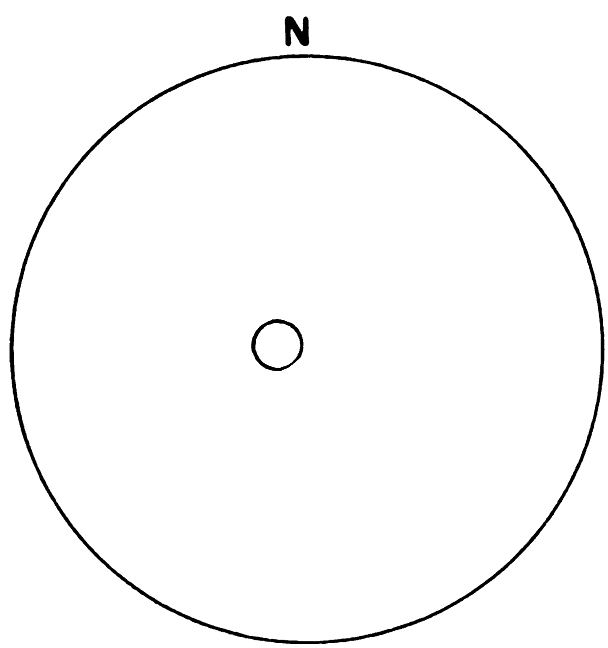


Figure 24. Generalized diagram of Figure 22 reoriented to pre-tectonic attitude, 0° dip.

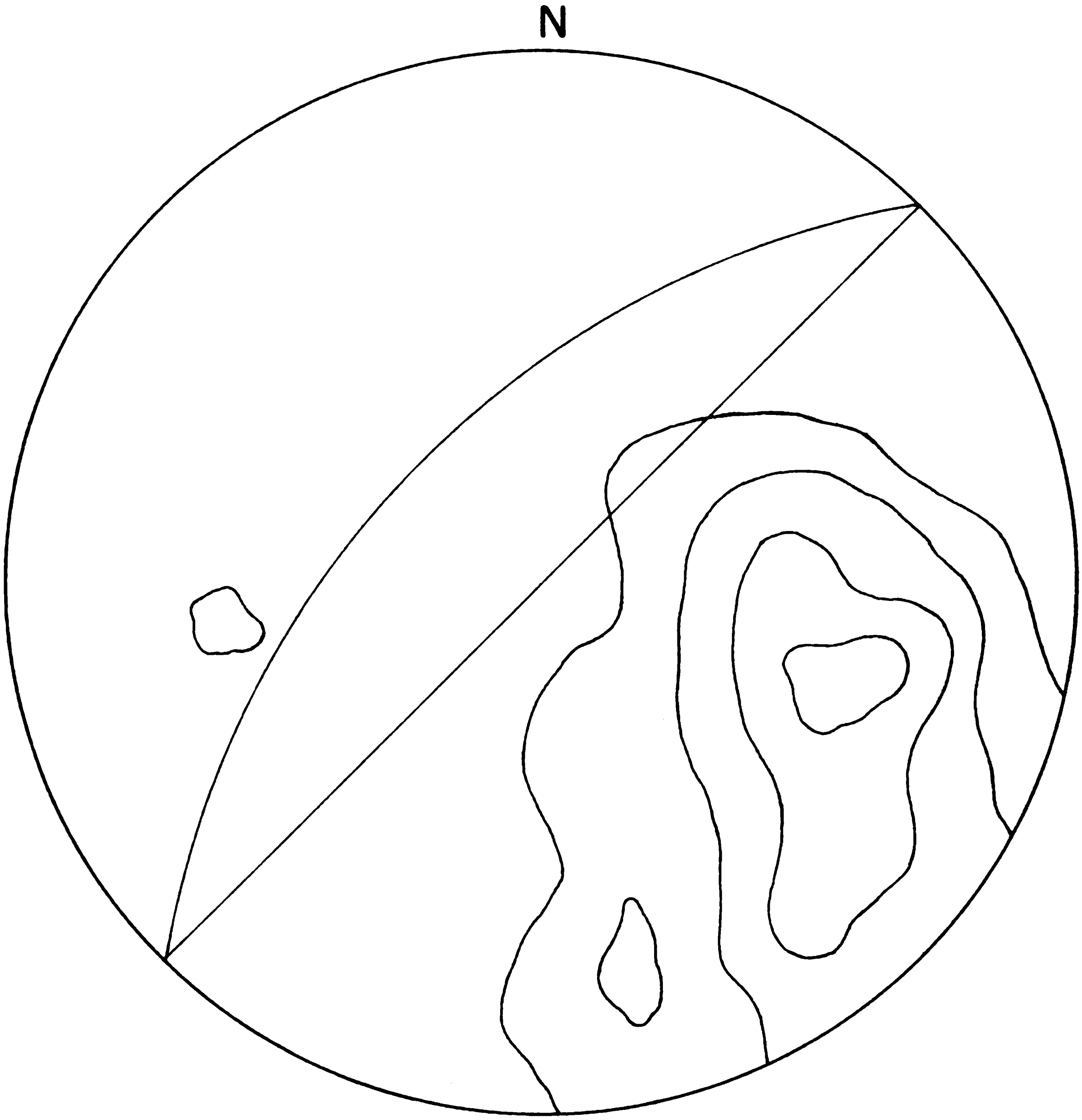


Figure 25. Sample 18 maximum projection area.
Contours 1-2-3-4-5 per cent.

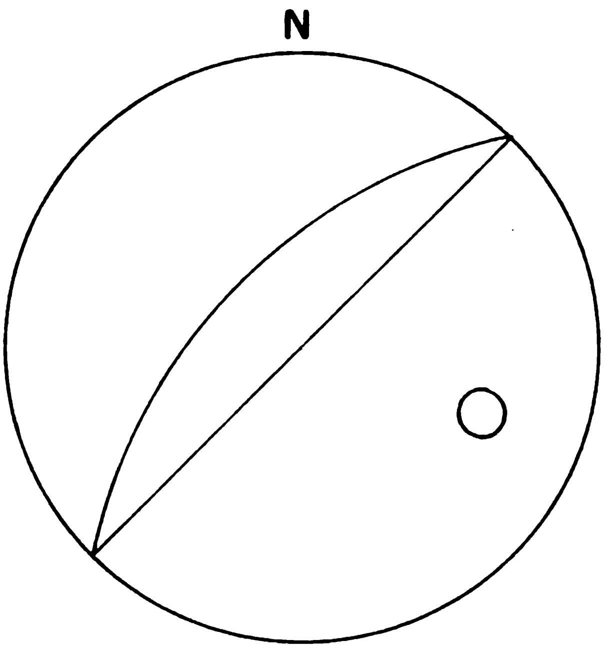


Figure 26. Generalized diagram of Figure 25 (post-tectonic, dip 71° N.W.).

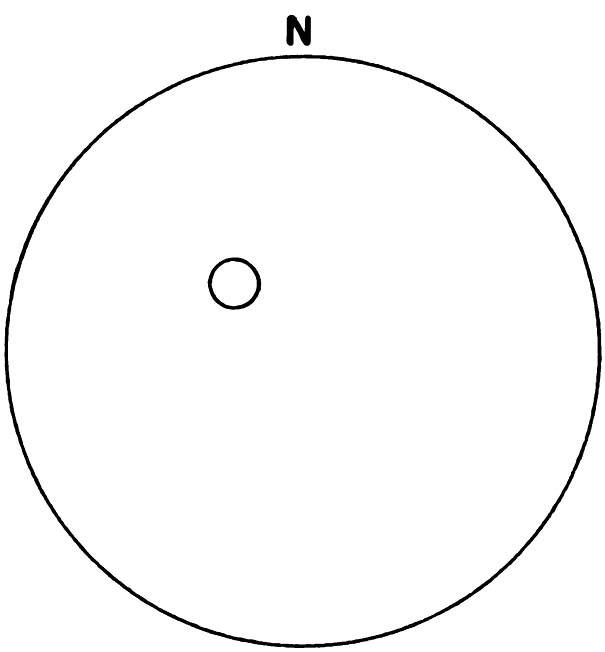


Figure 27. Generalized diagram of Figure 25 reoriented to pre-tectonic attitude, 0° dip.

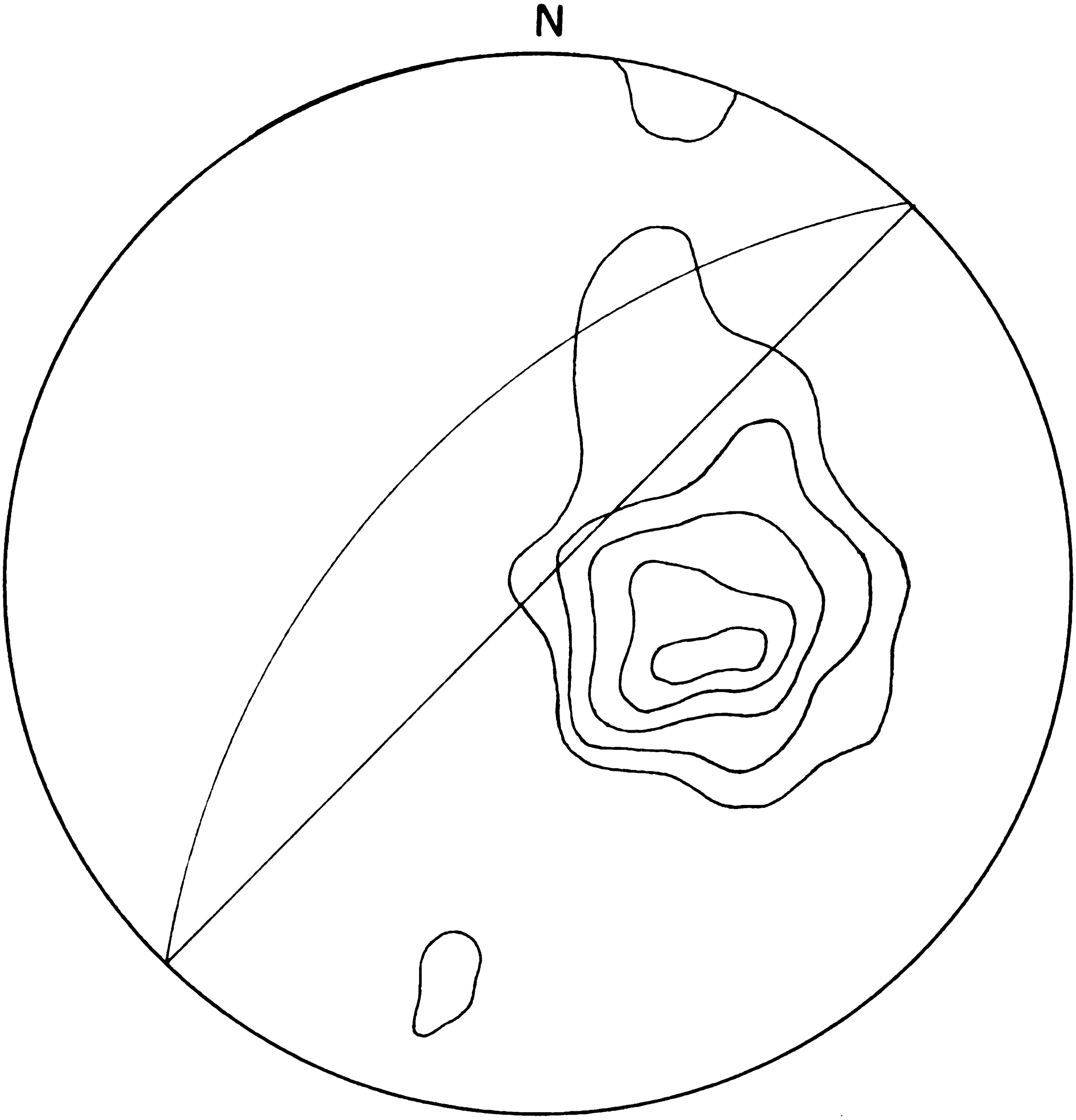


Figure 28. Sample 19 maximum projection area.
Contours 1-2-3-4-5 per cent.

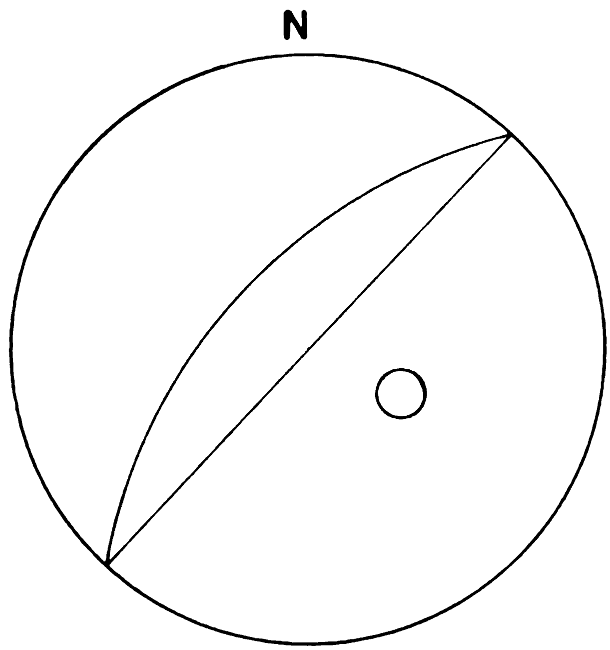


Figure 29. Generalized diagram of Figure 28 (post-tectonic, dip 71° N.W.).

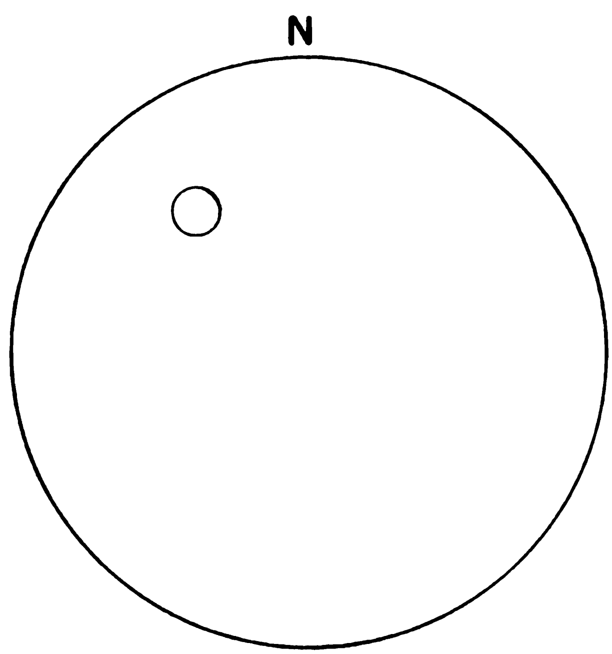


Figure 30. Generalized diagram of Figure 28 reoriented to pre-tectonic attitude, 0° dip.

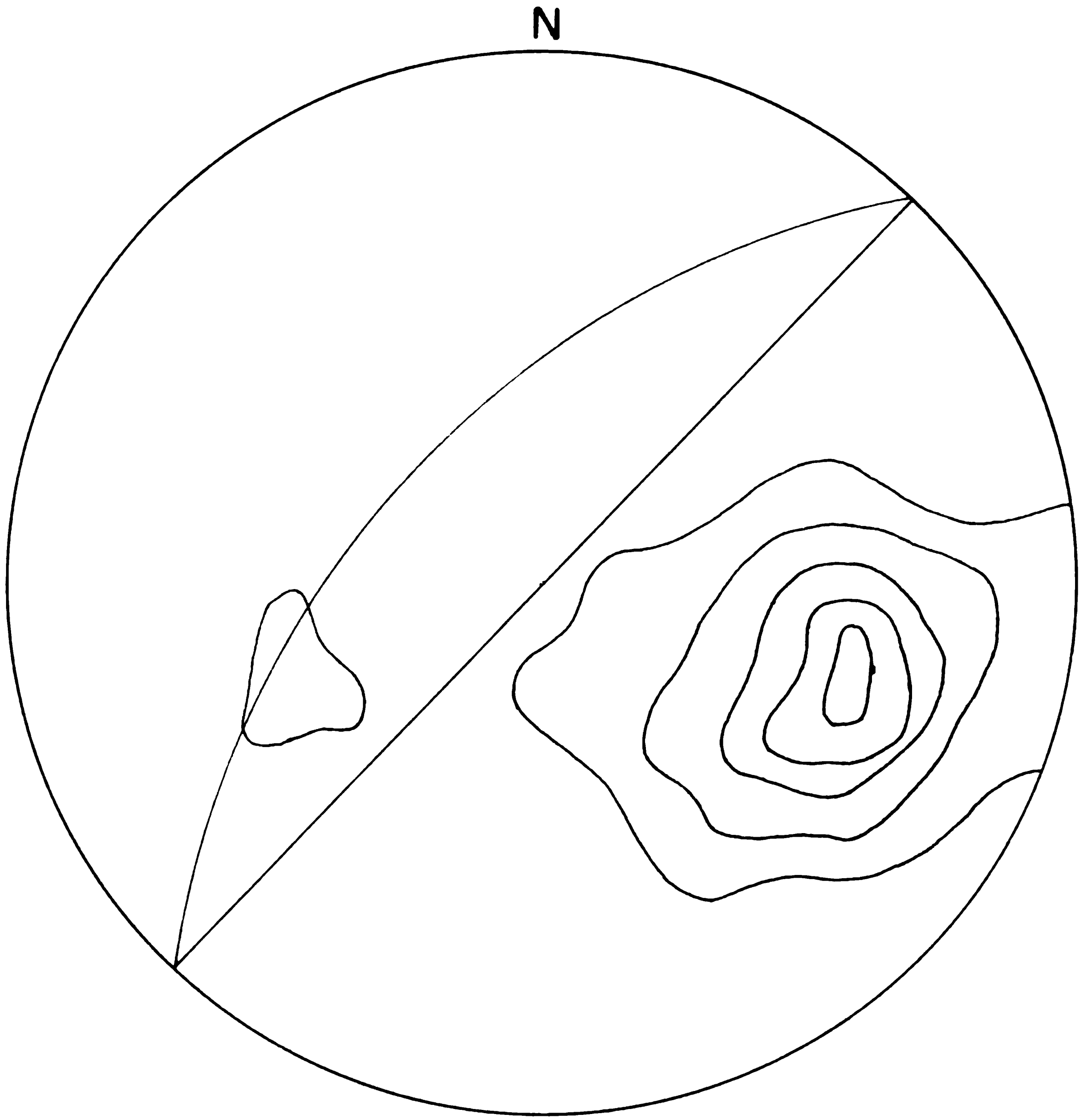


Figure 31. Sample 20 maximum projection area.
Contours 1-2-3-4-5 per cent.

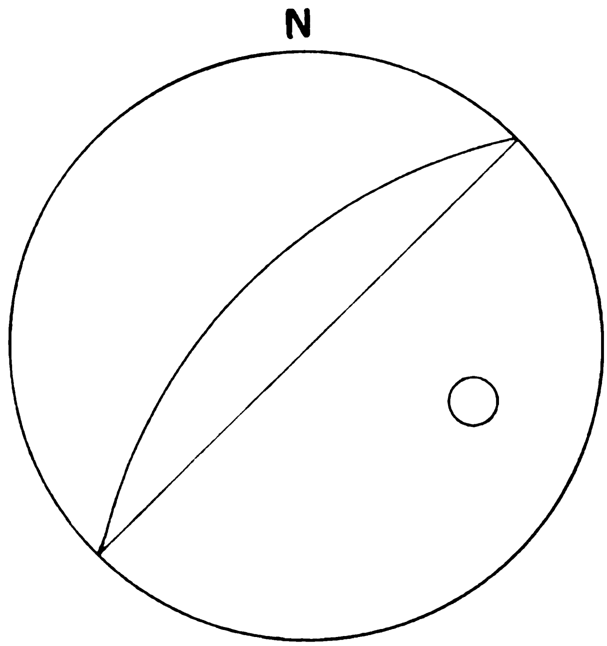


Figure 32. Generalized diagram of Figure 31 (post-tectonic, dip 71° N.W.).

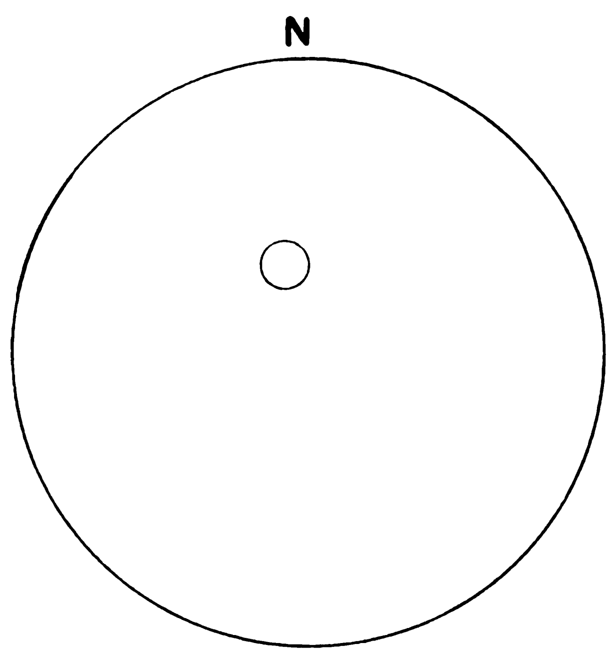


Figure 33. Generalized diagram of Figure 31 (reoriented to pre-tectonic attitude, 0° dip).

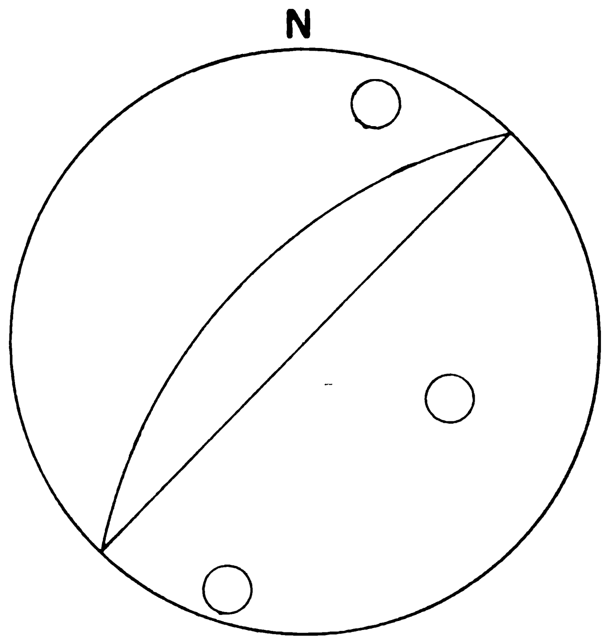


Figure 34. Generalized diagram of composite long axes pre-tectonic orientation, 0° dip.

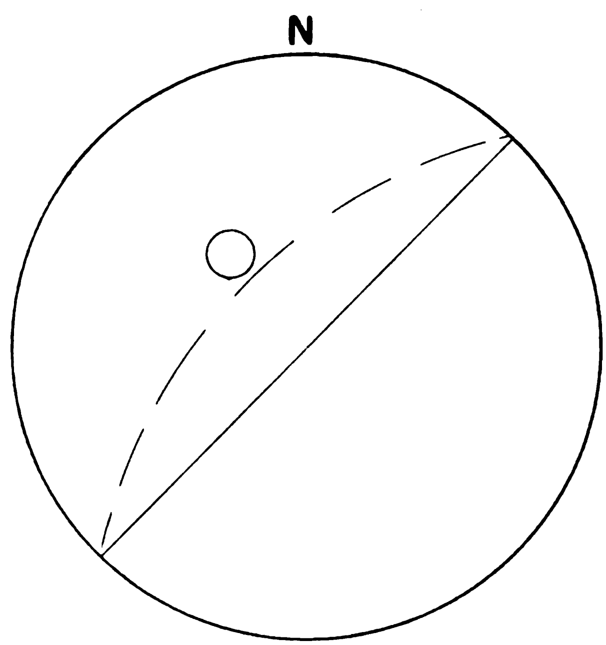


Figure 35. Generalized diagram of composite maximum projection area pre-tectonic orientation, 0° dip.

Here again a southeast-northwest trend dominates as shown by the composite diagram figure 35.

The evidence from the long axis and maximum projection concentrations favor a current direction from the southeast. White (1952) and Smale (1958) also report a current direction from the southeast.

The angle of inclination as indicated by the composite diagram is in excess of that proposed by Calleux. The inclination of the samples taken is approximately 45° S. E., as opposed to Cailleux's 15 to 30 degrees.

This greater dip can be explained in that the initial dip of the formation is probably not 0° but anywhere from 0° to 15°.

White (1952, p. 196) proposed another possible explanation:

> Where a pebble projecting above the stream bottom is appreciably larger than the material that underlies it, a small crater may form by scour in its lee. The pebble will slide or roll into a crater that becomes large enough to undermine it.

PETROGRAPHY

Seven matrix samples were taken and the thin sections studied with a petrographic microscope. Also studied were three thin sections of the channel or lens sands. Percentages were determined by using an ocular with a grid.

Samples 15, 20, 22, 26, 27, 28, and 29 are matrix samples, while samples 1, 16, and 21 are lens sand samples.

Modal Analysis of Matrix Samples

Sample Numbers

Analysis	15	20	22	26	27	28	29
Chalcedony	24.50	46.25	50.25	13.75			
Quartz	7.00				11.25	35.00	31.25
Biotite-Sericite	.50					1.50	
Feldspar	.50		5.75			7.50	2.00
Iron oxide			6.50	1.75			2.50
Calcite			7.50	28.75	37.50	4.50	
Epidote						.50	
Rock Paste							4.50
Rock fragments							
Acidic	33.50	27.50	27.50	29.25	32.25	26.25	28.75
Basic	34.00	26.25	2.50	28.50	19.00	24.70	31.25

Following are the megascopic-microscopic descriptions of the samples:

Sample 15. A dirty brown, highly weathered, granular porous sand. Very friable. The grain diameter varies from .5mm to larger than 1 mm. The average grain diameter is .3 mm. The quartz grains are angular. Chalcedony is the dominant cementing material.

Sample 20. A friable, medium grained red sandstone. Average grain diameter is .5 mm. Cementing agent is chalcedony.

Sample 22. A ferruginous colored medium to coarse grained sand with calcitic cement. Orthoclase is the dominant feldspar. Calcite is the cementing agent. Quartz has the appearance of microlites.

Sample 26. A friable red sandstone. Fractures occur around and across particles. The grain diameter varies from 1/10 mm to 1 mm.

Sample 27. Ferruginous, medium to coarse grained sand with calcite. Diameters vary from 1/8 mm to greater than 1 mm. Average diameter is 1/3 mm. The cement is calcite. Very little iron staining on rock fragments.

Sample 28. A ferruginous fine grained sand. Average grain diameter is . 3 mm. Feldspar is predominantly microcline and orthoclase with an occasional plagioclase fragment.

Sample 29. A red sand. The grain diameter varies with quartz ranging from 2/3 mm to 1 mm. The rock fragments average 1/6 mm. The lack of calcite and the prevalence of iron staining would give an indication that iron oxide and rock paste are the cementing materials. All the fragments are highly angular.

The percentages of basic to acidic components show a distinctive trend. The greater percentage of acidic material is near the base of the formation. As one goes up the formation the acidic

material although still dominant decreases in relation to the basic material. This coincides with what the other authors stated, namely, that the Nonesuch shale is the first formation to show a distinctive predominance of basic material while all the underlying formations are predominantly acidic. The change from acidic to basic is evident in the Outer conglomerate (see page 10).

Samples 1 and 16 are located at the top of the formation while sample 21 is at the base.

Sample 1

Megascopic description. A fine grained ferruginous sand containing flakes of muscovite which are as large as 1 mm in size. Weathers to a soft friable sand.

Microscopic description

Quartz	65.60	Biotite	1.25
Iron oxide	7.75	Chalcedony	2.25
Feldspar	3.50	Rock fragments	19.75

Grain diameter is from 1/20 mm to 3/10 mm. Quartz is angular. Biotite is bent around grains. Cementing material is iron oxide.

Sample 16

Megascopic description. An iron colored shaly sand. Fine grained with large crystals of feldspar.

Microscopic description

Quartz	61.00	Rock fragments	17.00
Feldspar	5.50		
Iron oxide	16.50		

Quartz varies from minute to 1/10 mm. Crystals of feldspar are 1/2 to 4 mm in diameter. The feldspar is andesine. The slide is dirty due to the iron oxide, which is the cementing material. The iron oxide is not fragmental but fills the voids.

Sample 21

Megascopic description. A very fine grained red shaly sand.

Microscopic description

Quartz	65.75	Rock fragments	16.75
Calcite	2.25	Iron oxide	7.75
Feldspar	7.50		

The average grain diameter is 1/8 mm. Some of the particles are silt size 1/32 mm. An occasional calcite crystal within a calcite seam will be up to 1/4 mm. The very few blades of mica which occur are aligned with the bedding plane.

The petrographic work indicates that the matrix samples are made up of essentially the same material as the pebbles that are present. The lack of feldspars and the predominance of quartz and rock fragments would place the matrix samples in the lithic arenite group.

STRUCTURE

The dominant structural feature of the region is the Lake Superior syncline which is a topographic basin. The center of this basin has been crowded out of place and lifted up. Two postulations have been proposed by Lane (1911). Slow contraction of the earth causing compression of the outer layer of crust may have sprung it up (figure 36a), or it may have been lifted up on the back of some vast sill of molten rock thrusting its way in beneath (figure 36b).

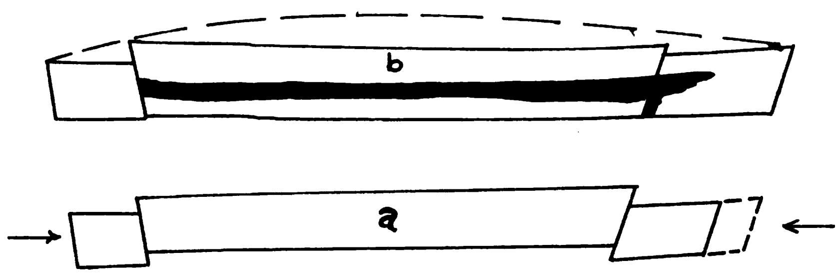


Figure 36 (after Lane, 1911, p. 21).

The south limb of the syncline is exposed along the south shore of Lake Superior from Wisconsin to Keweenaw Point. The north limb is exposed on Isle Royale and the north shore of Lake Superior. The syncline is asymmetrical, with the beds on the south dipping more steeply than those on the north. The vertical succession of rocks shows a change in dip with those at the base dipping more steeply than the upper beds.

The south limb of the syncline is irregular and contains broad anticlines and synclines that pitch down dip of the main trough. Basically there is a Keweenaw anticline, an Ontonagon syncline and a Bessemer and Ironwood anticline. Within these major folds are many subordinate folds (Butler and Burbank, 1929).

The Keweenaw fault is a major fault along the southern margin of Keweenawan exposures. The fault has been traced from near the end of Keweenaw Point to Lake Gogebic. It probably goes further east into Lake Superior and may be represented by faults to the west into Wisconsin. The fault is reverse and has forced Keweenawan rocks up and over Jacobsville sandstone of probable Cambrian age. The dip of the fault varies from 20° to 70° and in general follows the dip of the overlying lavas.

There seems to be a close relationship between folding, faulting and igneous activity in the region and this suggests a common cause.

Within the immediate vicinity of the Montreal River there are no local anticlines or synclines. However the area would be included in the Bessemer and Ironwood anticline. The dips, which along the Montreal River are steeper than either to the southwest or northeast, may be an indication that this area is nearer the axis of the anticline. This greater dip has also been postulated to be the result of a more extensive collapse in the Montreal River area, than in the other areas of the Lake Superior syncline (Aldrich, 1929). The dips in the Montreal River area are in excess of 70° N. W. while 15 miles northeast at the Black River the dips are 20° N. W. Southwest of the Montreal area the dips at the Potato River are approximately 50° N. W.

If just the Montreal River area is considered structurally, the upper Keweenawan would be classified as a homocline.

There are no recorded faults in the immediate vicinity of the Montreal River. Lane (1911) believes a fault might exist in the Freda sandstone where there are no exposures along the Montreal River. However, there is no definite proof of its existance.

GEOLOGIC HISTORY

After the Animikie deposition, the Lake Superior region was raised and subjected to a long period of erosion as evidenced by the conglomerates and other sediments. This sedimentation constituted the lower Keweenawan (Van Hise, 1911).

The middle Keweenawan began with the outbreak of regional volcanism. Interbedded with the igneous rocks are the conglomerates and sandstones derived from adjacent flows. The flows are basic while the debris is from acid rocks. This is probably the result of higher elevations attained by the acid flows.

The lower portion of the middle Keweenawan is dominantly made up of igneous rocks. More than eleven-twelfths of the section at the Black River is igneous (Van Hise, 1911).

The middle Keweenawan ended with the deposition of the Great conglomerate and the last igneous activity represented by the Lake Shore Traps. The Lake Shore Traps are absent in the Montreal River area.

The upper Keweenawan rocks are sedimentary. During this time detritus from pre-Keweenawan rocks appeared. The great thicknesses of the sediments indicate a steady subsidence of the basin during deposition.

SUMMARY AND CONCLUSIONS

The sedimentary properties of the Outer conglomerate indicate a continental origin for the formation. These properties are:

1. Rapid changes in lithology.
2. Overall thickness of formation.
3. Lack of gradational bedding.
4. Poor sorting.
5. Lithologic units thin rapidly along strike.
6. Red color, probably due to oxidizing conditions.

Using Pettijohn's classification (1957, p. 255), the Outer conglomerate would be classified as a Petromict conglomerate in the Orthoconglomerate group. These are characterized by:

1. Thick, wedge shaped, basin-margin accumulations of gravel-shed from sharply elevated highlands.

2. They may be basal or intercalated at several horizons.

3. Coarse grained variety of lithic and arkosic sandstone family.

4. One type of pebble predominates.

5. In regions of active volcanism gravels are prone to consist of felsitic lavas even though most associated flows are basic.

6. The conglomerate is marked by its coarseness.

7. It contains many unstable materials and is therefore immature.

The Outer conglomerate would be placed in the Arkosic Suite as to its consanguineous association. This facies is characterized by:

1. Coarseness of clastics.

2. High feldspathic character of beds.

3. Red color.

4. Absence of limestones.

The present day equivalent of the Outer conglomerate would be the fanglomerates or piedmont conglomerates located in the rift valleys of the United States.

The petrofabric study implies that the source area was from the southeast. The source of the material is probably Animikie, Lower and Middle Keweenawan. The mafic material is similar to the Keweenawan flows. The acidic material is probably derived from flows or volcanic plugs contemporaneous with the mafic flows. The jaspers, granites, and quartzites are probably Animikie.

As stated before the pipe amygdules of some of the flows suggest a flow from the northwest, while imbrication studies of the sedimentary rocks indicate a source from the southeast. This can be explained in that the sediments were derived from highlands to the southeast while the flows invaded the plain from the northwest. The Keweenawan sections, which we now observe, are the areas of interfingering between the flows and sediments.

SUGGESTIONS FOR FURTHER STUDY

During the writing of this thesis, other problems occurred which might warrant further study. They are:

1. A detailed sedimentary analysis of the Nonesuch shale which would disclose its composition and its source.

2. A paleocurrent study of the Keweenawan conglomerates along the northern limb of the Lake Superior syncline in order to determine the direction of sedimentation and the source area.

3. A regional study of the contact between the Outer conglomerate and the Nonesuch shale, which might disclose the environmental conditions causing the abrupt change in lithology.

4. A similar study of the Outer conglomerate along the southern limb of the Lake Superior syncline would help in the regional geologic Consanguineous association.

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Pocket has:
1 Map

MONTREAL RIVER AREA
R49W
14
13
18
MONTREAL RIVER
Power Line
T48N
T47N
23
24
FREDA SANDSTONE
CONTACT
NONESUCH SHALE
CONTACT
OUTER CONGLOMERATE
MICHIGAN
WISCONSIN
CONTACT
EAGLE RIVER GROUP
19
26
20
21
29
28
30
WIS. 122
LEGEND
OUTCROP
JOINTING
STRIKE & DIP
no's SAMPLE LOCATIONS
0 660' 1320'
SCALE
N
1959
RIE
C. STAR