



126
164
THS

SEDIMENTARY FABRICS IN
UNCONSOLIDATED SANDS

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE
Henry Carl Smith, Jr.
1952

THESIS

This is to certify that the
thesis entitled

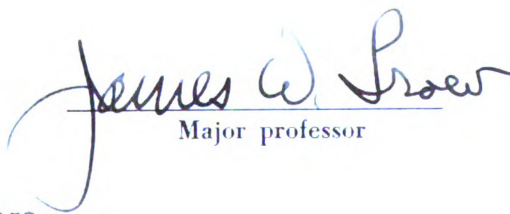
SEDIMENTARY FABRICS IN UNCONSOLIDATED SANDS

presented by

Henry C. Smith, Jr.

has been accepted towards fulfillment
of the requirements for

M.S. degree in Geology


Major professor

Date June 16, 1952

SEDIMENTARY FABRICS IN
UNCONSOLIDATED SANDS

By

Henry Carl Smith, Jr.

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Geology and Geography

1952

THESIS

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Dr. J. W. Trow for his many helpful suggestions and criticisms in the direction of the problem.

The writer is also deeply indebted to Dr. Miriam S. Lucas, of the Biological Science Department, for her aid and advice in the construction of the plastic hemisphere.

Grateful acknowledgment is also due to Dr. S. G. Bergquist for his assistance in the preparation of the manuscript and to Drs. W. A. Kelly and B. T. Sandefur for their cooperation and loan of various items of equipment.

TABLE OF CONTENTS

	Page
LIST OF PLATES	iv
LIST OF FIGURES	v
INTRODUCTION	1
PURPOSE OF THE INVESTIGATION	5
METHODS OF PLOTTING POINTS	6
THREE-AXIS UNIVERSAL STAGE	6
Description	6
Calibration	7
Operation	10
Construction	10
SAMPLING	11
Purpose	11
Equipment	11
Procedure	12
ANALYSIS OF SAMPLE DATA	14
General Explanation	14
Beach Sample	14
Current Ripple-mark	15
Wind Ripple-mark	18
Oscillation or Wave Ripple-mark	22
CONCLUSION	29
BIBLIOGRAPHY	30

LIST OF PLATES

Plate	Page
I. Three-axis Universal Stage, Disassembled	8
II. Operation of Three-axis Universal Stage	9
III. Sampling Equipment	13

LIST OF FIGURES

Figure	Page
1. Comparison of Long Dimension Elongation and Least Projection Elongation	2
2. Maximum Projection Area	2
3. Beach Sample, <u>ld</u> Fabric	16
4. Beach Sample, m.p.a. Fabric	16
5. Cross Section and Top View of Current Ripple Mark	17
6. Current Ripple Mark, <u>ld</u> Fabric (A to B)	19
7. Current Ripple Mark, m.p.a. Fabric (A to B)	19
8. Current Ripple Mark, <u>ld</u> Fabric (B to C)	20
9. Current Ripple Mark, m.p.a. Fabric (B to C)	20
10. Current Ripple Mark, <u>ld</u> Fabric (C to D)	21
11. Current Ripple Mark, m.p.a. Fabric (C to D)	21
12. Wind Ripple Mark Cross Section	24
13. Oscillation Ripple Mark Cross Section	24
14. Wind Ripple Mark, <u>ld</u> Fabric (A to B)	25
15. Wind Ripple Mark, m.p.a. Fabric (A to B)	25
16. Wind Ripple Mark, m.p.a. Fabric (B to C)	26
17. Wind Ripple Mark, <u>ld</u> Fabric (B to C)	26
18. Oscillation Ripple Mark, <u>ld</u> Fabric (A to B)	27
19. Oscillation Ripple Mark, m.p.a. Fabric (A to B)	27
20. Oscillation Ripple Mark, m.p.a. Fabric (B to C)	28
21. Oscillation Ripple Mark, <u>ld</u> Fabric (B to C)	28

INTRODUCTION

Very little petrofabric work has been attempted on sediments and sedimentary rocks in comparison with that already accomplished in the study of igneous and metamorphic rocks. This is largely because in the latter two fields, the investigations are concerned with crystallographic elements such as optic axes, poles to cleavage and twinning planes while in sediments, the interest is in the physical directions of the individual grains.

Crystallographic elements can be determined and their directions measured by means of a petrographic microscope equipped with a universal stage, but determining the physical directions of individual clastic grains has proven somewhat more difficult.

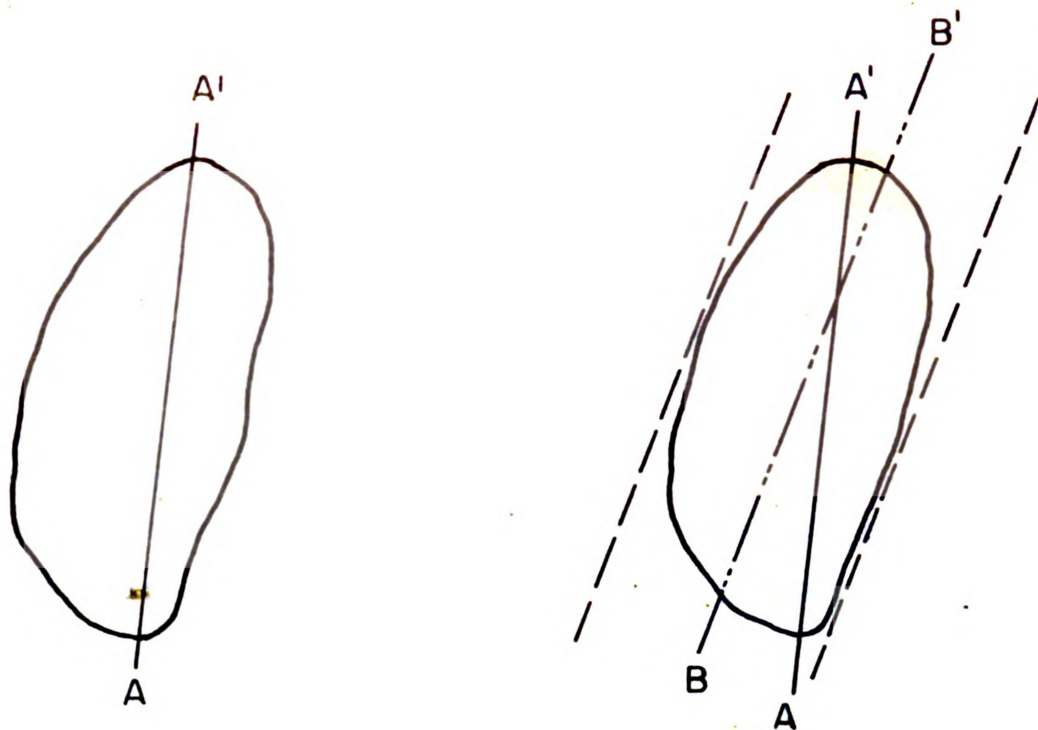
The two most important physical dimensions of a grain are the longest direction (ld), and the maximum projection area (m.p.a.). In the following diagrams, those showing the long dimension actually represent the "least-projection elongation" of Dapples.*

*Dapples, E. C., and Rominger, J. F., Orientation Analysis of Fine-grained Clastic Sediments: Journal of Geology, Vol. 53, 1945, p. 251.

He has defined this elongation direction as that of two parallel lines with the minimum amount of separation that can be drawn tangent to the grain (Figure 1).

The maximum projection area is explained by Krumbein* as the plane

*Krumbein, W. C., Preferred Orientation of Pebbles in Sedimentary Deposits: Journal of Geology, Vol. 47, 1939, p. 677.



Long Dimension Elongation
A - A'

Least Projection Elongation
B - B'

Figure 1. Comparison of Long Dimension Elongation and Least Projection Elongation

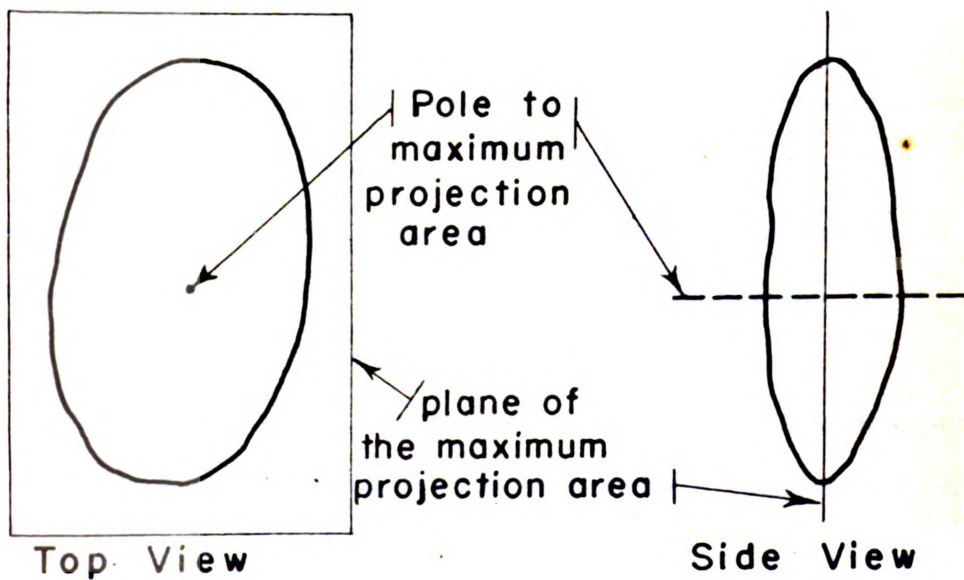


Figure 2. Maximum Projection Area

defined by the longest and intermediate diameter of the grain. The position of this area can be located by the co-ordinates of a pole perpendicular to the surface of this plane.

Krumbein* and others have demonstrated that it is possible to

*Ibid., pp. 673-706.

prepare orientation diagrams when the particles were large enough to be sampled individually, but this, of course, is not possible with items as small as sand grains.

Dapples* found definite orientation in a given plane and prepared

*Dapples, E. C., and Rominger, J. F., op. cit., pp. 246-261.

two-dimensional fabric diagrams. Shortly afterwards Rowland* developed

*Rowland, R. A., Grain-shape Fabrics of Clastic Quartz: Geological Society of America Bulletin, Vol. 57, 1946, pp. 547-564.

a technique for preparing orientation diagrams of fine-grained clastic sediments in three dimensions. He determined statistically the angular relationship between the optic axis of quartz grains and their physical dimensions and used this data to construct grain-shape diagrams from optic axis diagrams.

The most recent published improvement in sedimentary petrofabrics was developed by Schwarzacher* who successfully constructed grain-shape

*Schwarzacher, W., Grain Orientation in Sands and Sandstones: Journal of Sedimentary Petrology, Vol 21, 1951, pp. 162-172.

diagrams with a binocular microscope and a two-axis universal stage. With this method the grain's ld was brought to a horizontal N-S position using the N-S hair of the binocular as a reference line. The azimuth and dip of the grain's original position was determined by reading the angles on the universal stage and these values were plotted in the conventional "Schmidt" equal-area net. The stereoscopic view obtained with the binocular gave a sufficiently accurate estimation of both horizontal and vertical directions and the author was able to produce definite orientations with forms of wind and water deposition under experimental conditions.

PURPOSE OF THE INVESTIGATION

The purposes of this study are as follows:

1. To investigate the possibility of shortening and improving the procedure used in sedimentary petrofabric work without a corresponding loss in accuracy.
2. To devise a satisfactory method of collecting permanent oriented samples of unconsolidated sands.
3. To test these methods in an effort to determine the effects of various components of a natural environment on small sedimentary features.

METHODS OF PLOTTING POINTS

Petrofabric diagrams are conventionally produced by means of the "Schmidt" equal-area net which represents the inside of the lower one-half of a sphere. Azimuth or strike is read from the periphery and the dip is determined by the distance from the edge of the circle. A point at the center of the hemisphere represents a vertical line while one located near the outer edge shows the line to be nearly horizontal. Any line or plane can be plotted on the net in two steps. First the proper azimuth is found on the periphery and this point is rotated to either the 90 or the 180 degree position where the dip or plunge can be marked off to give the true position of the plane or line.

As it was only necessary to plot lines and not planes, equiareal polar co-ordinate paper was substituted for the "Schmidt" net in the diagrams prepared for this problem. This method proved somewhat faster and its use has been discussed more fully by Krumbein.*

*Krumbein, W. C., op. cit., pp. 681-682.

THREE-AXIS UNIVERSAL STAGE

Description

Even with the use of a binocular, petrofabric diagrams are tedious and lengthy to prepare and these are limiting factors in their general usefulness. All of the following petrofabric diagrams were prepared with the aid of a simplified universal stage.

This instrument consists of the following three parts as shown

in Plate I.

1. Six-inch hollow plastic hemisphere ruled at five degree intervals with a vertical center post flattened on one side.
2. Plastic sample stage with two magnets, spring clip and a simplified mechanical stage.
3. Circular plastic ring base with four reference points (N, S, O, and E) and three reference arms.

Specimens to be examined were glued to their metal sample slides (Plates I and II) and the slides were held to the stage by the two magnets fastened underneath the stage platform. To facilitate the movement of the sample, a small mechanical stage (Plates I and II) was added and this allowed both N-S and E-W traverses. The stage fitted on the center post of the hemisphere and was held at any desired elevation by the friction of the steel spring on the flattened center post. The hemisphere merely rested in the plastic ring base and was movable in any direction.

Calibration

The instrument was calibrated by adjusting the hemisphere so that zero degrees azimuth coincided with point "N", 90° with point "E", 180° with point "S", and the center with point "O". Then the binocular was moved so that the center of the field was directly over a center point marked on the stage and the N-S crosshair paralleled a N-S line of the stage. The instrument was then ready for use except for occasional vertical adjustments of the stage to allow for variable sample thickness. Any grain near the center of the field at the proper elevation was at the center of the hemisphere and could be observed even when rotated 70 degrees in a vertical direction.

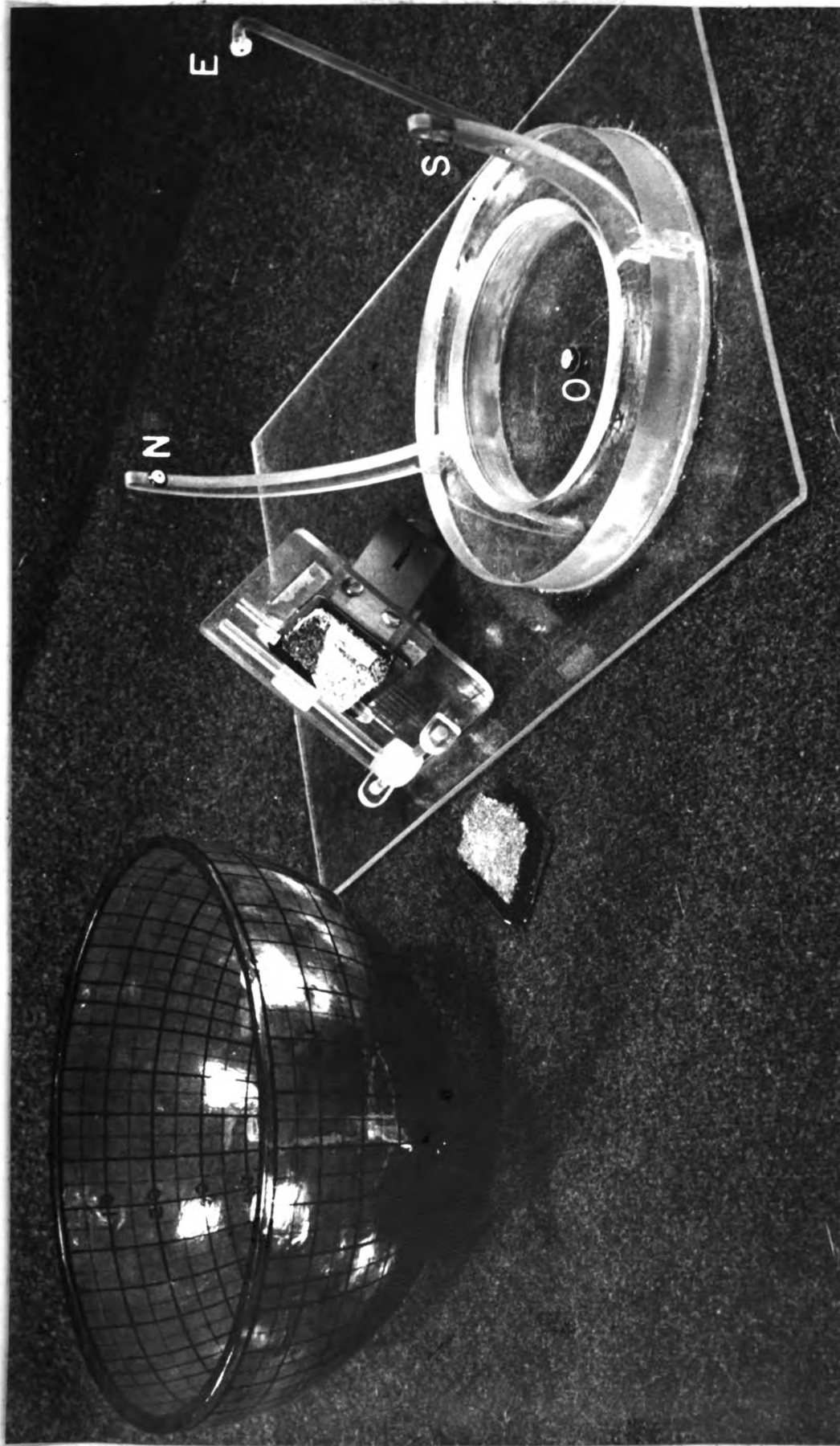


PLATE I The three - axis universal stage, disassembled

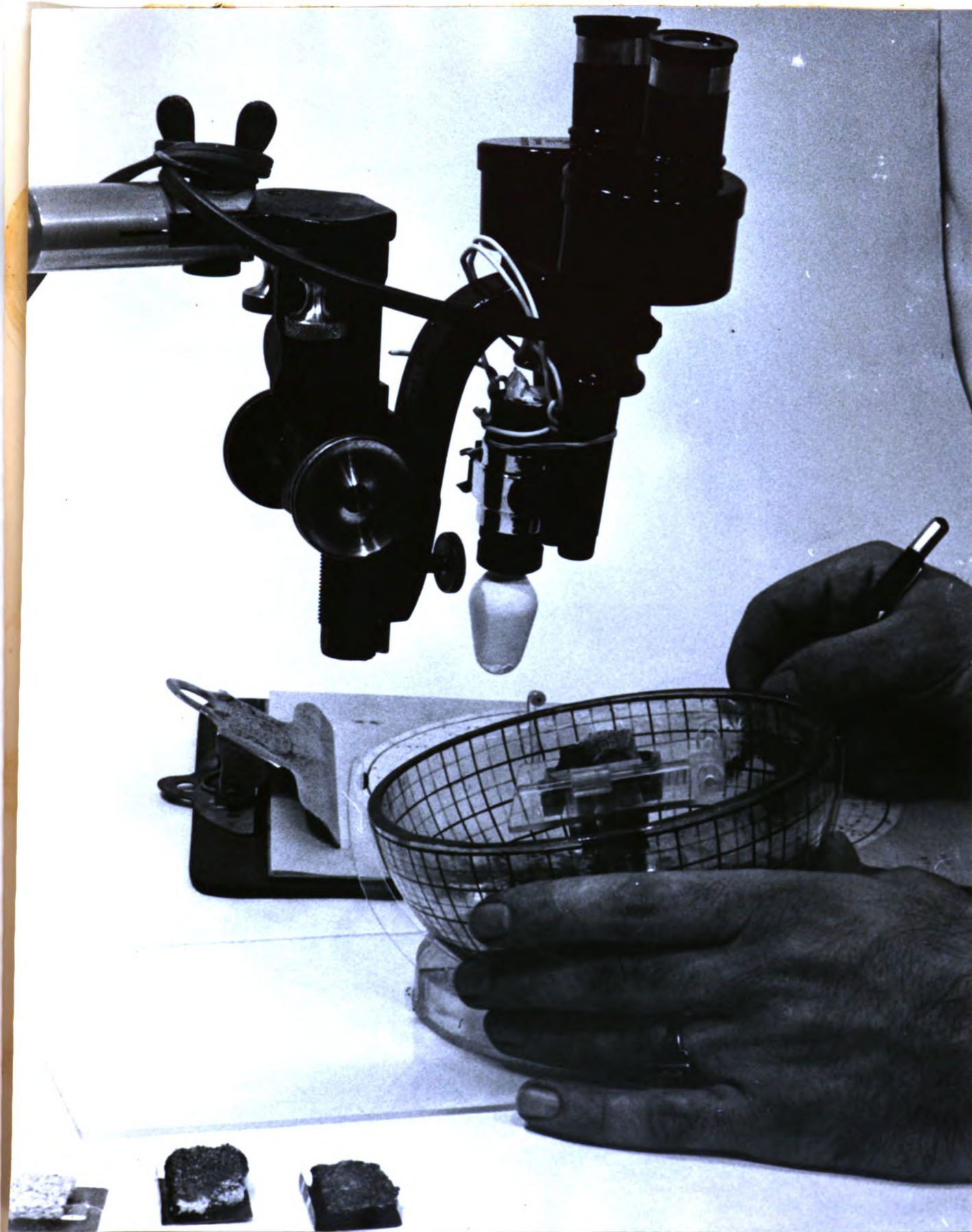


PLATE II Operation of the three-axis universal stage

Operation (Plate II)

Once a sample was adjusted on the stage, a grain was brought into position under the crosshairs so that its long dimension paralleled the N-S crosshair and its m.p.a. was perpendicular to the microscope axis. The original position of the grain was then determined by observing the position of the reference points through the transparent hemisphere. The position of the long-dimension was found at either "N" or "S", depending on whether the grain dipped north or south. The m.p.a. was located at "O" which is 90° from both "N" and "S" and directly in line with the axis of the binocular.

With steeply dipping grains the procedure was reversed; the ld was brought to the vertical position and plotted at "O" while the m.p.a. was found at either "n" or "S". Occasionally a grain was encountered with both ld and m.p.a. almost horizontal. In this case the long-dimension of the grain was made to parallel the E-W crosshair, the ld was located at point "E" and the m.p.a. at either "N" or "S".

Construction

With the exception of the hemisphere, the instrument was made of readily obtainable sheet and tubular plastic. The details of construction may be observed in Plate II. The hemisphere was molded from liquid casting plastic sold by the Castolite Company of Woodstock, Illinois or Ward's Natural Science Establishment of Rochester, New York.

The mold was constructed from plaster of Paris. An ordinary six-inch rubber ball was used as a form for the outer mold and was cut in half when used as a form for the inner mold. To prevent the penetration

of the plaster by the liquid plastic, the mold was sprayed with a thin solution of Molding Compound No. 10099-A made by American Anode, Incorporated, of Akron, Ohio. Lines of ordinary India ink were ruled on the hemisphere with the aid of a curved ruler and drawing compass and these were protected by several coats of lacquer.

SAMPLING

Purpose

Sandstones capable of having their surfaces roughened so that the individual grains can readily be observed under a binocular are fairly common, but the petrofabric diagrams prepared from such specimens are of little if any interpretive value. Samples prepared experimentally are excellent for interpretation, but these can hardly duplicate natural conditions of sedimentation. For these reasons it was decided to confine the following limited investigation of sedimentary fabrics to recent unconsolidated sands where the effects of the natural environment could be observed and recorded. Of the four specimens examined, the beach sample and both the wind and current ripple-marks were collected in the field while the oscillation ripple-mark was formed under experimental conditions.

Equipment (Plate III)

Several types of impregnating materials were tried and the following two plastics were found to be most satisfactory for consolidating incoherent sands into samples suitable for use under a binocular: A five percent solution of either vinylite VYHH plastic or cellulose acetate and

acetone gave equally good results. A complete account of the use of these materials is given by Smith.*

*Smith, H. W., and Moodie, C. D., Collection and Preservation of Soil Profiles: Soil Science, Vol. 64, 1947, pp. 61-67.

These materials are almost invisible in the hand specimen and show only as a thin coating over the individual grains under the binocular. Additional equipment consisted of a small hand spray gun, an eyedropper, several 2 X 2 inch squares of thin metal and sample containers made by cutting cans in half and sharpening the cut edges.

Procedure

The sharpened cans were first pressed down to a depth of one to two inches in the area to be sampled. The spray gun was used to apply a thin coat of plastic over the enclosed area. Once this protective coating was applied, additional plastic was carefully flowed on with an eyedropper until the sample was saturated. The sample was then oriented, an area was cleared to one side and the thin supporting metal square was slipped under both the can and impregnated sand.

The proper percentage of plastic in the solution was found to be dependent upon both grain size and the amount of moisture present. For any particular sample the percentage was best determined by experimentation. The time required to harden is also variable and depends upon sample size, grain size and moisture. The samples should be handled with care for at least twenty-four hours after collection.

After the specimens were completely hardened, they were removed from the cans and cut to the required size with a fine-bladed coping saw.



PLATE III Sampling equipment

ANALYSIS OF SAMPLE DATA

General Explanation

In each of the following petrofabric diagrams, the contours show the percentage density of 200 points which represent the orientation concentrations of either the long dimension or the maximum projection area of 200 sand grains.

All the diagrams have been rotated to a horizontal plane with the exception of that of the beach sample which lies in the plane of the beach surface.

All grains were not counted because in some cases it was impossible to determine the true shape of a grain with the stereoscopic view afforded by the binocular.

Beach Sample (Figures 3 and 4)

The beach sample was obtained near the top of the wave limit on Lake Michigan, east of Gary, Indiana. The strike of the beach at this location was $N 80^{\circ} E$, the strike of the incoming waves was $N 84^{\circ} W$, and the wind direction was approximately $N 25^{\circ} E$. The sample was oriented N-S in the plane of the beach which dipped nine degrees to the north.

The diagrams (Figures 3 and 4) of the ld and m.p.a. show an interesting relationship between the slope of the beach and the action of the incoming waves. On striking the shore, smaller waves were reoriented perpendicular to the shoreline while the larger waves struck at an angle and the water expended its energy in a curving horseshoe-like path.

In Figure 3 the ld diagram shows a definite imbrication or shingle-like arrangement of the grains toward the wave direction. This

arrangement offers maximum resistance to reorientation and least resistance to the flow of the depositing medium. The imbrication of larger particles in beach and stream deposits has been discussed by Lahee.*

*Lahee, F. H., Field Geology, McGraw-Hill Book Company, New York, 1941, pp. 94-95.

There are also four small maxima near the strike of the waves and this suggests some rolling of the grains parallel to the beach. The two smaller maxima located at the shoreward edge might be explained as imbrication toward the returning waves; one toward the weaker waves returning directly and the other toward the stronger waves returning by a curving path.

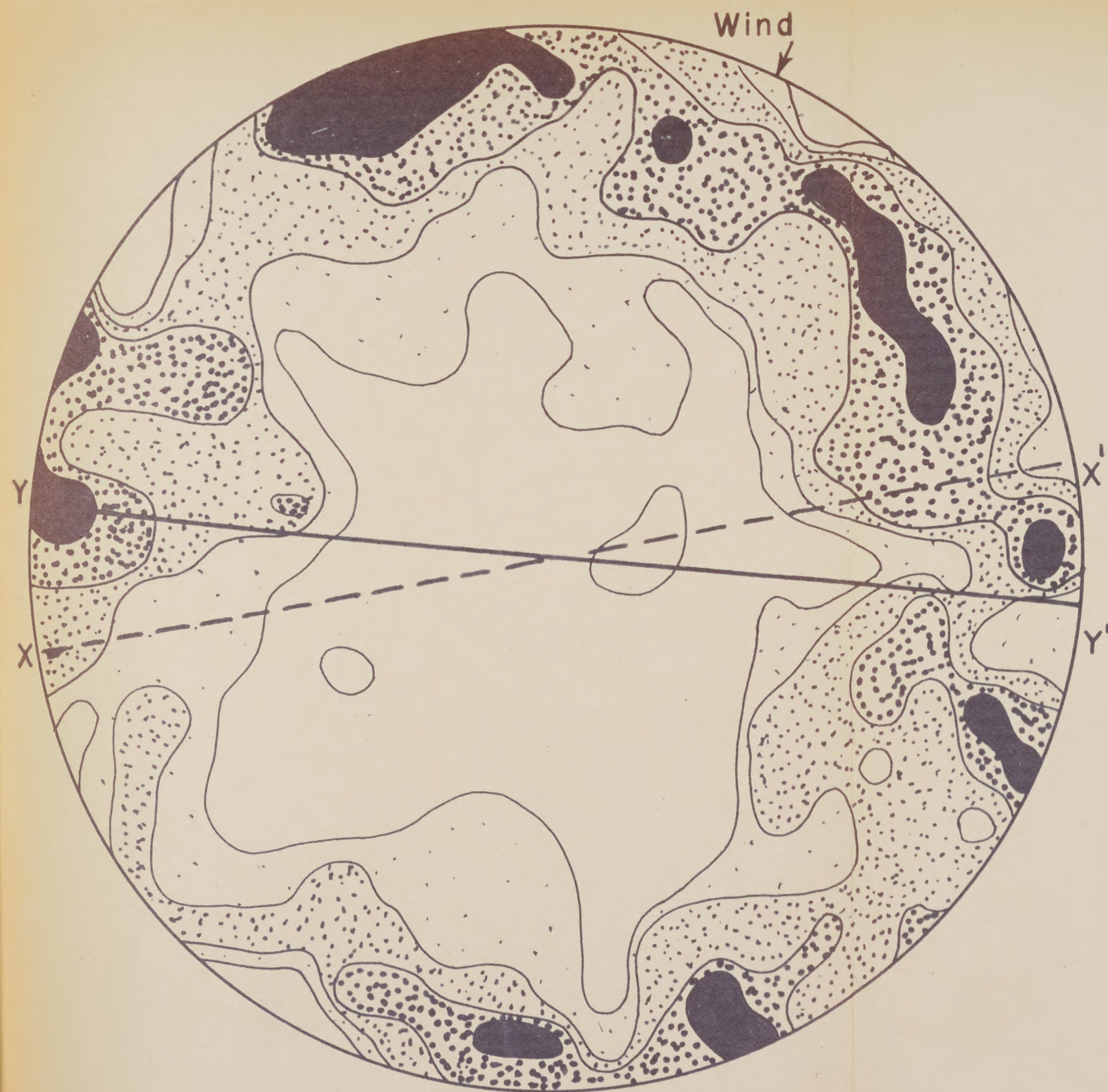
The m.p.a. diagram (Figure 4) has little interpretive value except to support the theory of imbrication and to show that the majority of the grains lie with their m.p.a. close to the plane of the beach slope. The results are very similar to those obtained by Krumbein* in

*Krumbein, W. C., op. cit., pp. 702-705.

his work on dolomite pebbles.

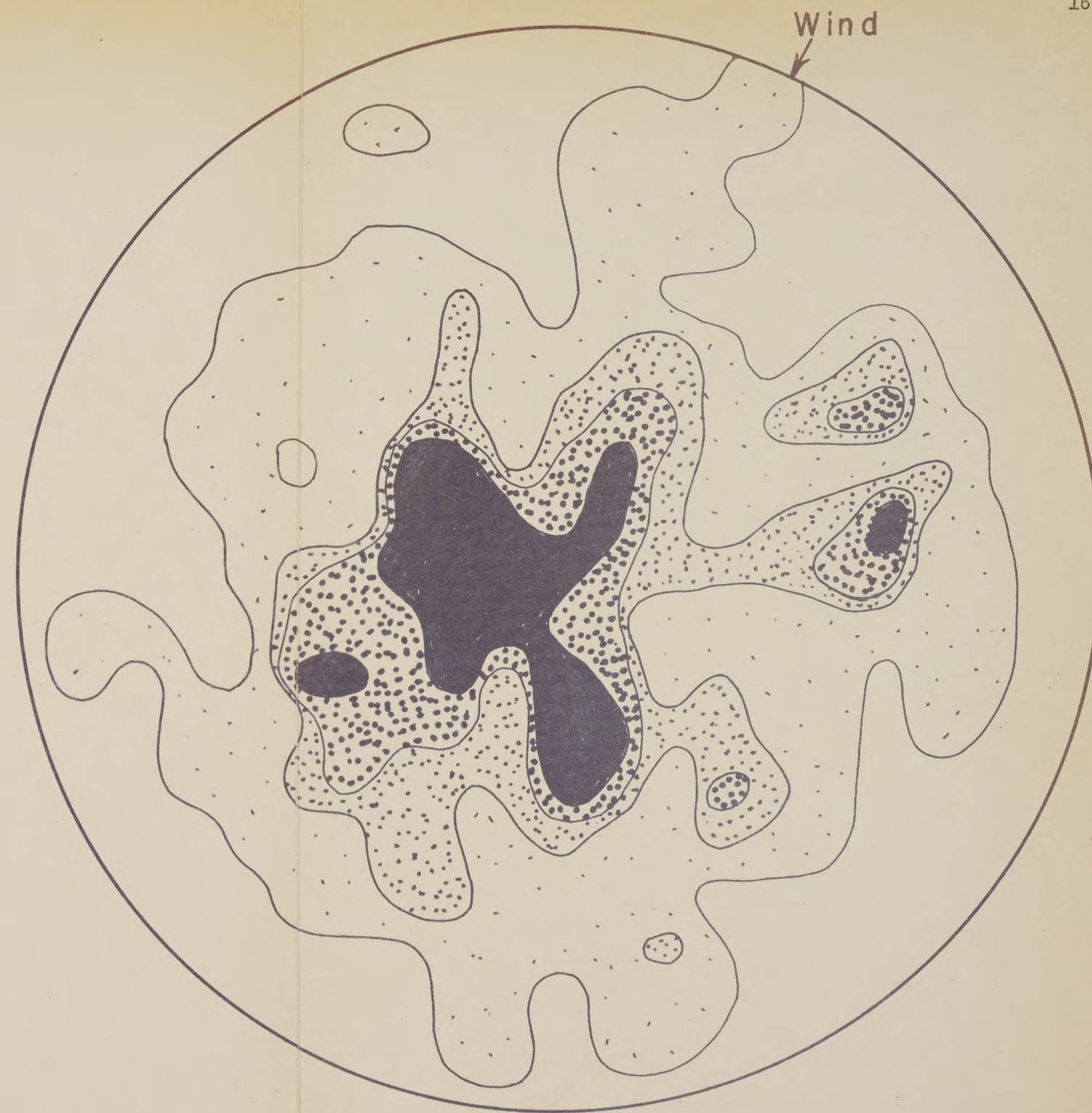
Current Ripple-mark

The current ripple-mark was collected near the beach south of Grand Haven, Michigan. It was chosen because its axis did not lie perpendicular to the current direction and the resulting diagram shows the combined effects of both current and slopes. Close observation disclosed that the ripple contained three distinct and different slopes and petrofabric diagrams were prepared for each of these.



Beach Sample
Long-dimension Fabric > 3-2-1-0 %
Strike of beach X-X', Strike of waves Y-Y'

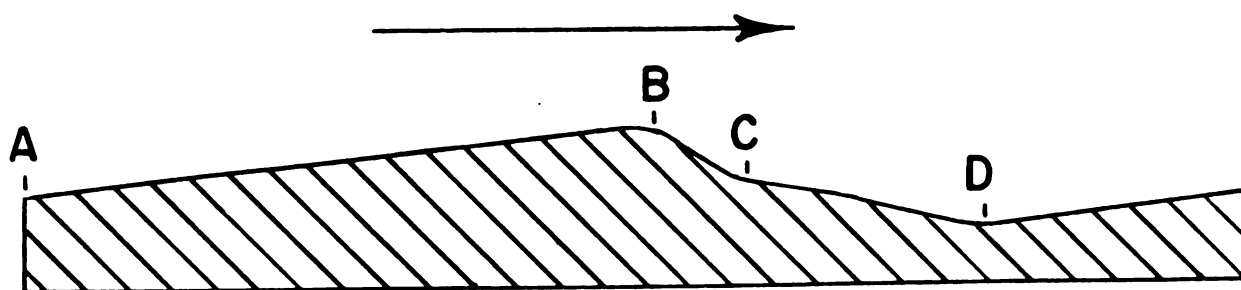
Figure 3.



Beach Sample
m.p.a. Fabric > 5-4-3-2-0 %
Strike of beach X-X', Strike of waves Y-Y'

Figure 4.

Cross section of current ripple-mark (2X)



Wave length - 3.2 inches

Amplitude - 0.23 inches

Top view - current ripple-mark (2X)

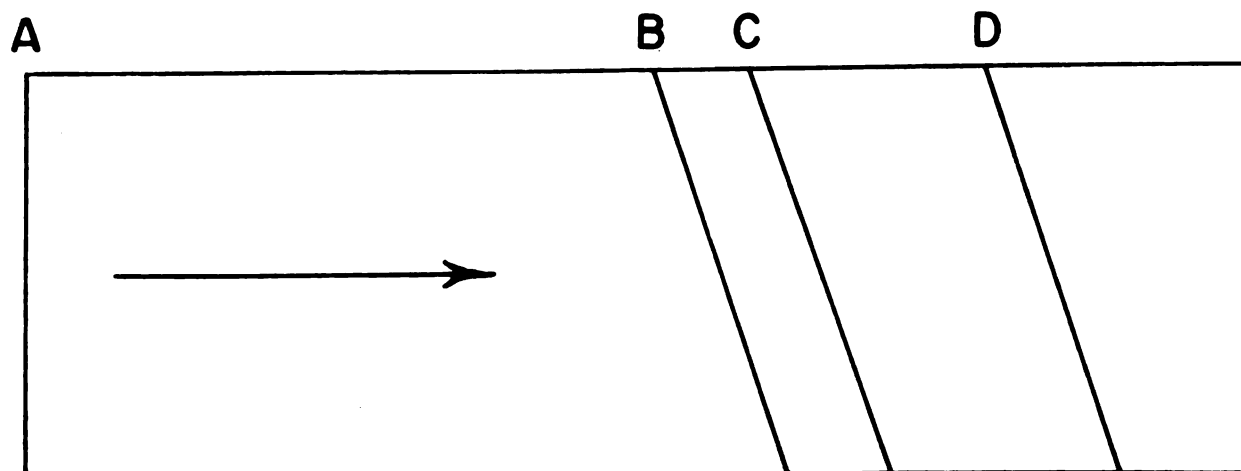


Figure 5. Cross Section and Top View of Current Ripple-mark

In the area from A to B (Figure 5), which sloped toward the current direction, both the m.p.a. and ld diagrams (Figures 6 and 7) showed a distinct imbrication toward the current direction.

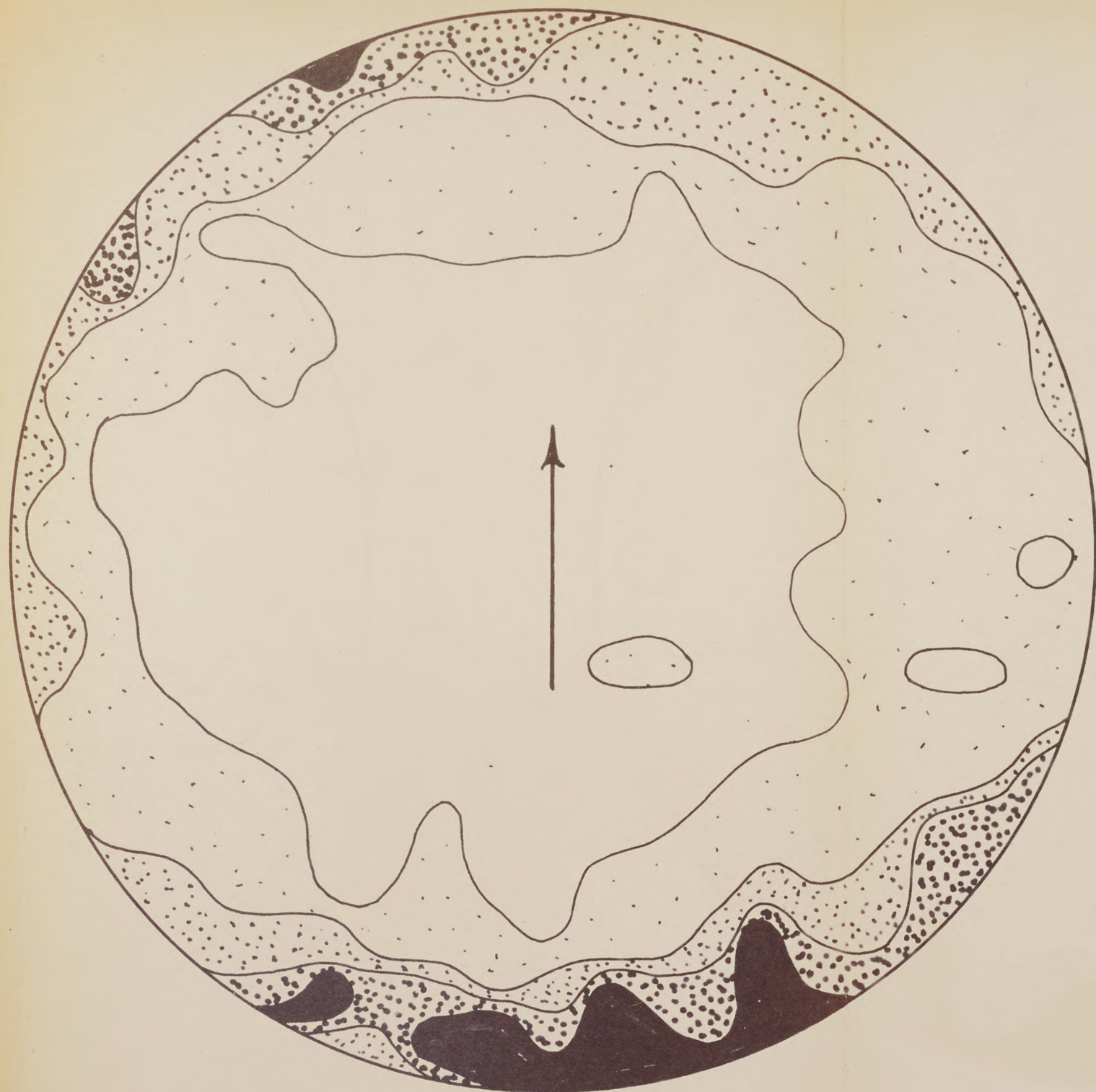
In Figures 8 and 9, representing the area from B to C, the effects of both current and slope were apparent. There was a noticable girdle from lower left to upper right which corresponds to the plane and direction of the slope. The maxima of both the ld and m.p.a. have been pushed to the left and right respectively because of the effects of the slope.

The area from C to D (Figures 10 and 11) showed a diminished imbrication in the current direction and the development of fairly strong maxima at the sides. These maxima may represent grains rolling perpendicular to the current direction because of the turbulence of the current after passing over the crest of the ripple-mark. This possibility of rolling grains was also supported by the m.p.a. diagram (Figure 10).

Wind Ripple-mark (Figures 12, 14 to 17)

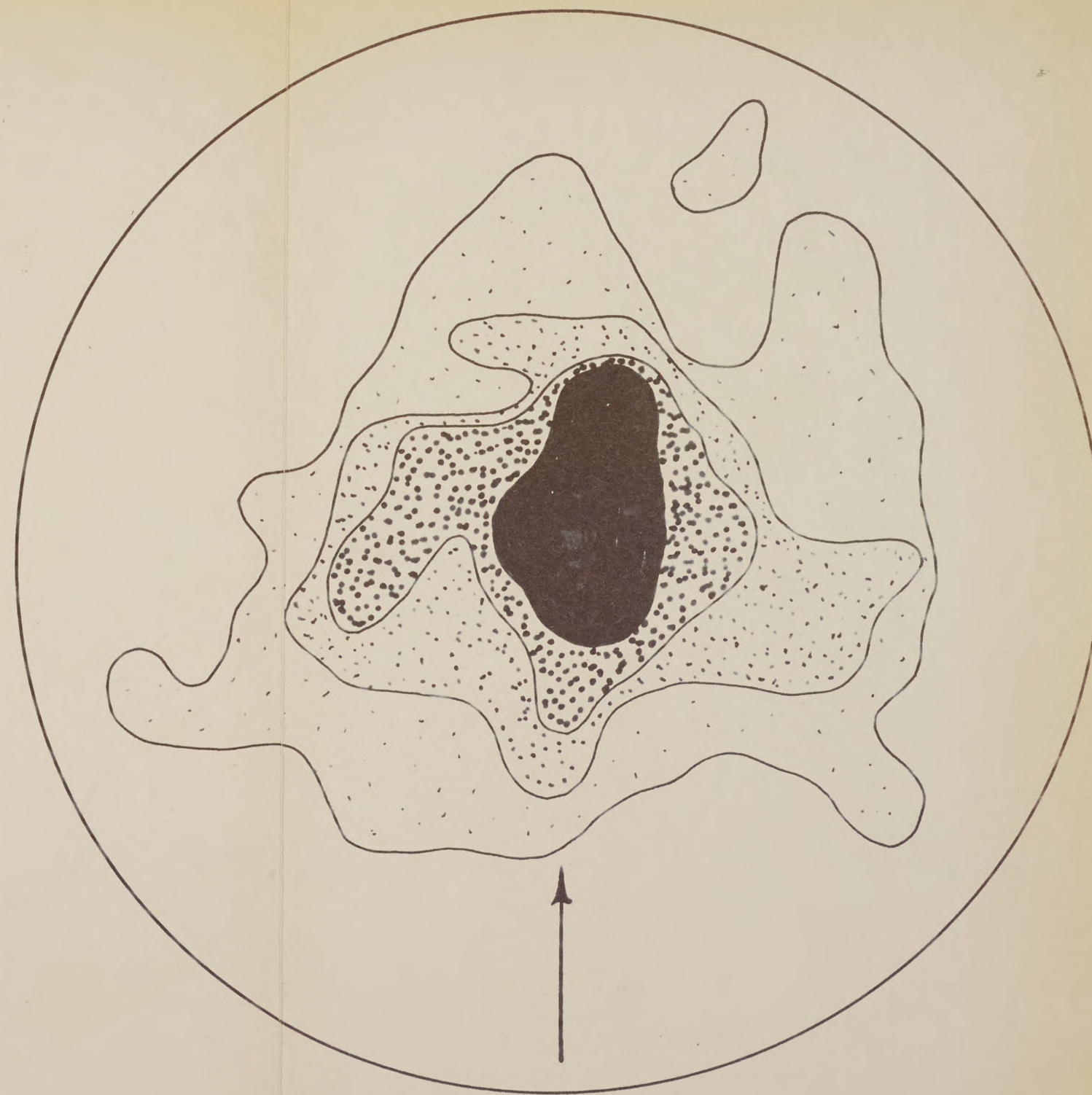
The wind ripple-mark was collected from the same area as the beach sample east of Gary, Indiana. The ld diagram of the windward slope (area from A to B) showed scattered maxima while the fabric of the lee slope had a well-developed elongation parallel to the direction of wind. This coincides with the origin of wind ripple-marks as described by Gilluly* who says the windward slopes are bombarded by the impacts

*Gilluly, J., Waters, A. C., and Woodford, A. C., Principles of Geology, W. H. Freeman and Company, San Francisco, California, 1951, pp. 368-369.



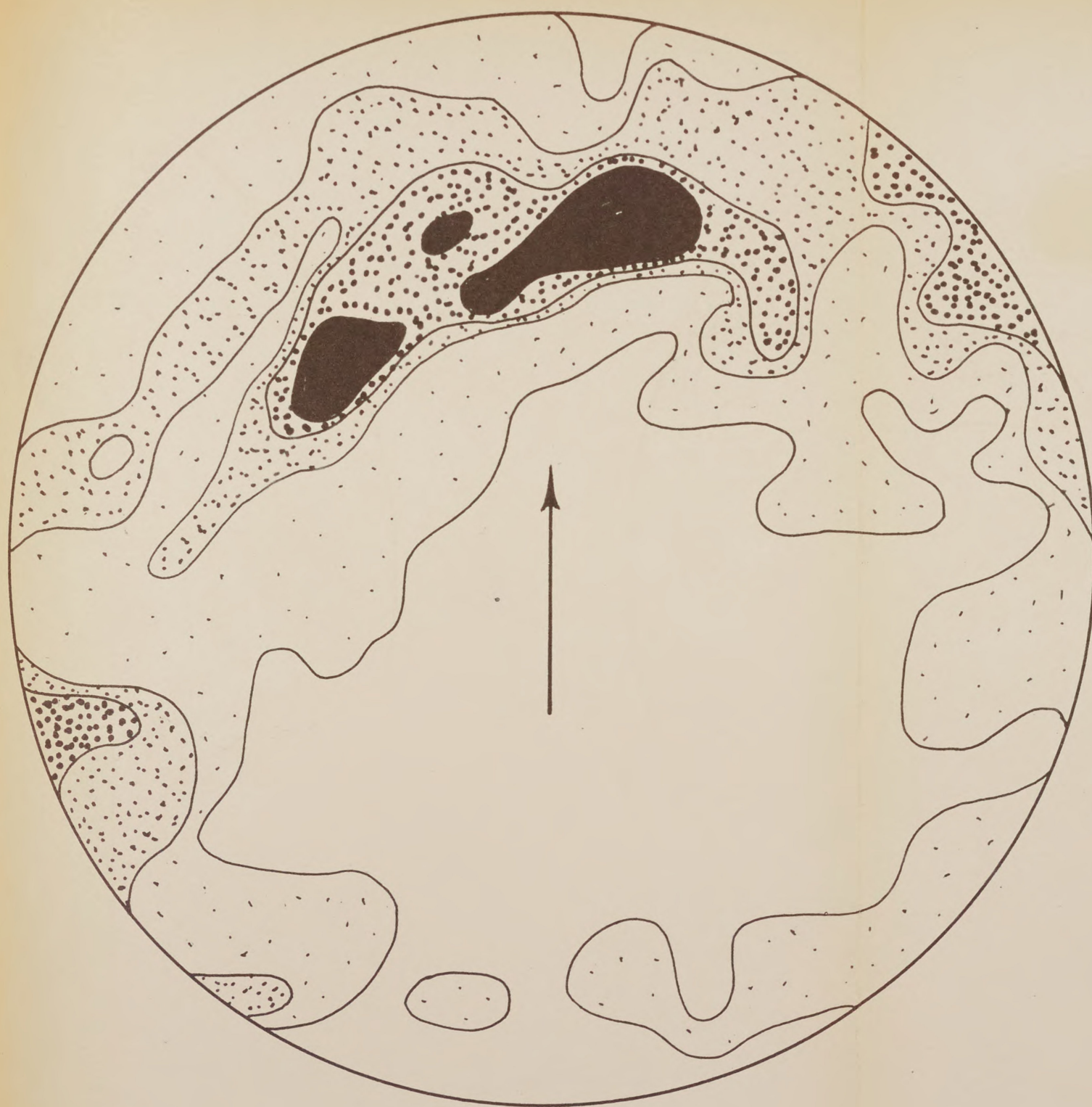
Current Ripple-mark
Long-dimension Fabric > 4-3-2-0 %
Area from A to B

Figure 6.



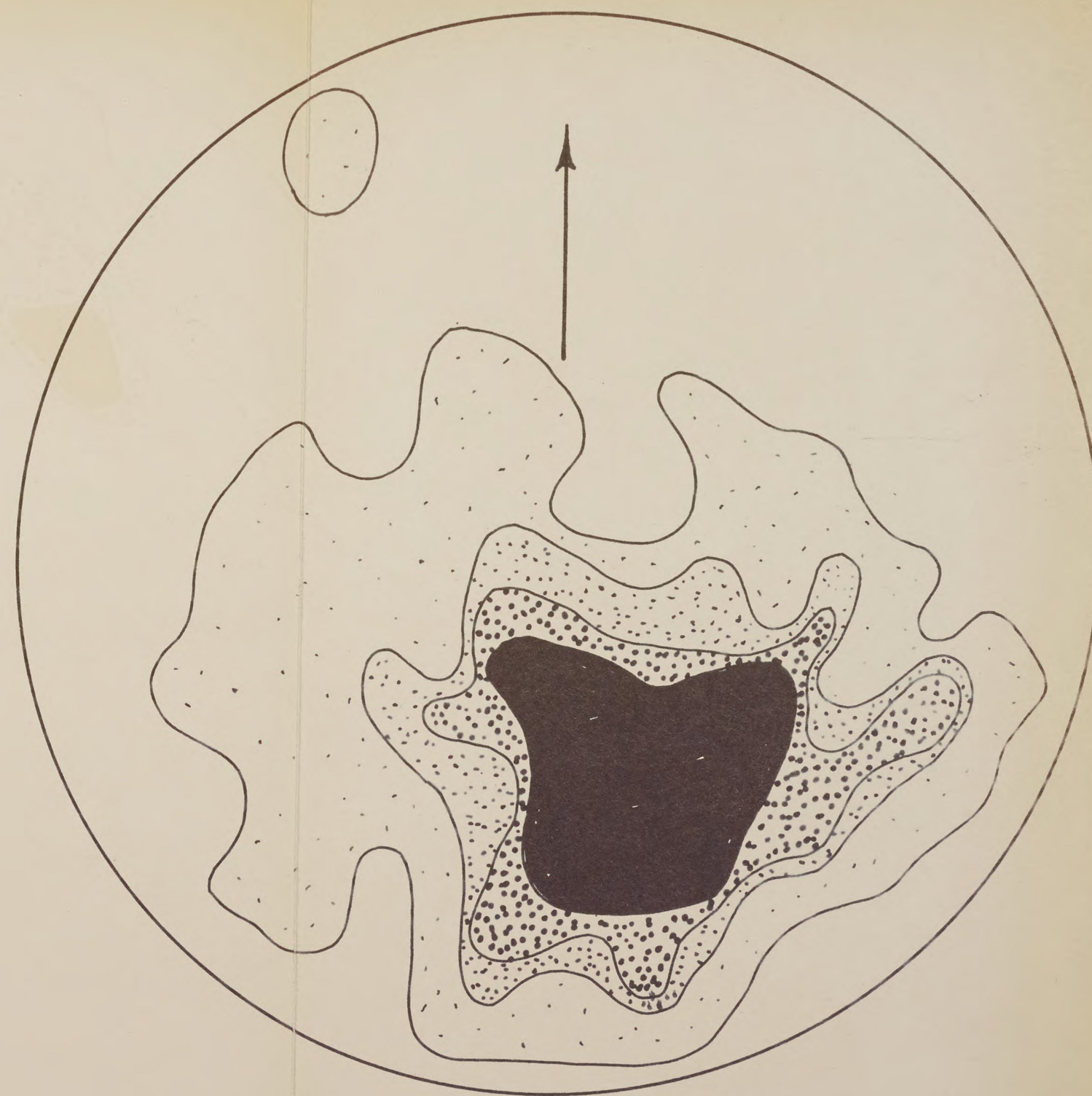
Current Ripple-mark
m.p.a. Fabric > 7-3.5-2-0 %
Area from A to B

Figure 7.



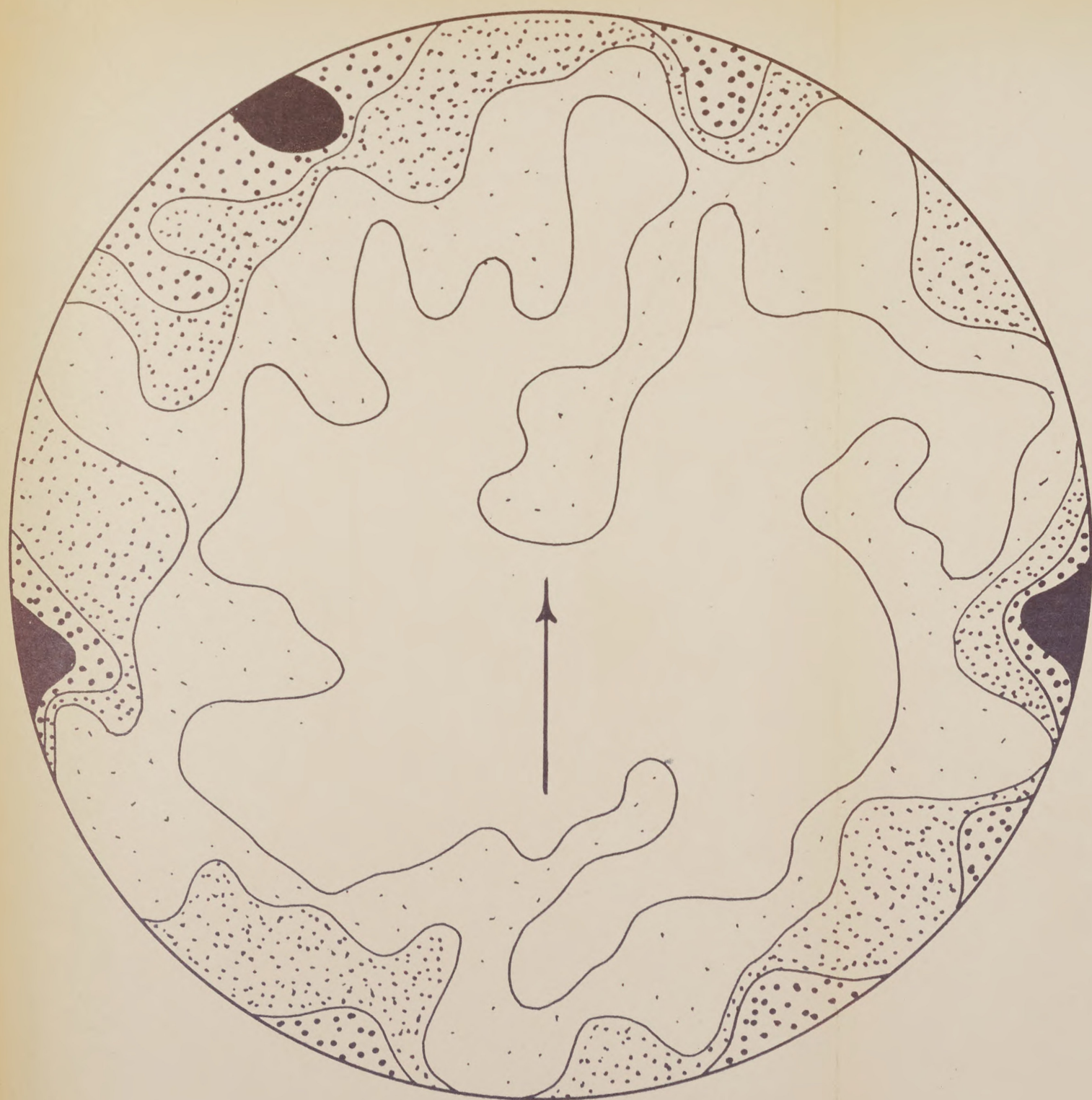
Current Ripple-mark
Long-dimension Fabric >5-4-3-2-0 %
Area from B to C

Figure 8.



Current Ripple-mark
m.p.a. Fabric >4.5-3-2-0 %
Area from B to C

Figure 9.



Current Ripple-mark
Long-dimension Fabric >4-3-2-0 %
Area from C to D

Figure 10.



Current Ripple-mark
m.p.a. Fabric >5-4-3-2-0 %
Area from C to D'

Figure 11.

of moving sand grains while the lee slopes are relatively protected. This splashing effect would probably cause a loss of orientation similar to that of Figure 14. Both m.p.a. diagrams merely showed that the majority of grains lie with their m.p.a. in the plane of the slopes.

Oscillation or Wave Ripple-mark (Figures 13, 18 to 21)

The oscillation ripple-mark was formed experimentally in a small tank one foot wide and four feet long. Short boards dipping toward the center of the tank were placed at the ends to simulate beaches and to reduce turbulence. The ripples were formed by the oscillatory action of the water moving between the ends of the tank. It was presumed, before attempting the experiment, that the ld might parallel the strike of the ripple as Ingerson* thought might be the case in his work

* Ingerson, E., Fabric Criteria for Distinguishing Pseudo Ripple-marks from Ripple-marks: Geological Society of America Bulletin, Vol 51, 1940, pp. 557-570.

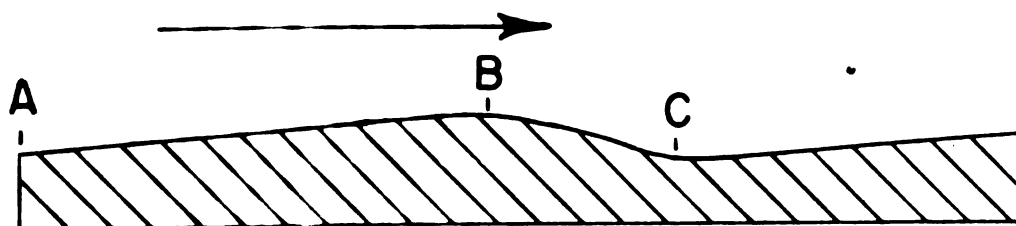
using the optic axis of quartz. A strong maximum was found almost parallel to the ripple-mark axis in both trough and crest areas, but there was also an equally strong maximum perpendicular to the axis and parallel to the current. The question as to whether this is normally the case or merely a quirk of the experiment will have to await further investigation.

The fact that the maxima parallel to the current direction, in both the trough and slope areas, were located on the same side of the diagram suggests the future possibility that wave ripple-marks may

reveal the direction of paleogeologic shorelines under petrofabric analysis.

An interesting observation was the fact that the crest and slope areas were composed of larger grains, rather loosely packed, while the trough area was composed of smaller grains, apparently winnowed from above, and these formed a tight, pavement-like surface.

Cross section of wind ripple-mark (2X)

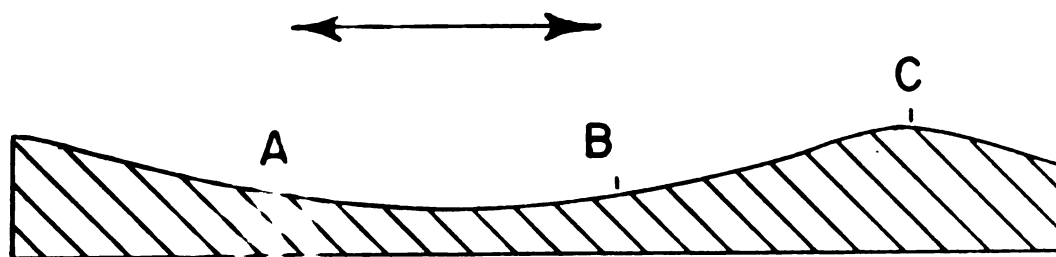


Wave length - 2.6 inches

Amplitude - 0.13 inches

Figure 12. Wind Ripple-mark Cross Section

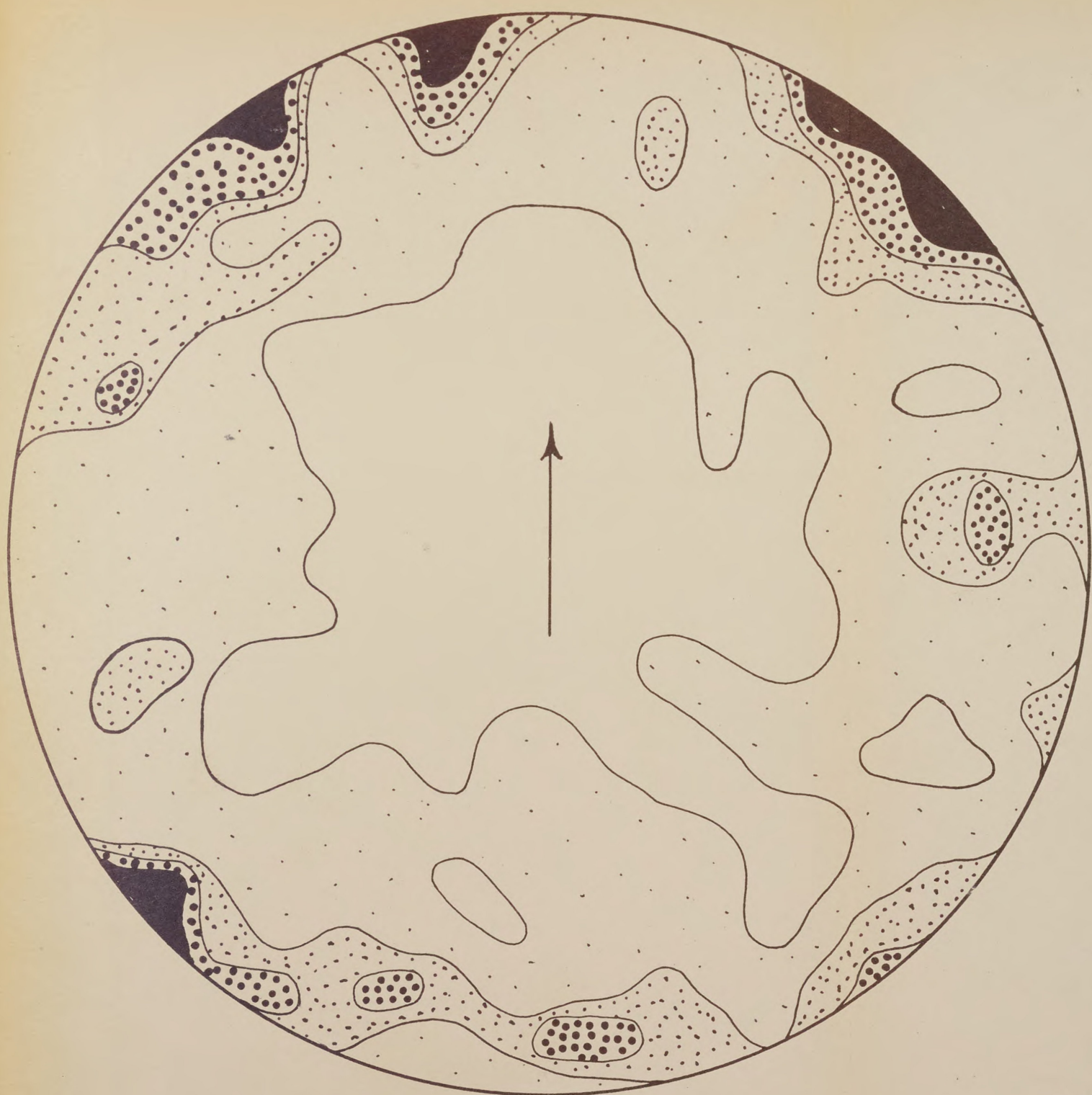
Cross section of oscillation ripple-mark



Wave length - 2.3 inches

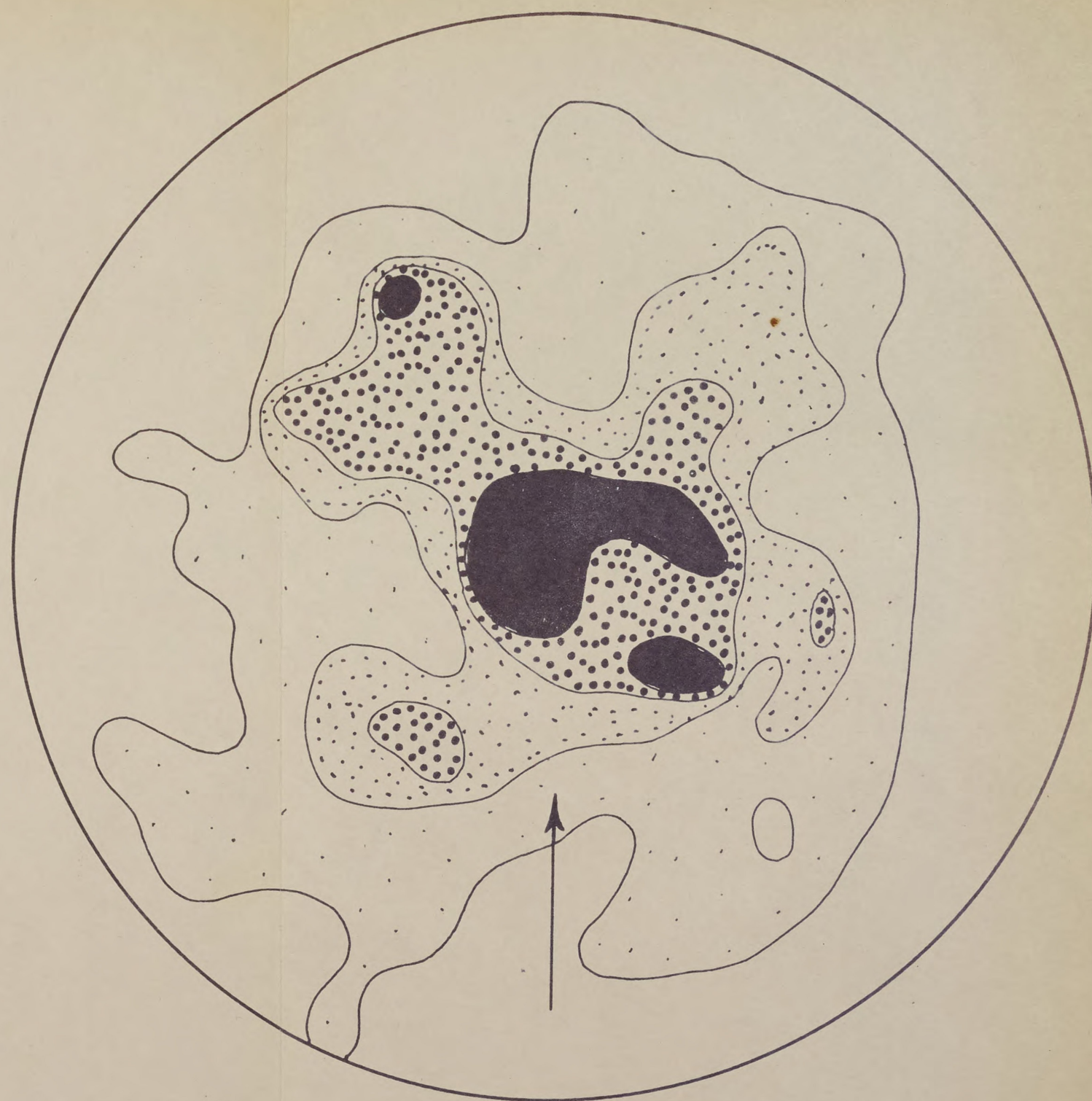
Amplitude - 0.21 inches

Figure 13. Oscillation Ripple-mark Cross Section



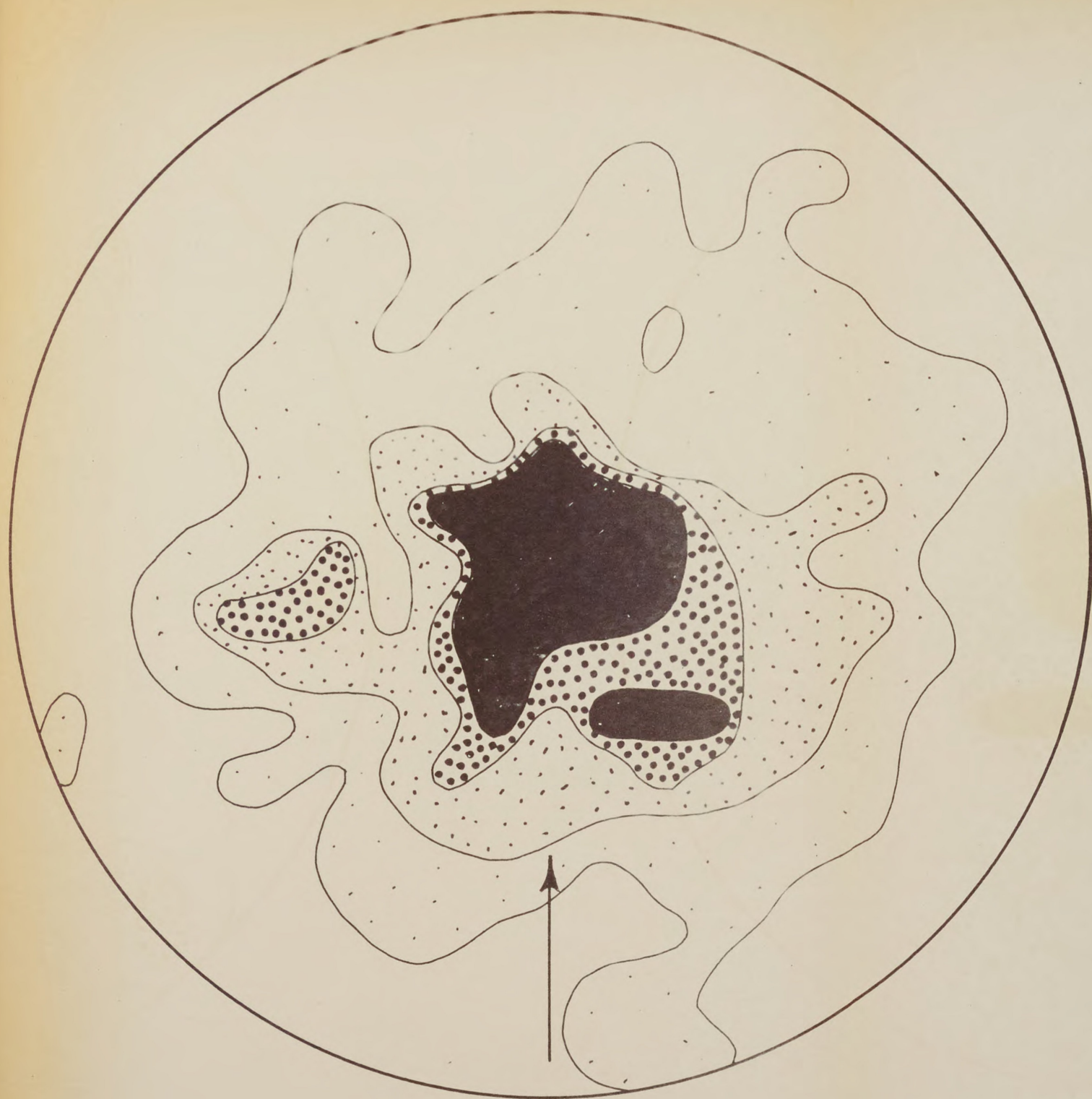
Wind Ripple-mark
Long-dimension Fabric > 4-3-2-0 %
Area from A to B

Figure 14.



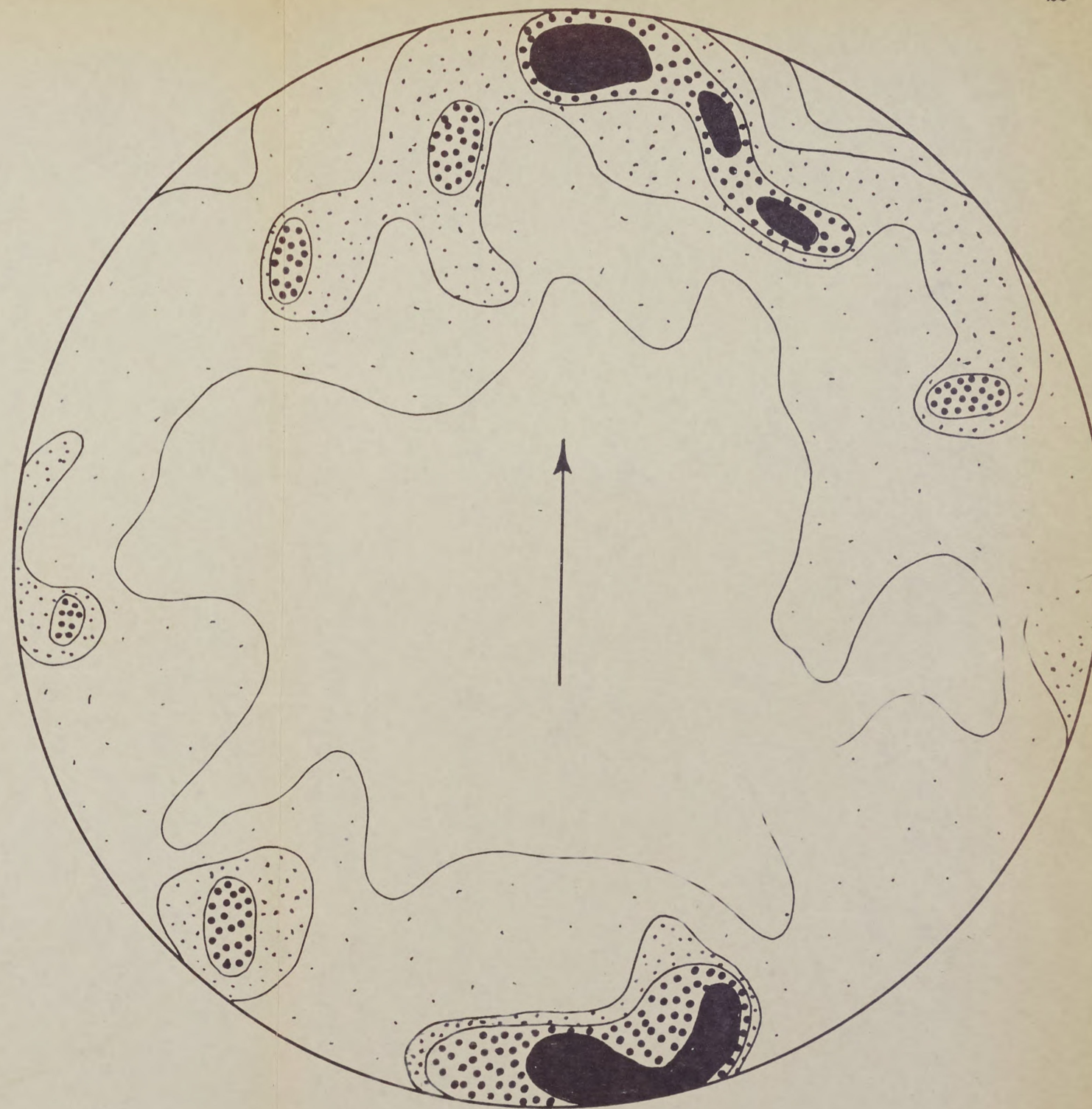
Wind Ripple-mark
m.p.a. Fabric > 4-3-2-0 %
Area from A to B

Figure 15.



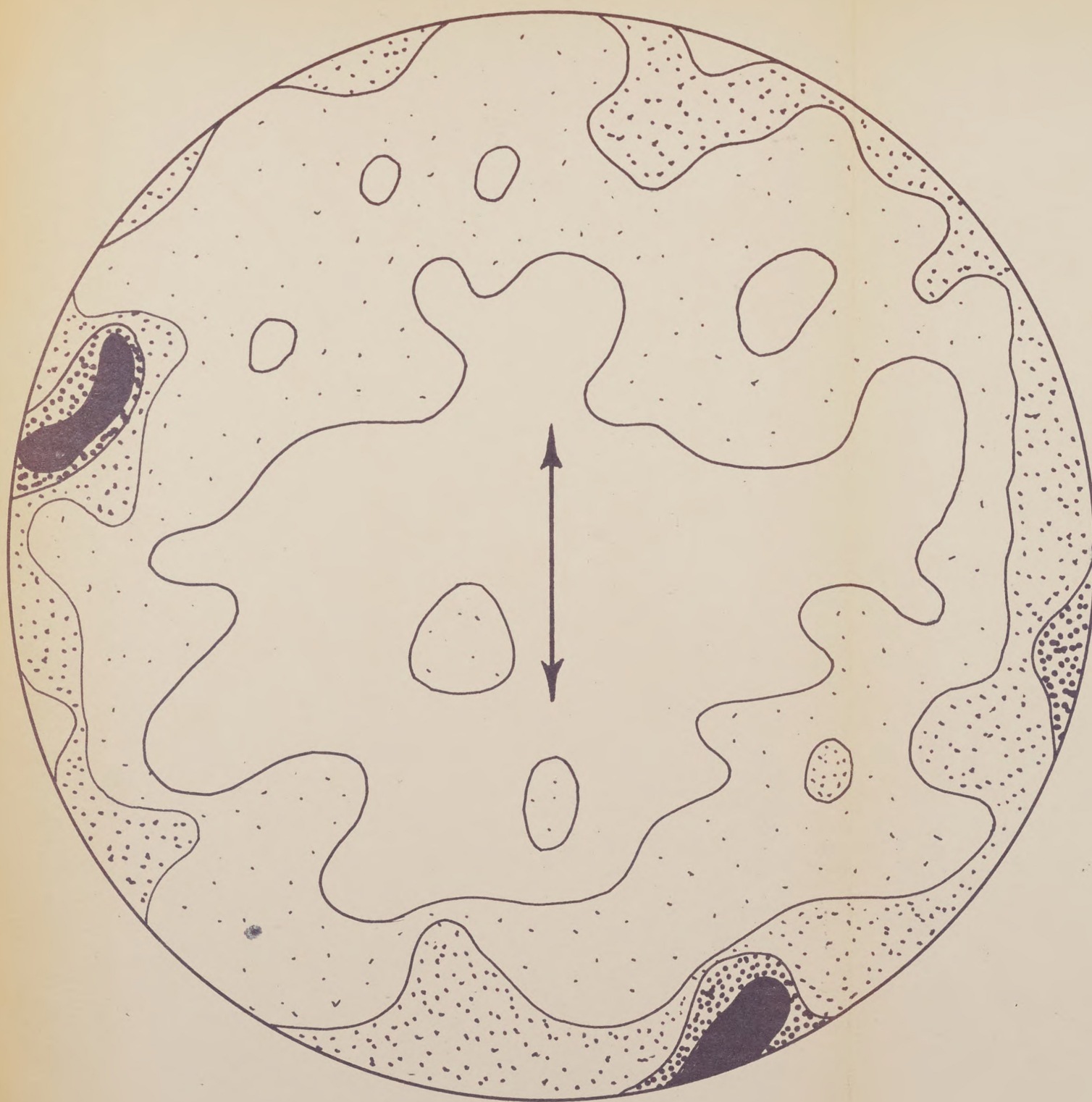
Wind Ripple-mark
m.p.a. Fabric > 4-3-2-0 %
Area from B to C

Figure 16.



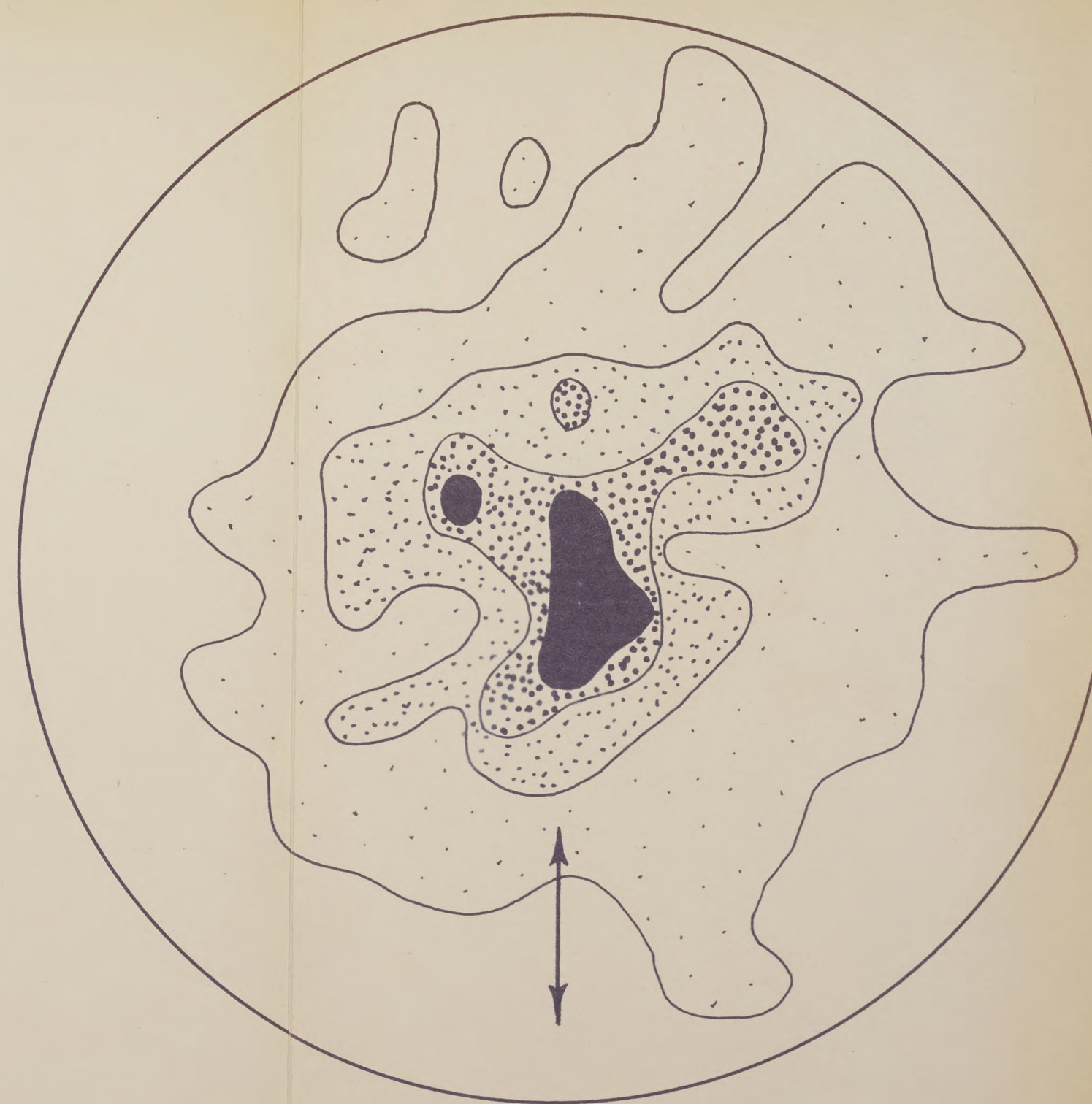
Wind Ripple-mark
Long dimension Fabric > 4-3-2-0 %
Area from B to C

Figure 17.



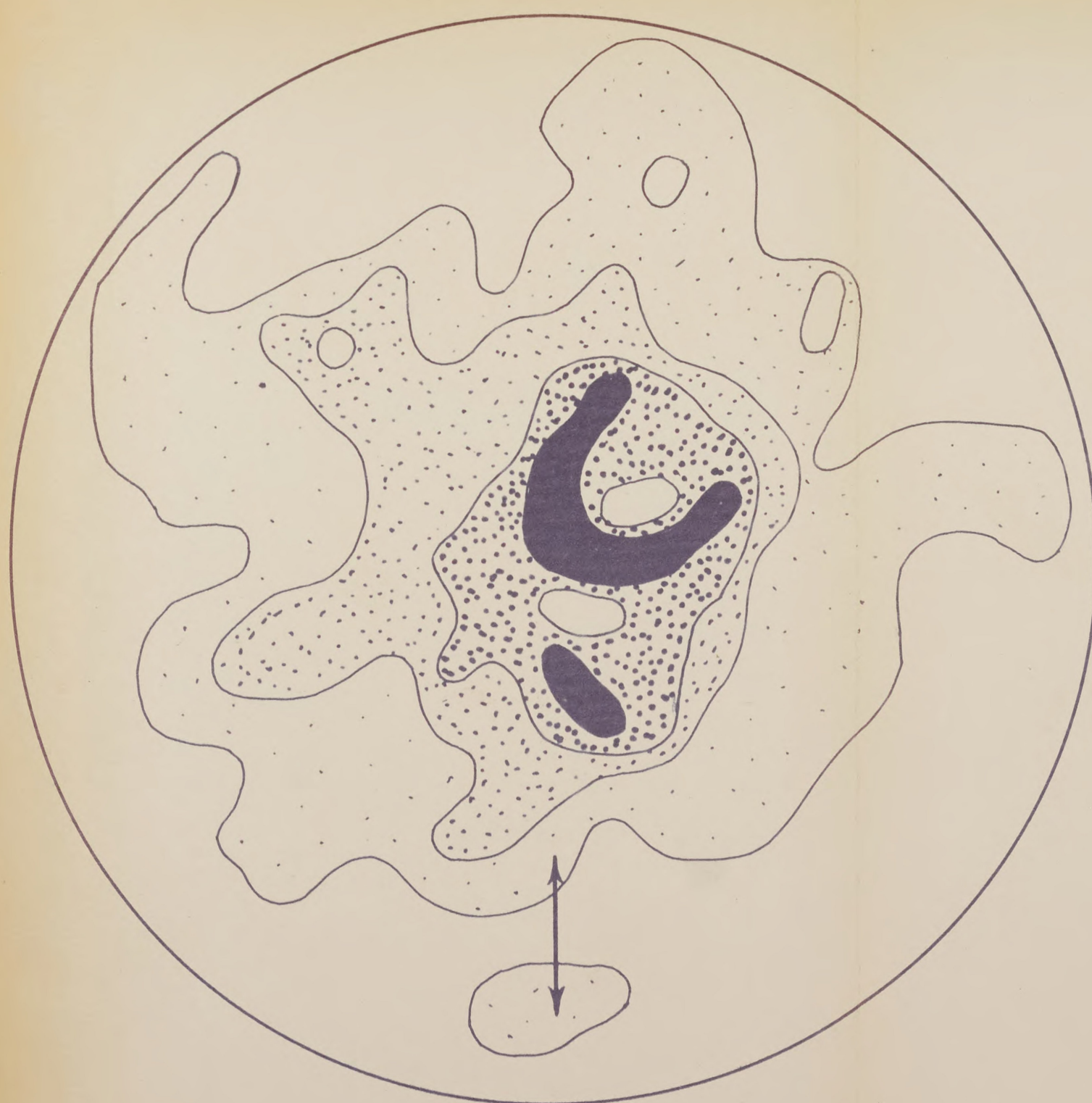
Oscillation Ripple-mark
Long-dimension Fabric > 4-3-2-0 %
Area from A to B

Figure 18.



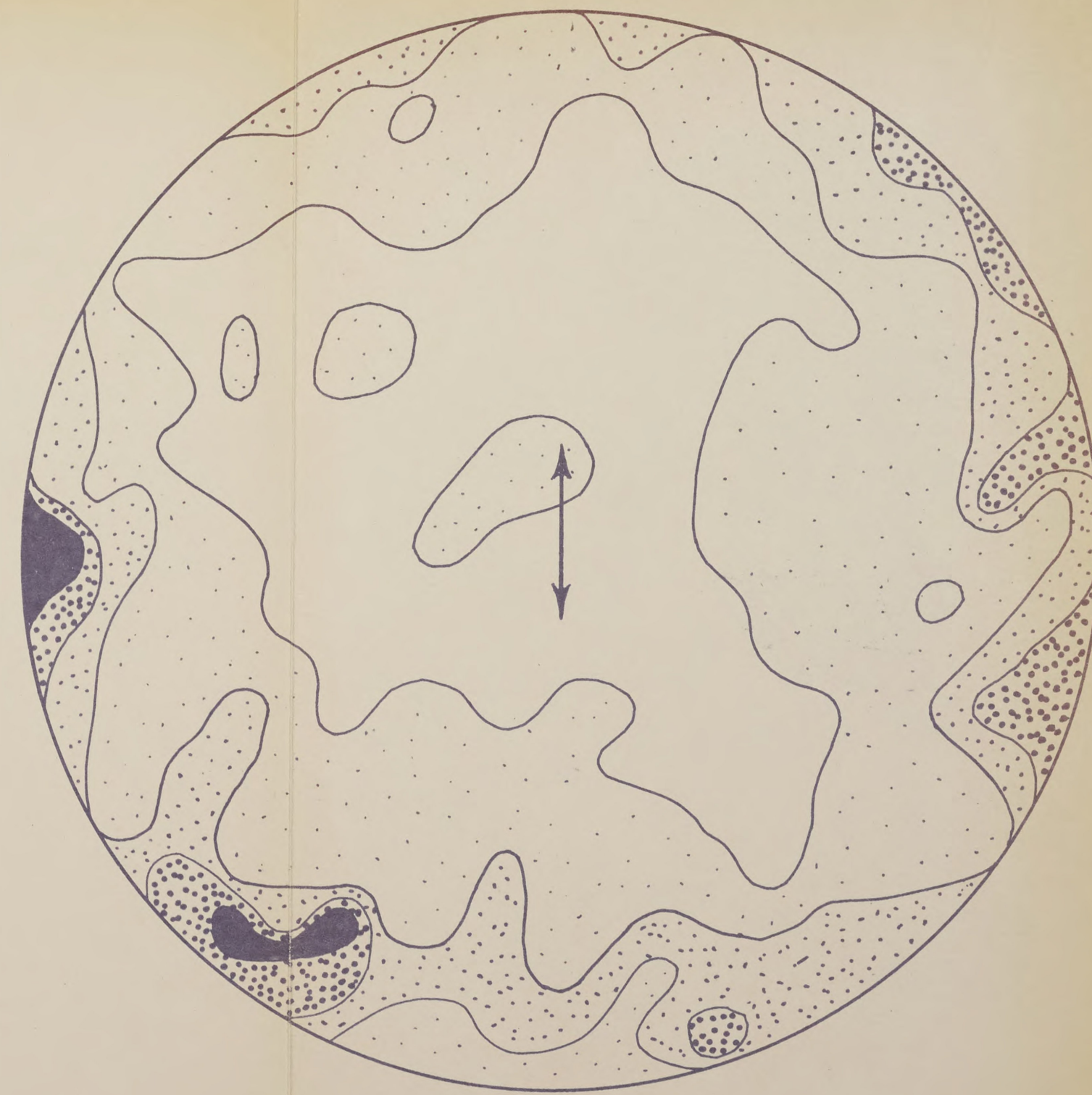
Oscillation Ripple-mark
m.p.a. Fabric > 7-4-2-0 %
Area from A to B

Figure 19.



Oscillation Ripple-mark
m.p.a. Fabric > 5 -4-2-0 %
Area from B to C

Figure 20.



Oscillation Ripple-mark
Long dimension Fabric > 4-3-2-0 %
Area from B to C

Figure 21.

CONCLUSION

The evidence obtained during the completion of this problem shows definitely that the physical shapes of individual sand grains cause them to respond to both depositional agents and environments by the preferred orientation of certain physical dimensions. The explanations of the orientation diagrams were necessarily both general and theoretical because of the lack of published research in the field of sedimentary petrofabrics. Further work, incorporating such factors as roundness, size, shape, sphericity, compaction, and their effect upon preferred orientation must be completed before valid information as to sediment source direction or the agent of deposition can be inferred from the petrofabric analysis of clastic sediments. With further research, petrofabrics may be applied also to other sedimentary problems such as the settling of foundations, porosity and permeability.

The use of polar co-ordinate paper was found to be more rapid and equally as accurate as the "Schmidt" equal area net.

The three-axis universal stage proved to be very rapid in determining the position of both the long dimension and maximum projection. Ordinarily these would have to be measured separately, but by means of the hemisphere, both can be observed and recorded for a single grain at the same time.

The use of plastics in obtaining oriented samples of unconsolidated material offers a satisfactory method of obtaining these in permanent form. An added advantage of this method is the possibility that after petrofabric analysis, the plastic can be easily dissolved and the sample becomes readily available for other types of sedimentary study.

BIBLIOGRAPHY

Books

Gilluly, J., Waters, A. C., and Woodford, A. C., Principles of Geology.
San Francisco, California: W. H. Freeman and Company, 1951.

Lahee, F. H., Field Geology. New York: McGraw-Hill Book Company, 1941.

Articles

Dapples, E. C., and Rominger, J. F., "Orientation Analysis of Fine-grained
Clastic Sediments," Journal of Geology, Vol. 53, 1945, pp. 246-261.

Ingerson, E., "Fabric Criteria for Distinguishing Pseudo Ripple Marks
from Ripple Marks," Geological Survey of America Bulletin, Vol. 51,
1940, pp. 557-574.

Ingerson, E., and Ramisch, J. L., "Origin of Shapes of Quartz Sand Grains,"
American Mineralogist, Vol. 27, 1942, pp. 595-606.

Krumbein, W. C., "Preferred Orientation of Pebbles in Sedimentary
Deposits," Journal of Geology, Vol. 47, 1939, pp. 673-706.

Rowland, R. A., "Grain-shape Fabrics of Clastic Quartz," Geological
Survey of America Bulletin, Vol. 57, 1946, pp. 547-564.

Schwarzacher, W., "Grain Orientation in Sands and Sandstones," Journal
of Sedimentary Petrology, Vol. 21, 1951, pp. 162-172.

Smith, H. W., and Moodie, C. D., "Collection and Preservation of Soil
Profiles," Soil Science, Vol. 64, 1947, pp. 61-67.

~~NOV 4 1960~~

~~42111-23-60~~

~~OCT 14 1963~~

~~JUN 1 1964~~

~~NOV 19 1964~~

~~JUN 23 1965~~

~~JUN 21 1967~~

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03174 9983