

AD-A174 937

AUTOMATED ULTRASONIC INSPECTION OF ARAMID (KEVLAR)

1/1

COMPOSITE PLASTIC HELMETS FEASIBILITY STUDY(U)

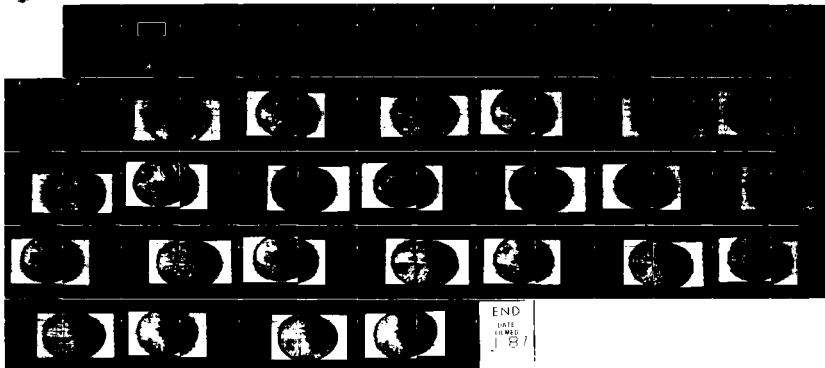
AUTOMATION/SPERRY CHATTIMORTH CA D R KAMMERER 82 JUN 86

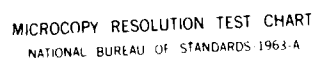
UNCLASSIFIED

TR-86-1 DLA986-86-M-2929

P/C 14/2

NL

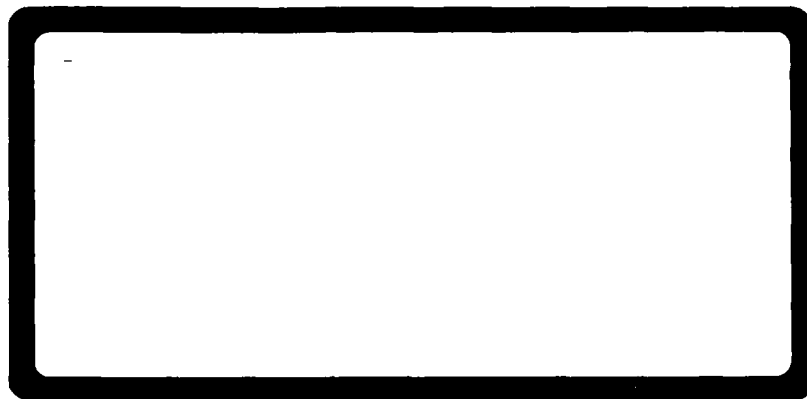




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A174 037

①



This document has been approved
for public release and sale; its
distribution is unlimited.

NOV 13 1988
[Handwritten signature]

NTIC FILE COPY



AUTOMATION INDUSTRIES, INC.
SPERRY PRODUCTS DIVISION

20327 NORDHOFF STREET
CHATSWORTH, CA 91311
(213) 882-2600

86 11 18 018

encl 1

UNCLAS

SECURITY CLASSIFICATION OF THIS PAGE

30 AUG 89

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLAS			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE			Unlimited		
4. PERFORMING ORGANIZATION REPORT NUMBER(S) TR-86-1			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION Automation/Sperry		6b. OFFICE SYMBOL (if applicable)		7a. NAME OF MONITORING ORGANIZATION Defense Logistics Agency	
6c. ADDRESS (City, State, and ZIP Code) 20327 Nordhoff St. Chatsworth, CA 91311			7b. ADDRESS (City, State, and ZIP Code) Cameron Station Alexandria, VA 22304-6100		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION Defense Logistics Agency		8b. OFFICE SYMBOL (if applicable) DLA-PR		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DLA-900-86-M-2929	
8c. ADDRESS (City, State, and ZIP Code) Cameron Station Alexandria, VA 22304-6100			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO. 78011S	PROJECT NO. 0010	TASK NO.
			WORK UNIT ACCESSION NO.		
11. TITLE (Include Security Classification) UNCLAS AUTOMATED ULTRASONIC INSPECTION OF ARMID (KEVLAR) COMPOSITE PASGT HELMETS FEASIBILITY STUDY					
12. PERSONAL AUTHOR(S) Kammerer, David R. Automation Sperry					
13a. TYPE OF REPORT Interim		13b. TIME COVERED FROM 5/86 TO 9/86		14. DATE OF REPORT (Year, Month, Day) 86-6-2	
15. PAGE COUNT 33					
16. SUPPLEMENTARY NOTATION This					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Composites - Nondestructive Test - Aramid - Kevlar - Ultrasonics - Inspection		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Study was conducted to determine feasibility of using ultrasonic nondestructive inspection on compression molded aramid (Kevlar) composite helmets. Results indicated detection capability for internal discontinuities voids & delaminations. Detection of number of layers of aramid does not show much promise.					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLAS		
22a. NAME OF RESPONSIBLE INDIVIDUAL Krilowicz, Robert L.			22b. TELEPHONE (Include Area Code) 202-274-6445		22c. OFFICE SYMBOL DLA-PR (DPMSO)

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.

All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLAS

INSTRUCTIONS FOR PREPARATION OF REPORT DOCUMENTATION PAGE

GENERAL INFORMATION

The accuracy and completeness of all information provided in the DD Form 1473, especially classification and distribution limitation markings, are the responsibility of the authoring or monitoring DoD activity.

Because the data input on this form will be what others will retrieve from DTIC's bibliographic data base or may determine how the document can be accessed by future users, care should be taken to have the form completed by knowledgeable personnel. For better communication and to facilitate more complete and accurate input from the originators of the form to those processing the data, space has been provided in Block 22 for the name, telephone number, and office symbol of the DoD person responsible for the input cited on the form.

All information on the DD Form 1473 should be typed.

Only information appearing on or in the report, or applying specifically to the report in hand, should be reported. If there is any doubt, the block should be left blank.

Some of the information on the forms (e.g., title, abstract) will be machine indexed. The terminology used should describe the content of the report or identify it as precisely as possible for future identification and retrieval.

NOTE: Unclassified abstracts and titles describing classified documents may appear separately from the documents in an unclassified context, e.g., in DTIC announcement bulletins and bibliographies. This must be considered in the preparation and marking of unclassified abstracts and titles.

The Defense Technical Information Center (DTIC) is ready to offer assistance to anyone who needs and requests it. Call Data Base Input Division, Autovon 284-7044 or Commercial (202) 274-7044.

SECURITY CLASSIFICATION OF THE FORM

In accordance with DoD 5200.1-R, Information Security Program Regulation, Chapter IV Section 2, paragraph 4-200, classification markings are to be stamped, printed, or written at the top and bottom of the form in capital letters that are larger than those used in the text of the document. See also DoD 5220.22-M, Industrial Security Manual for Safeguarding Classified Information, Section II, paragraph 11a(2). This form should be unclassified, if possible.

SPECIFIC BLOCKS

Block 1a. Report Security Classification: Designate the highest security classification of the report. (See DoD 5220.1-R, Chapters I, IV, VII, XI, Appendix A.)

Block 1b. Restricted Marking: Enter the restricted marking or warning notice of the report (e.g., CNWDI, RD, NATO).

Block 2a. Security Classification Authority: Enter the commonly used markings in accordance with DoD 5200.1-R, Chapter IV, Section 4, paragraph 4-400 and 4-402. Indicate classification authority.

Block 2b. Declassification / Downgrading Schedule: Indicate specific date or event for declassification or the notation, "Originating Agency Determination Required" or "OADR." Also insert (when applicable) downgrade to on (e.g., Downgrade to Confidential on 6 July 1983). (See also DoD 5220.22-M, Industrial Security Manual for Safeguarding Classified Information, Appendix II.)

NOTE: Entry must be made in Blocks 2a and 2b except when the original report is unclassified and has never been upgraded.

Block 3. Distribution/Availability Statement of Report: Insert the statement as it appears on the report. If a limited distribution statement is used, the reason must be one of those given by DoD Directive 5200.20, Distribution Statements on Technical Documents, as supplemented by the 18 OCT 1983 SECDEF Memo, "Control of Unclassified Technology with Military Application." The Distribution Statement should provide for the broadest distribution possible within limits of security and controlling office limitations.

Block 4. Performing Organization Report Number(s): Enter the unique alphanumeric report number(s) assigned by the organization originating or generating the report from its research and whose name appears in Block 6. These numbers should be in accordance with ANSI STD 239.23-74, "American National Standard Technical Report Number." If the Performing Organization is also the Monitoring Agency, enter the report number in Block 4.

Block 5. Monitoring Organization Report Number(s): Enter the unique alphanumeric report number(s) assigned by the Monitoring Agency. This should be a number assigned by a DoD or other government agency and should be in accordance with ANSI STD 239.23-74. If the Monitoring Agency is the same as the Performing Organization, enter the report number in Block 4 and leave Block 5 blank.

Block 6a. Name of Performing Organization: For in-house reports, enter the name of the performing activity. For reports prepared under contract or grant, enter the contractor or the grantee who generated the report and identify the appropriate corporate division, school, laboratory, etc., of the author.

Block 6b. Office Symbol: Enter the office symbol of the Performing Organization.

Block 6c. Address: Enter the address of the Performing Organization. List city, state, and ZIP code.

Block 7a. Name of Monitoring Organization: This is the agency responsible for administering or monitoring a project, contract, or grant. If the monitor is also the Performing Organization, leave Block 7a. blank. In the case of joint sponsorship, the Monitoring Organization is determined by advance agreement. It can be either an office, a group, or a committee representing more than one activity, service, or agency.

Block 7b. Address: Enter the address of the Monitoring Organization. Include city, state, and ZIP code.

Block 8a. Name of Funding/Sponsoring Organization: Enter the full official name of the organization under whose immediate funding the document was generated, whether the work was done in-house or by contract. If the Monitoring Organization is the same as the Funding Organization, leave 8a blank.

Block 8b. Office Symbol: Enter the office symbol of the Funding/Sponsoring Organization.

Block 8c. Address: Enter the address of the Funding/Sponsoring Organization. Include city, state and ZIP code.

Block 9. Procurement Instrument Identification Number: For a contractor grantee report, enter the complete contract or grant number(s) under which the work was accomplished. Leave this block blank for in-house reports.

Block 10. Source of Funding (Program Element, Project, Task Area, and Work Unit Number(s)): These four data elements relate to the DoD budget structure and provide program and/or administrative identification of the source of support for the work being carried on. Enter the program element, project, task area, work unit accession number, or their equivalents which identify the principal source of funding for the work required. These codes may be obtained from the applicable DoD forms such as the DD Form 1498 (Research and Technology Work Unit Summary) or from the fund citation of the funding instrument. If this information is not available to the authoring activity, these blocks should be filled in by the responsible DoD Official designated in Block 22. If the report is funded from multiple sources, identify only the Program Element and the Project, Task Area, and Work Unit Numbers of the principal contributor.

Block 11. Title: Enter the title in Block 11 in initial capital letters exactly as it appears on the report. Titles on all classified reports, whether classified or unclassified, must be immediately followed by the security classification of the title enclosed in parentheses. A report with a classified title should be provided with an unclassified version if it is possible to do so without changing the meaning or obscuring the contents of the report. Use specific, meaningful words that describe the content of the report so that when the title is machine-indexed, the words will contribute useful retrieval terms.

If the report is in a foreign language and the title is given in both English and a foreign language, list the foreign language title first, followed by the English title enclosed in parentheses. If part of the text is in English, list the English title first followed by the foreign language title enclosed in parentheses. If the title is given in more than one foreign language, use a title that reflects the language of the text. If both the text and titles are in a foreign language, the title should be translated, if possible, unless the title is also the name of a foreign periodical. Transliterations of often used foreign alphabets (see Appendix A of MIL-STD-847B) are available from DTIC in document AD-A080 800.

Block 12. Personal Author(s): Give the complete name(s) of the author(s) in this order: last name, first name, and middle name. In addition, list the affiliation of the authors if it differs from that of the performing organization.

List all authors. If the document is a compilation of papers, it may be more useful to list the authors with the titles of their papers as a contents note in the abstract in Block 19. If appropriate, the names of editors and compilers may be entered in this block.

Block 13a. Type of Report: Indicate whether the report is summary, final, annual, progress, interim, etc.

Block 13b. Time Covered: Enter the inclusive dates (year, month, day) of the period covered, such as the life of a contract in a final contractor report.

Block 14. Date of Report: Enter the year, month, and day, or the year and the month the report was issued as shown on the cover.

Block 15. Page Count: Enter the total number of pages in the report that contain information, including cover, preface, table of contents, distribution lists, partial pages, etc. A chart in the body of the report is counted even if it is unnumbered.

Block 16. Supplementary Notation: Enter useful information about the report in hand, such as: "Prepared in cooperation with..." "Translation of (or by)..." "Symposium..." If there are report numbers for the report which are not noted elsewhere on the form (such as internal series numbers or participating organization report numbers) enter in this block.

Block 17. COSATI Codes: This block provides the subject coverage of the report for announcement and distribution purposes. The categories are to be taken from the "COSATI Subject Category List" (DoD Modified), Oct 65, AD-624 000. A copy is available on request to any organization generating reports for DoD. At least one entry is required as follows:

Field - to indicate subject coverage of report.

Group - to indicate greater subject specificity of information in the report.

Sub-Group - if specificity greater than that shown by Group is required, use further designation as the numbers after the period (.) in the Group breakdown. Use only the designation provided by AD-624 000.

Example: The subject "Solid Rocket Motors" is Field 21, Group 08, Subgroup 2 (page 32, AD-624 000).

Block 18. Subject Terms: These may be descriptors, keywords, posting terms, identifiers, open-ended terms, subject headings, acronyms, code words, or any words or phrases that identify the principal subjects covered in the report, and that conform to standard terminology and are exact enough to be used as subject index entries. Certain acronyms or "buzz words" may be used if they are recognized by specialists in the field and have a potential for becoming accepted terms. "Laser" and "Reverse Osmosis" were once such terms.

If possible, this set of terms should be selected so that the terms individually and as a group will remain UNCLASSIFIED without losing meaning. However, priority must be given to specifying proper subject terms rather than making the set of terms appear "UNCLASSIFIED." Each term on classified reports must be immediately followed by its security classification, enclosed in parentheses.

For reference on standard terminology the "DTIC Retrieval and Indexing Terminology" DRIT-1979, AD-A068 500, and the DoD "Thesaurus of Engineering and Scientific Terms (TEST) 1968, AD-672 000, may be useful.

Block 19. Abstract: The abstract should be a pithy, brief (preferably not to exceed 300 words), factual summary of the most significant information contained in the report. However, since the abstract may be machine-searched, all specific and meaningful words and phrases which express the subject content of the report should be included, even if the word limit is exceeded.

If possible, the abstract of a classified report should be unclassified and consist of publicly releasable information (Unlimited), but in no instance should the report content description be sacrificed for the security classification.

NOTE: An unclassified abstract describing a classified document may appear separately from the document in an unclassified context e.g., in DTIC announcement or bibliographic products. This must be considered in the preparation and marking of unclassified abstracts.

For further information on preparing abstracts, employing scientific symbols, verbalizing, etc., see paragraphs 2.1(n) and 2.3(b) in MIL-STD-847B.

Block 20. Distribution / Availability of Abstract: This block must be completed for all reports. Check the applicable statement: "unclassified / unlimited," "same as report," or, if the report is available to DTIC registered users "DTIC users."

Block 21. Abstract Security Classification: To ensure proper safeguarding of information, this block must be completed for all reports to designate the classification level of the entire abstract. For CLASSIFIED abstracts, each paragraph must be preceded by its security classification code in parentheses.

Block 22a,b,c. Name, Telephone and Office Symbol of Responsible Individual: Give name, telephone number, and office symbol of DoD person responsible for the accuracy of the completion of this form.



A UNIT OF QUALCORP

1

TR 86-1

AUTOMATED ULTRASONIC INSPECTION
OF ARAMID (KEVLAR) COMPOSITE
PASGT HELMETS
FEASIBILITY STUDY

UNITED STATES DEFENSE LOGISTICS AGENCY
DEFENSE ELECTRONICS SUPPLY CENTER
DAYTON, OHIO
CONTRACT NO. DLA900-86-M-2929
JUNE 2, 1986

Written by

David R. Kammerer
Field Applications Engineer

AUTOMATION/SPERRY, a unit of Qualcorp
Chatsworth, California
U.S.A.

1986

NOV 13 1986



A UNIT OF QUALCORP

TABLE OF CONTENTS

SECTION I

- 1.0 INTRODUCTION
- 2.0 SUMMARY OF RESULTS
- 3.0 CONCLUSIONS

SECTION II

- 4.0 EQUIPMENT
- 5.0 TEST PROCEDURE
- 6.0 TEST RESULTS
- 7.0 CONCLUSIONS
- 8.0 TEST DATA



A-1



A UNIT OF QUALCORP

1.0 INTRODUCTION

This study was conducted to determine the feasibility of using ultrasonic non-destructive inspection on compression molded aramid (Kevlar) Paratrooper and Support Ground Troop (PASGT) helmets. The present destructive testing method (ballistic) has been determined to be inadequate and costly.

In order to determine the feasibility of using ultrasonic NDT to inspect these PASGT helmets, (6) sample helmet shells were provided to Automation/Sperry by the Defense Logistics Agency. These test samples were representative of production helmets with the exception of their configuration (top of helmet crown only) and internal, artificially manufactured defects.

The objective of this evaluation was to qualify the acoustical attenuation characteristics of the (19) ply kevlar lay-up. Computerized Ultrasonic attenuation measurements in the form of numeric symbols are provided in a C-scan format to substantiate the acoustic properties of the test samples. Several ultrasonic techniques were explored to identify the most reliable and practical method that could be used to meet production inspection requirements.

2.0 SUMMARY OF RESULTS

The (6) PASGT helmet samples were evaluated using the Squirter Thru-Transmission method of Ultrasonic Inspection. (24) Computerized Data Acquisition plots are presented in the test data section of this report. All plots were generated in a plan view or "C-Scan" format of the PASGT samples.

Using either conventional Ultrasonic "Pulse-echo" or "Reflector Plate" techniques to examine the PASGT samples was not feasible. No results were attainable due to the excessive acoustical attenuation of the (19) layer kevlar material. It is suspected that the compression mold process yields non-uniform pressure distribution/resin flow and therefore a very acoustically non-uniform structure. The overall acoustical attenuation within each sample varied over 30 dB.



A UNIT OF QUALCOMP

3.0 CONCLUSIONS

Low frequency, ultrasonic squirter thru-transmission inspection can be applied to examine PASGT helmets for their acoustical attenuation characteristics. Detection of internal discontinuities, voids, delaminations, etc. is feasible. Detection of ply lay-up attenuation differences (18 ply versus 19 plys) does not show much promise due to the overall acoustical attenuation variation over the total helmet area. Real-Time Radiography inspection as described in TR-86-2 would be a more feasible approach to detecting differences in ply number and orientation.

Further work must be done to assist in development of acceptable Ultrasonic reference standards.

4.0 EQUIPMENT

- * US-542S MIDUS/TM COMPUTER CONTROLLED ULTRASONIC SCANNING SYSTEM With US-874a Water Squirters

This dedicated, microprocessor based scanning system provided the high speed motion control after being "taught" a profile to Scan/Index the Ultrasonic transducers.

- * US-960 INTELLIGENT PLOTTER

The US-960 micro-computer based data acquisition system was used to acquire and digitize the ultrasonic data. Once each helmet sample had been inspected, the data was recalled to provide an "Electronic Rescan".

- * S-80 Reflectoscope
PR-4R Remote Pulser/Receiver with a 60DB dynamic range logarithmic amplifier
GT-1 Gate Module with 0-5 VDC fast analog output

The S-80 Ultrasonic instrument pulsed the transducer, amplified its' ultrasonic received signal and provided the US-960 with a gated, peak detected analog signal.

- * DM-2 36DB REMOTE PREAMP

To obtain a gateable, Thru-transmission signal a DM-2 in-line preamp was used to boost the received ultrasonic signal.

- * SIJS Series .4 mhz undamped transducers
57K0625P2 transmit transducer (50 OHM impedance matched)
57K0625 receiver transducer



A UNIT OF QUALCOMM

5.0 TEST PROCEDURE

After intializing the equipment mentioned as listed in section 4.0, each PASGT helmet shell sample was positioned between opposing water squirters. The sample was then oriented such that the one half of the shell was as normal to the water squirters' scanning plane as possible (see figure 1). In addition, a foam tape/ lead tape strip of .250" x 1.0" was placed next to the identification mark on the inside of the helmet. This strip served as a marker (ultrasound attenuator) and can be observed on each helmet's corresponding C-Scan plot.

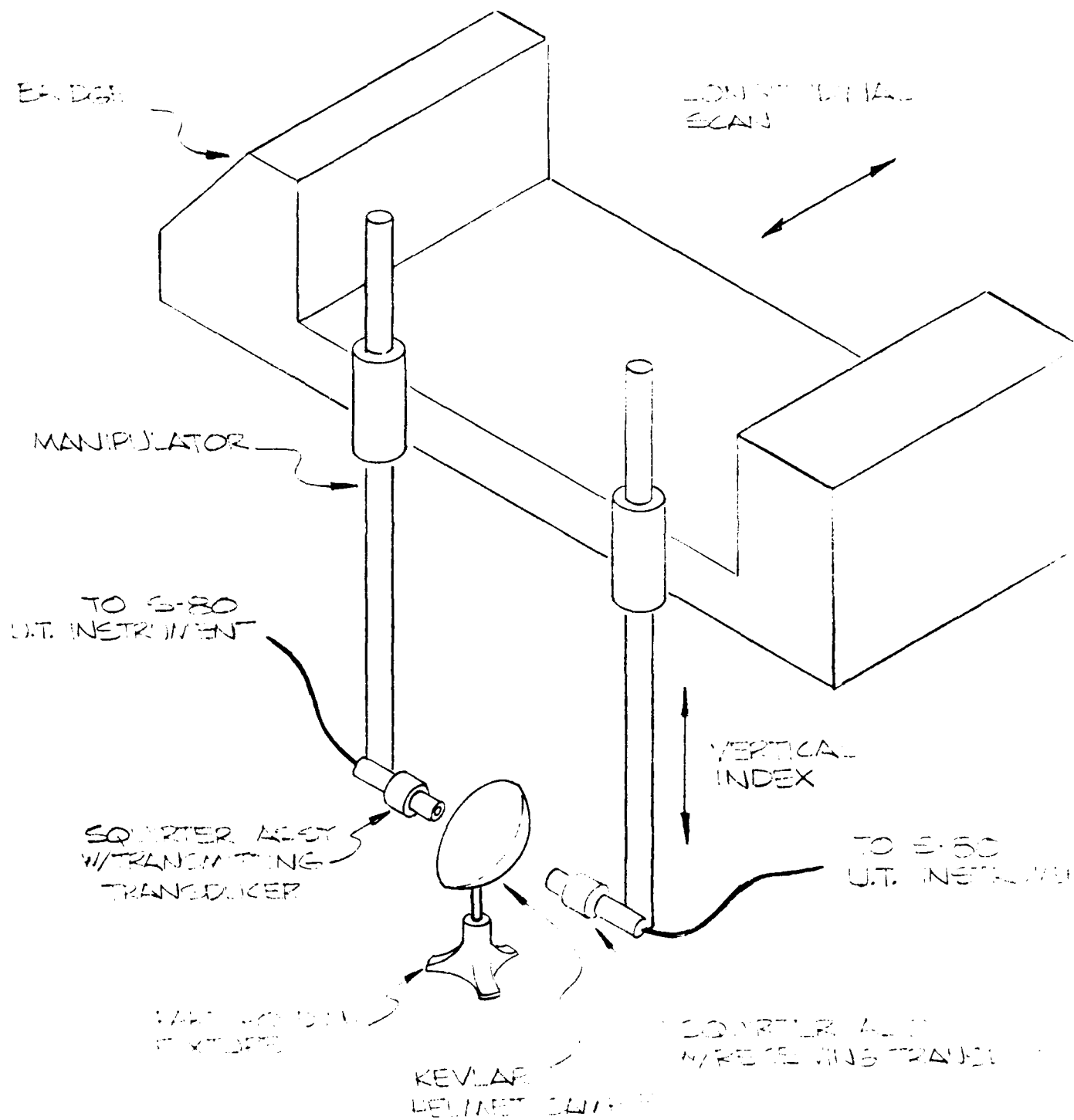
The US-542/s MIDUS (tm) scanning system was programmed to scan one half of the shell in a thru-transmission, rectilinear mode. The same scan/index window coordinates or "scan plan" was used for each subsequent sample. (2) scans were made of each shell to provide maximum coverage allowed by the part geometry. A total of (12) scans or (2) scans each of the (6) samples provided. (2) additional " Electronic Rescans " were made of each sample to enhance the presentation. A total of (24) plots are presented in section 8.0 of this report.

Using the S-80 instrument, the receiver gain level was adjusted to a sensitivity that allowed all test samples to be inspected at one setting. This was made possible by the 60 dB dynamic range logarithmic amplifier. All (6) PASGT samples could then be compared collectively for their attenuation characteristics.

To record the Ultrasonic attenuation measurements, a destination data file was created with the US-960 for each scan to be made. All pertinent identifying information was entered into the "Header block" such as the title, s/n and description.

While acquiring the Data during a scan, each .040" Sample point is compared to a grey scale Look-up table and one of (14) numerical characters is plotted. Each grey scale character represents a dB attenuation value. The darkest character (#) is the least attenuative section of the sample and the lightest character (blank) is the most attenuative. Since the 60db Dynamic Range of the pulser/receiver is directly proportional to the 0-5 VDC analog output, .083 volts is equal to 1 dB.

During a scan, all data sample points are stored in an 8 bit digitized value from 0-255 on the 40 megabyte winchester hard disk drive within the US-960. The data file which holds all the data sample points can be recalled for an "Electronic Rescan" using different grey scale look-up tables for comparative purposes with known acceptance criteria.





A UNIT OF QUALCOMM

6.0 TEST RESULTS

Low frequency (.4 mhz) Ultrasonic Squirter Thru-Transmission inspection was used to inspect the PASGT helmet samples.

Since defect size resolution is partly dependent on transducer frequency, test frequencies higher than .4 mhz are desired. Additional tests showed that higher frequencies (1.0 mhz, 2.25 mhz) could not be used to examine the samples since the higher frequency transducers yielded an unacceptable signal to noise ratio. To improve this, a special high-power pulser module was used in place of the standard spike pulser within the ultrasonic instrument. This approach improved the signal to noise ratio, but not enough to justify using it for these tests.

Because such a low frequency is required to acoustically penetrate the (19) layer Kevlar samples, Conventional "Pulse-Echo" and "Reflector Plate" techniques were determined not to be feasible. The inherent material attenuation characteristics of the Kevlar helmet samples prevent using transducer frequencies above .4 mhz.

There were (2) grey scale look-up tables chosen to generate the plots in the Test Data Section of this report. Plots 1-12 used a 3 db/grey scale character look-up table and Plots 13-24 used an enhanced grey scale. The enhanced grey scale in Plots 13-24 used an (8) shade, high contrast, grey scale representing 6 db of acoustical attenuation change per character.

OBSERVATIONS:

Visually, the PASGT helmet samples exhibit wrinkles and overlapping of layers. The resin content also appears to be variable through-out the entire structure. Whether or not these conditions are permissible per specification MIL-H-44099, most all processing variables will affect the acoustical attenuation characteristics of the samples.

By examining the Plots in section 8.0, note that the Ultrasonic attenuation is most pronounced on sample number 3 and number 4. The attenuation in the crown of these (2) samples is also the most severe, although all samples exhibit high attenuation patterns in this area. It is therefore suspected that the helmet crown area is an area where the layers are not being compressed sufficiently and/or resin flow is being restricted.

The artificial defects can be seen in samples 2 thru 6 as a complete loss of sound, (blank/white) although their size varies. Since these artificial defects were created by cutting 1" squares in alternate layers, it is suspected that resin has flowed into the cut-out and created a partial bond.



A UNIT OF QUALCOMM

In the case of sample 6 where (5) of (19) layers have been cut-out, the alignment and superimposing of the squares on top of one another also contributes to the definition of a "square" on the plots.

The overall attenuation range of the samples (30 dB) is excessive if compared with other composite materials. This is most likely due to the non-autoclaved process used to fabricate the PASGT helmets as well as the helmet geometry. Typically the greater the Ultrasonic attenuation range, the greater the porosity content of the structure.

7.0 CONCLUSIONS

Low Frequency Ultrasonic inspection, using the Squirter Thru-Transmission technique, can be applied to the inspection of the PASGT helmets. Although, because of the high acoustical attenuation characteristics of the samples, .4 mhz frequency transducers were required. This is the lowest standard transducer frequency used in ultrasonic inspection and the least sensitive in terms of defect resolution.

Developing an ultrasonic test technique capable of determining an acoustical attenuation difference between an area of 15 plies versus 16 plies of Kevlar does not appear to be feasible. This is due to the overall acoustical attenuation inconsistencies exhibited within this structure. The use of Real-Time Radiography inspection as described in the technical report (TR-86-2) would be a more feasible approach to detecting differences in ply number and orientation.

Additional work will need to be undertaken to assist in development of acceptable ultrasonic reference standards.

RECOMMENDATIONS

Further ultrasonic evaluations should be carried out to qualify using the .4 mhz, Thru-transmission inspection method for production inspection of the PASGT helmets. Reference standards with artificial defects of various known sizes and types must be examined to determine the minimum size defect that can be detected within a (19) layer kevlar structure.

Additional effort in equipment development is required. A study of through-put rate versus system configuration is required to provide design direction that can meet production inspection rate requirements.

A rapid, cost effective method would be to develop a go/no-go ultrasonic test using (2) opposing multi-element transducer arrays that conform to the inside and outside geometry of the helmet. This approach would not require complex contour following of the transducers to the helmet geometry.



A UNIT OF QUALCOMM

Each helmet could be immersed between the transducer arrays and the ultrasonic attenuation measurements compared to a computerized data base. Deposition of the helmets' integrity would then be logged and printed out for the operator. The number of elements or transducers required within an array would be dependent upon the minimum size defect to be detected.

8.0 TEST DATA

- * PASGT HELMET SHELL SAMPLES
(19) LAYERS OF ARAMID (KEVLAR)

NOTE: ALL SAMPLES (EXCEPT # 1) HAD ARTIFICIAL DEFECTS FABRICATED INTO THE CENTER OF THE CROWN (TOP) OF THE SHELL SAMPLE. THESE DEFECTS WERE CREATED BY CUTTING A 1.0" SQUARE FROM THE LAYER(S) PRIOR TO BONDING. EACH OF THE (19) LAYERS ARE IDENTIFIED AS 1 THROUGH 19 WITH LAYER 1 ON THE INSIDE (DATE CODE SIDE) OF THE SAMPLE. IN ADDITION TO THE MANUFACTURED DEFECTS A .250" x 1.0" FOAM TAPE STRIP WAS AFFIXED TO THE INSIDE OF THE HELMET NEXT TO THE CODE FOR PLOT ORIENTATION PURPOSES.

SAMPLE NO.	DEFECT PLACEMENT LAYER(S)	ATTENUATION RANGE
1	NONE	
2	3	
3	3,5	
4	3,5,7	
5	3,5,7,9	
6	5,7,9,11,13	

Each Scan (Data File) made of a PASGT Helmet sample had the following header information associated with it. This is an example of the typical operator inputs made prior to scanning.

ATTENUATION SPEED	8 - 960 PLOTTER	POST SCAN PLOT
-------------------	-----------------	----------------

CURRENT DATE TIME: 11-14-86 11:44:15

1. PASGT HELMET SAMPLE NO. 1 2. DATE OF SCAN 11-14-86 3. TIME OF SCAN 11:44:15 4. OPERATOR NAME J. J. JONES 5. LOCATION OF SCAN 11-14-86 6. SCAN INDEX 1 7. SCAN TYPE 1 8. SCAN MODE 1 9. SCAN RATE 1 10. SCAN AREA 1 11. SCAN TIME 1 12. SCAN STATUS 1 13. SCAN RESULT 1 14. SCAN COMMENT 1 15. SCAN END	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>LEVEL</th> <th>MAX VOLTS</th> <th>MIN VOLTS</th> <th>AVG VOLTS</th> </tr> </thead> <tbody> <tr><td>1</td><td>4.000</td><td>4.000</td><td>4.000</td></tr> <tr><td>2</td><td>3.750</td><td>3.750</td><td>3.750</td></tr> <tr><td>3</td><td>3.500</td><td>3.500</td><td>3.500</td></tr> <tr><td>4</td><td>3.250</td><td>3.250</td><td>3.250</td></tr> <tr><td>5</td><td>3.000</td><td>3.000</td><td>3.000</td></tr> <tr><td>6</td><td>2.750</td><td>2.750</td><td>2.750</td></tr> <tr><td>7</td><td>2.500</td><td>2.500</td><td>2.500</td></tr> <tr><td>8</td><td>2.250</td><td>2.250</td><td>2.250</td></tr> <tr><td>9</td><td>2.000</td><td>2.000</td><td>2.000</td></tr> <tr><td>10</td><td>1.750</td><td>1.750</td><td>1.750</td></tr> <tr><td>11</td><td>1.500</td><td>1.500</td><td>1.500</td></tr> <tr><td>12</td><td>1.250</td><td>1.250</td><td>1.250</td></tr> <tr><td>13</td><td>1.000</td><td>1.000</td><td>1.000</td></tr> <tr><td>14</td><td>0.750</td><td>0.750</td><td>0.750</td></tr> <tr><td>15</td><td>0.500</td><td>0.500</td><td>0.500</td></tr> <tr><td>16</td><td>0.250</td><td>0.250</td><td>0.250</td></tr> <tr><td>17</td><td>0.000</td><td>0.000</td><td>0.000</td></tr> <tr><td>18</td><td>0.000</td><td>0.000</td><td>0.000</td></tr> <tr><td>19</td><td>0.000</td><td>0.000</td><td>0.000</td></tr> </tbody> </table>	LEVEL	MAX VOLTS	MIN VOLTS	AVG VOLTS	1	4.000	4.000	4.000	2	3.750	3.750	3.750	3	3.500	3.500	3.500	4	3.250	3.250	3.250	5	3.000	3.000	3.000	6	2.750	2.750	2.750	7	2.500	2.500	2.500	8	2.250	2.250	2.250	9	2.000	2.000	2.000	10	1.750	1.750	1.750	11	1.500	1.500	1.500	12	1.250	1.250	1.250	13	1.000	1.000	1.000	14	0.750	0.750	0.750	15	0.500	0.500	0.500	16	0.250	0.250	0.250	17	0.000	0.000	0.000	18	0.000	0.000	0.000	19	0.000	0.000	0.000
LEVEL	MAX VOLTS	MIN VOLTS	AVG VOLTS																																																																														
1	4.000	4.000	4.000																																																																														
2	3.750	3.750	3.750																																																																														
3	3.500	3.500	3.500																																																																														
4	3.250	3.250	3.250																																																																														
5	3.000	3.000	3.000																																																																														
6	2.750	2.750	2.750																																																																														
7	2.500	2.500	2.500																																																																														
8	2.250	2.250	2.250																																																																														
9	2.000	2.000	2.000																																																																														
10	1.750	1.750	1.750																																																																														
11	1.500	1.500	1.500																																																																														
12	1.250	1.250	1.250																																																																														
13	1.000	1.000	1.000																																																																														
14	0.750	0.750	0.750																																																																														
15	0.500	0.500	0.500																																																																														
16	0.250	0.250	0.250																																																																														
17	0.000	0.000	0.000																																																																														
18	0.000	0.000	0.000																																																																														
19	0.000	0.000	0.000																																																																														



A UNIT OF QUALCORP

In order to ease the interpretation and identification of the plots, the following data reduction form is presented instead of individual header information for each plot.

DATA REDUCTION FORM

The following tabulation is given for plot identification and comparison:

PLOT NO.	Db/GREY SCALE CHARACTER	AREA OF INTEREST
1a	3	RIGHT HALF
1b	3	LEFT HALF
1c	6	RIGHT HALF
1d	6	LEFT HALF
2a	3	RIGHT HALF
2b	3	LEFT HALF
2c	6	RIGHT HALF
2d	6	LEFT HALF
3a	3	RIGHT HALF
3b	3	LEFT HALF
3c	6	RIGHT HALF
3d	6	LEFT HALF
4a	3	RIGHT HALF
4b	3	LEFT HALF
4c	6	RIGHT HALF
4d	6	LEFT HALF
5a	3	RIGHT HALF
5b	3	LEFT HALF
5c	6	RIGHT HALF
5d	6	LEFT HALF
6a	3	RIGHT HALF
6b	3	LEFT HALF
6c	6	RIGHT HALF
6d	6	LEFT HALF

The following letters designate the typical ultrasonic indications found on each plot:

- A : .250" x 1.0" Foam tape strip
- B : Tooling (clamping fixture)
- C : 1.0" x 1.0" Artificial Defect

I-A

SAMPLE NO. 1

area of interest

13

12

11

10

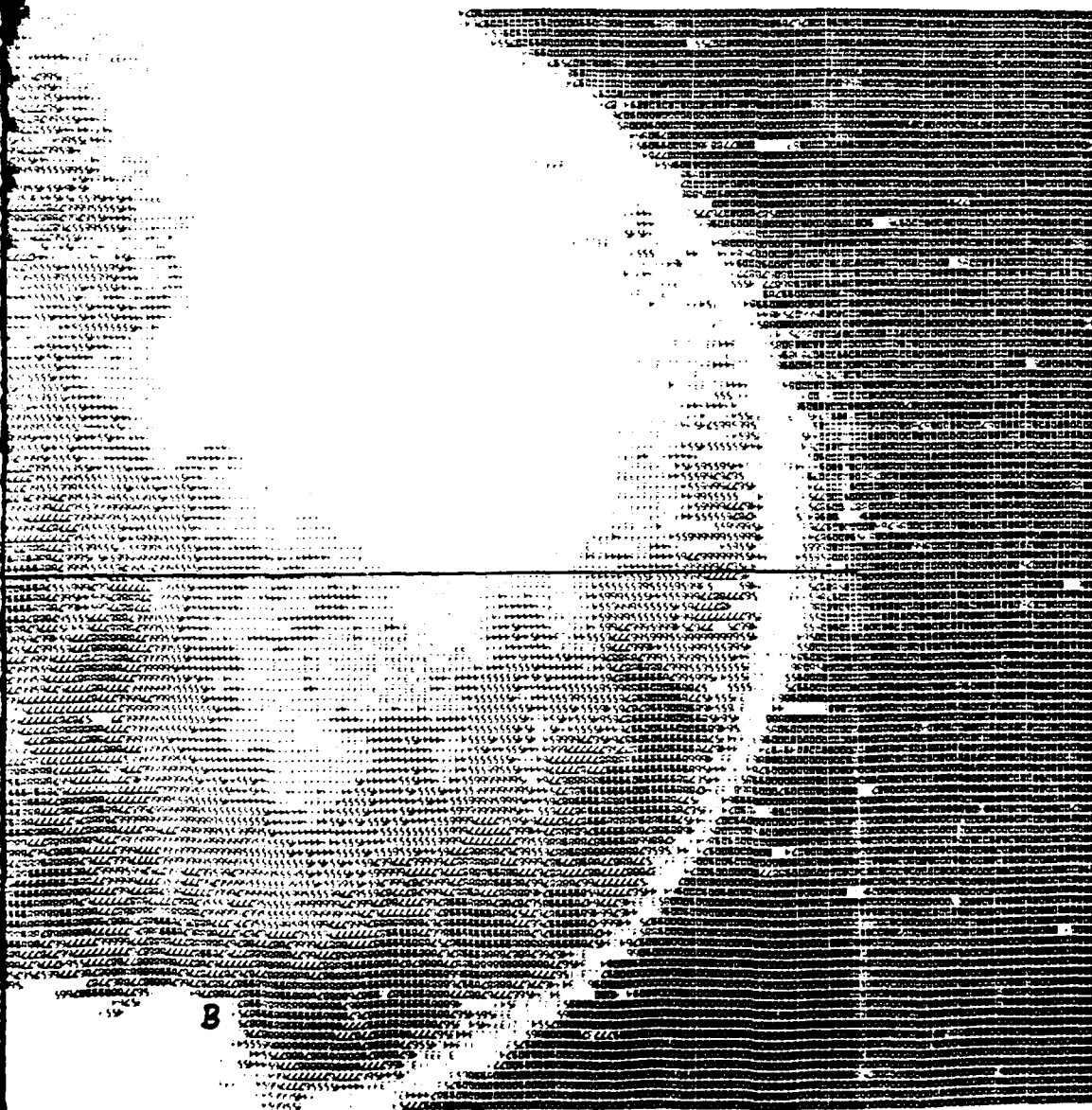
9

8

7

6

NO. 1



8

0 inches 1 2 3 4 5 6

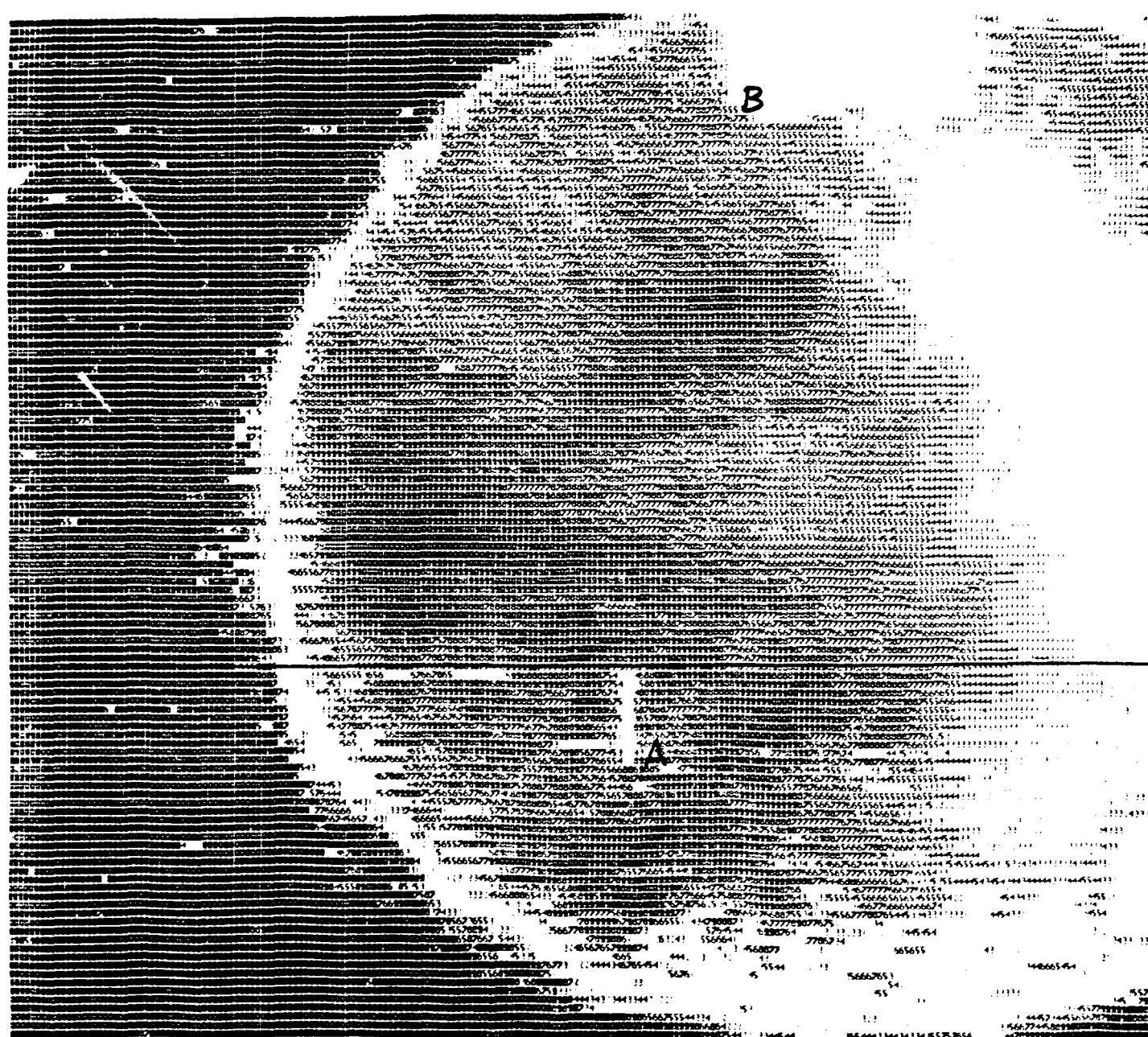
DATA FILE = C001

POST

DATA FILE = D0012

POST SCAN PLOT

0 inches 1 2 3 4 5 6 7



SAMPLE NO. I

I-B

3

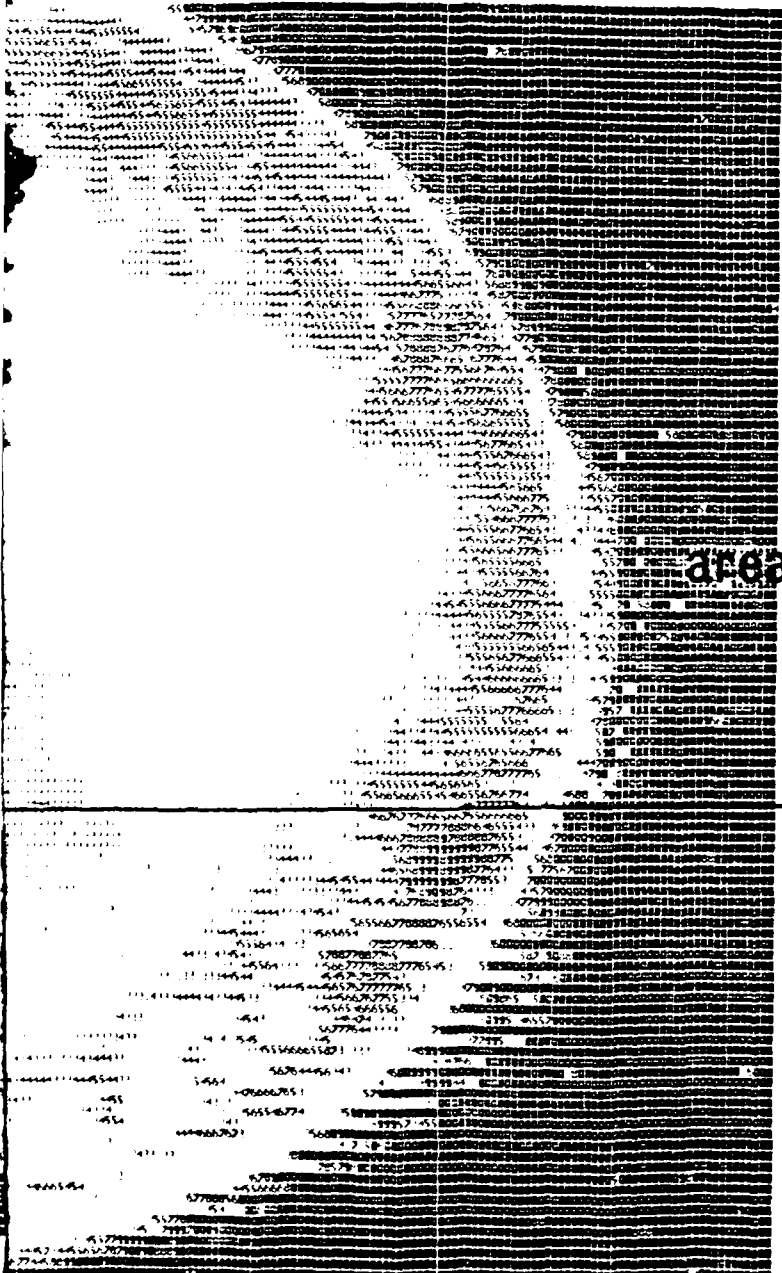
9

10

11

12

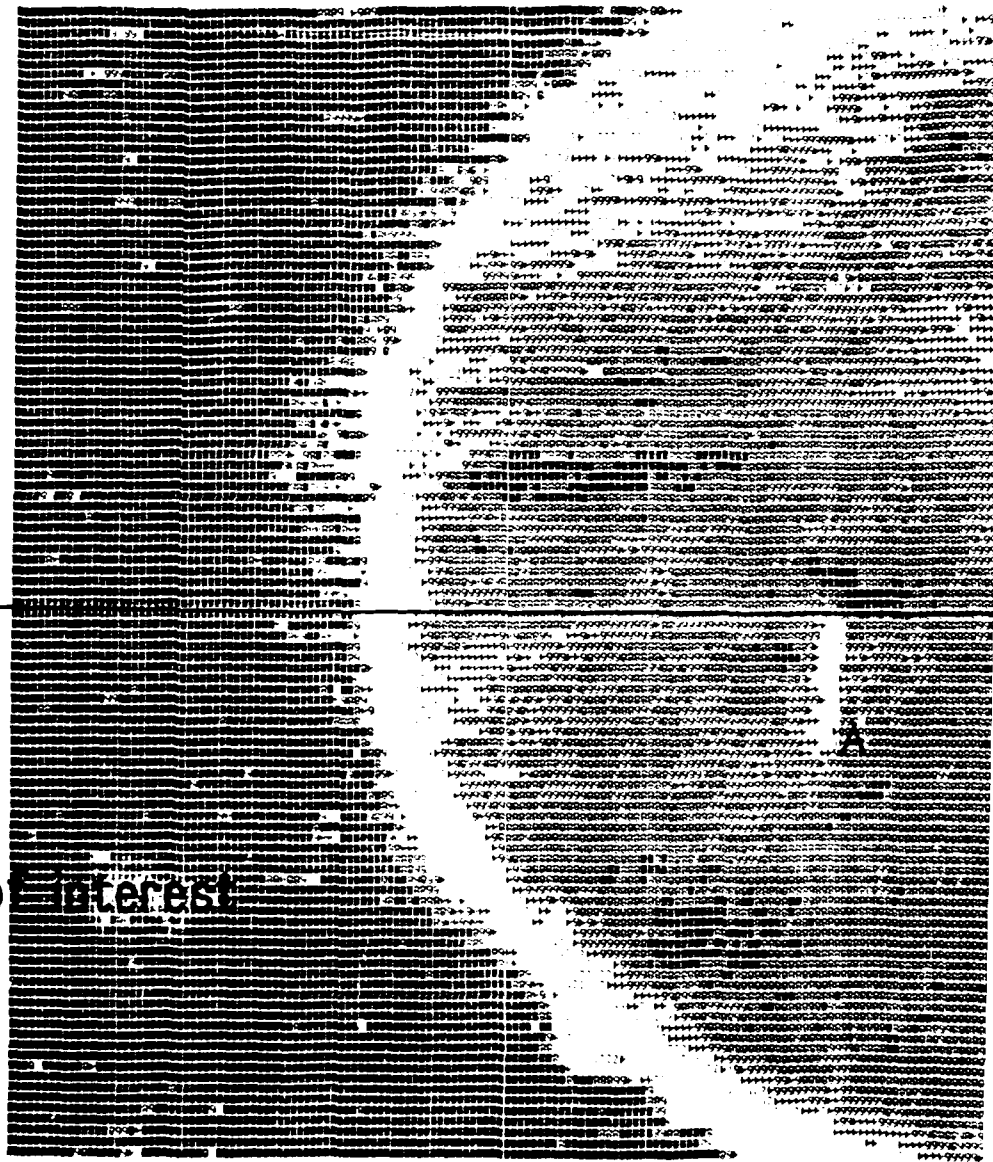
13



area of interest



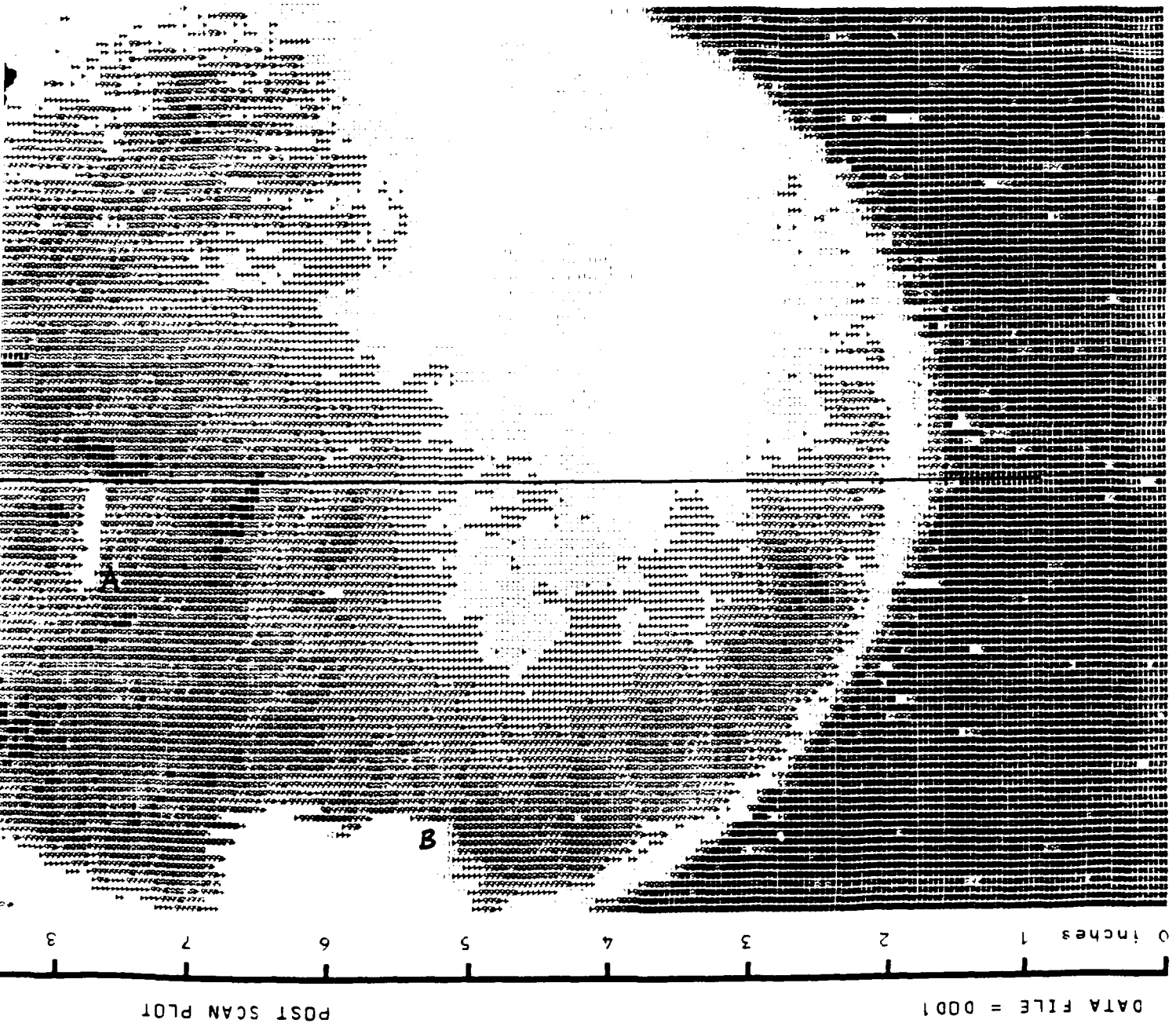
SAM



area of interest

7 8 9 10 11 12 13

I-C
SAMPLE NO. 1



2

DATA FILE = D0012

POST SCAN PLOT

0 inches

1

2

3

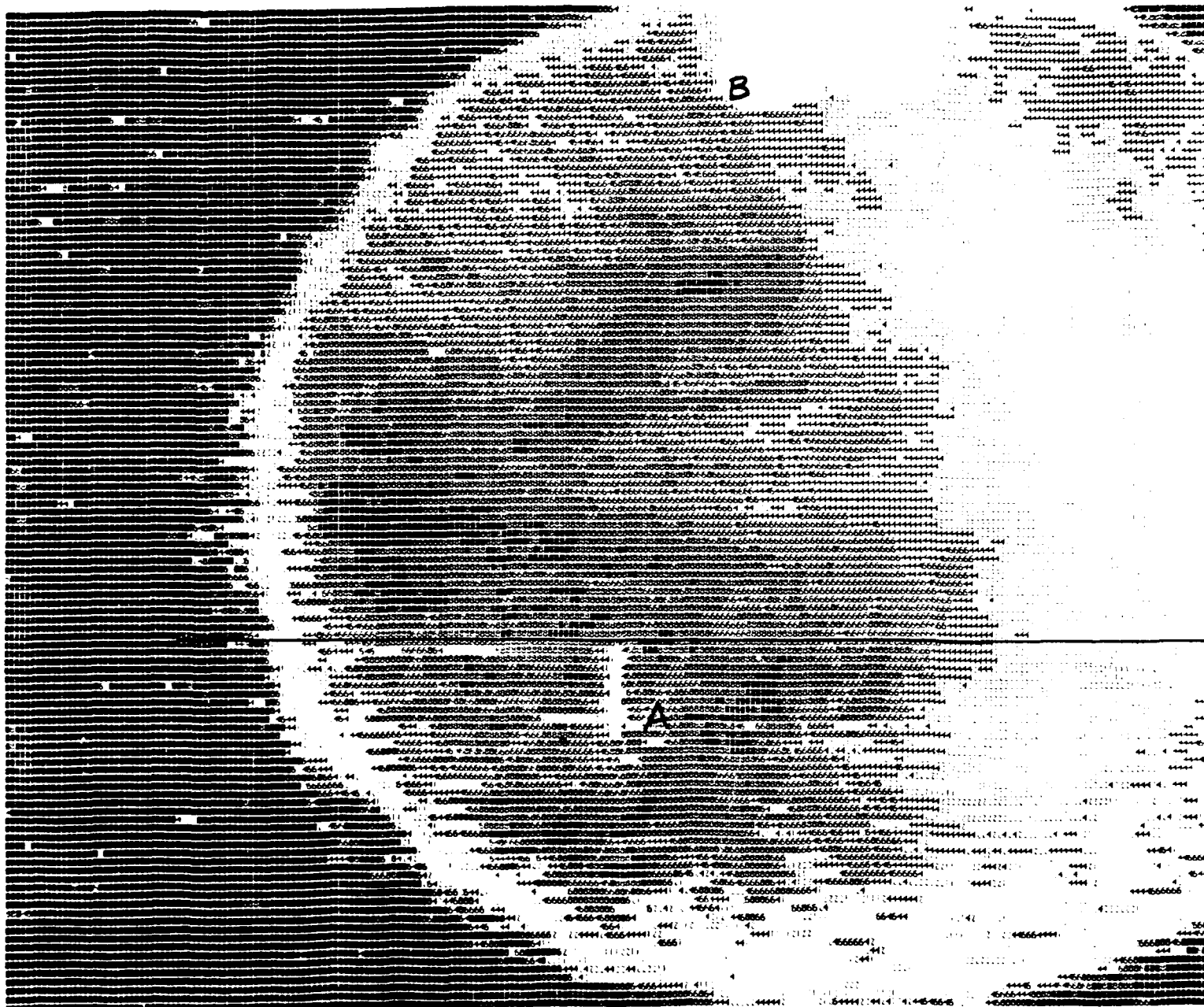
4

5

6

7

8



SAMPLE NO. 1

I-D

9

11

13

of interest

2

SAMPLE

area of interest

13

12

11

10

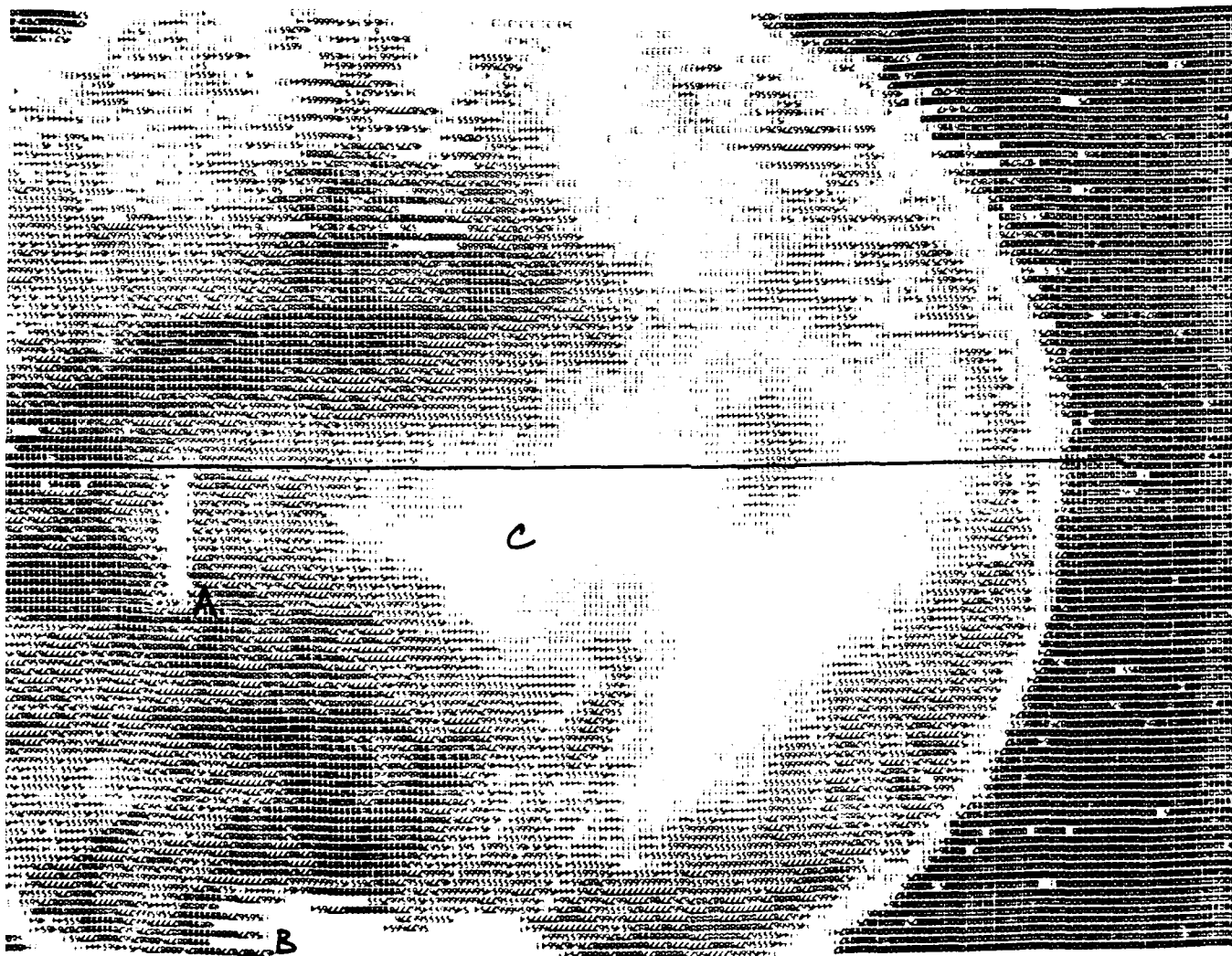
9

8

7

2-A

SAMPLE NO.2



0 inches 1 2 3 4 5 6 7 8

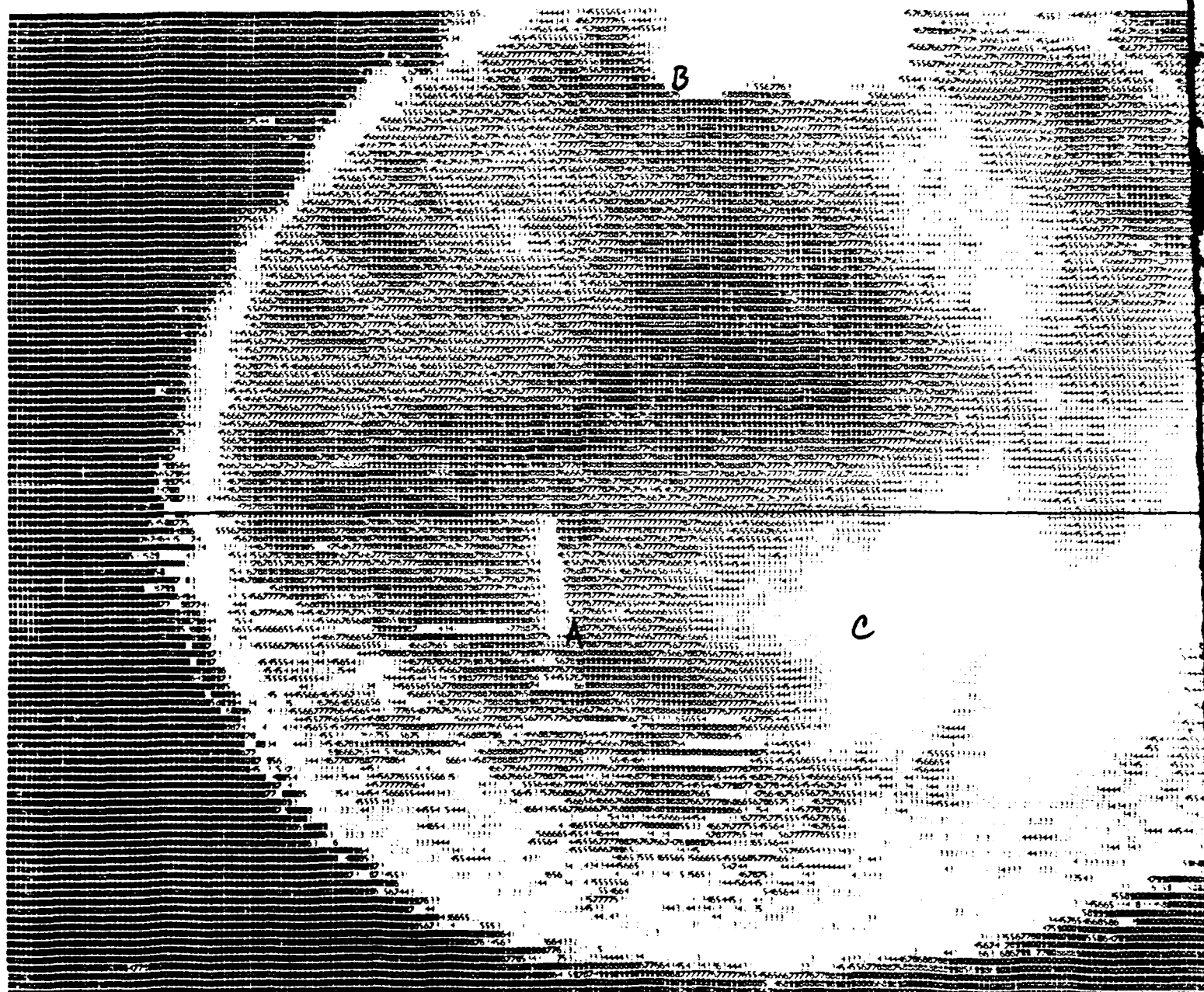
DATA FILE = 0002

POST SCAN PLOT

1

2

0 inches	1	2	3	4	5	6	7	8
----------	---	---	---	---	---	---	---	---



SAMPLE NO.2

2-B

3 4 5 6 7 8 9 10 11 12 13



area of interest



area of interest



13

12

11

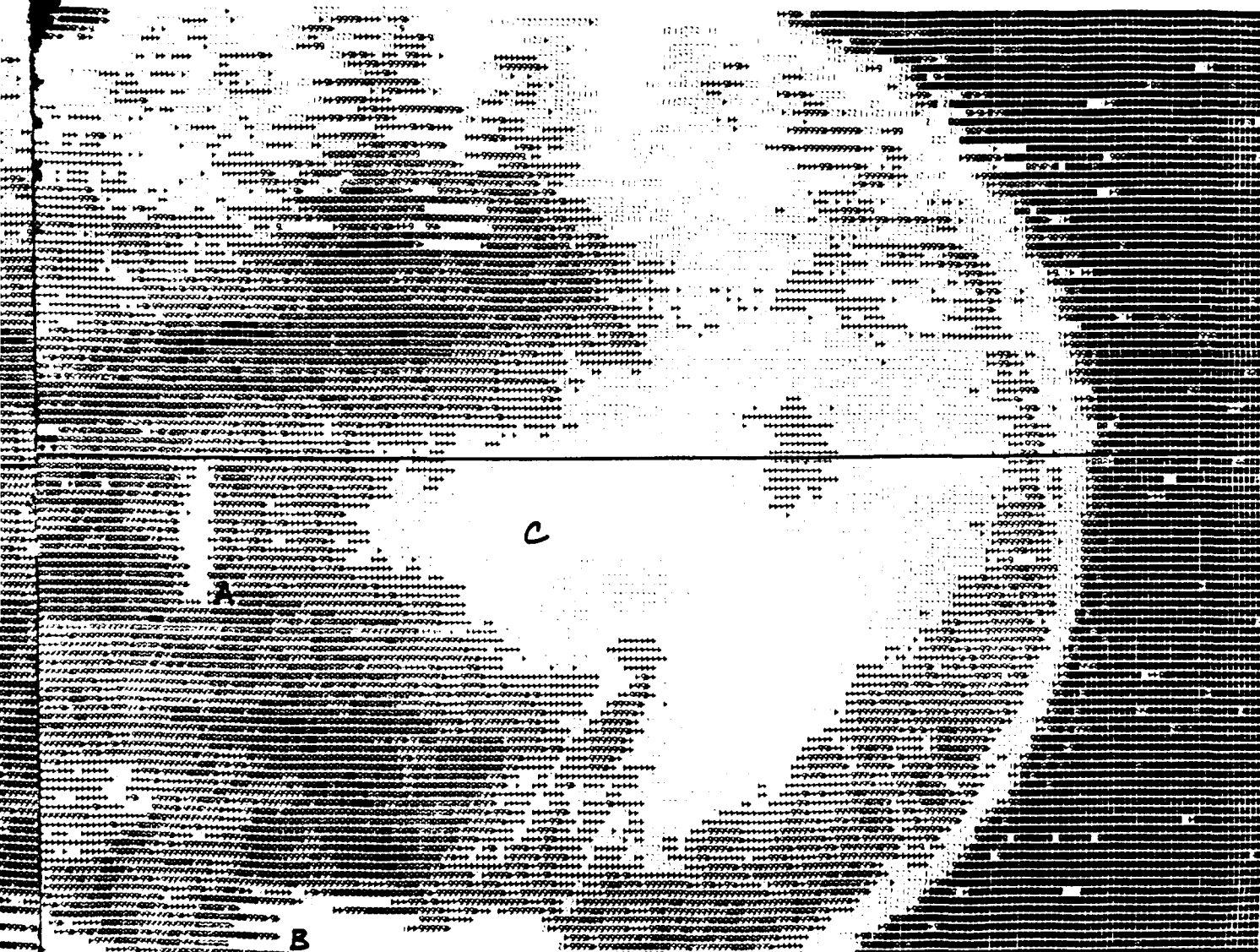
10

9

8

2-C

SAMPLE NO. 2



C

B

0 inches 1 2 3 4 5 6 7 8

POST SCAN PLOT

DATA FILE = 0002

2

0 inches

1

2

3

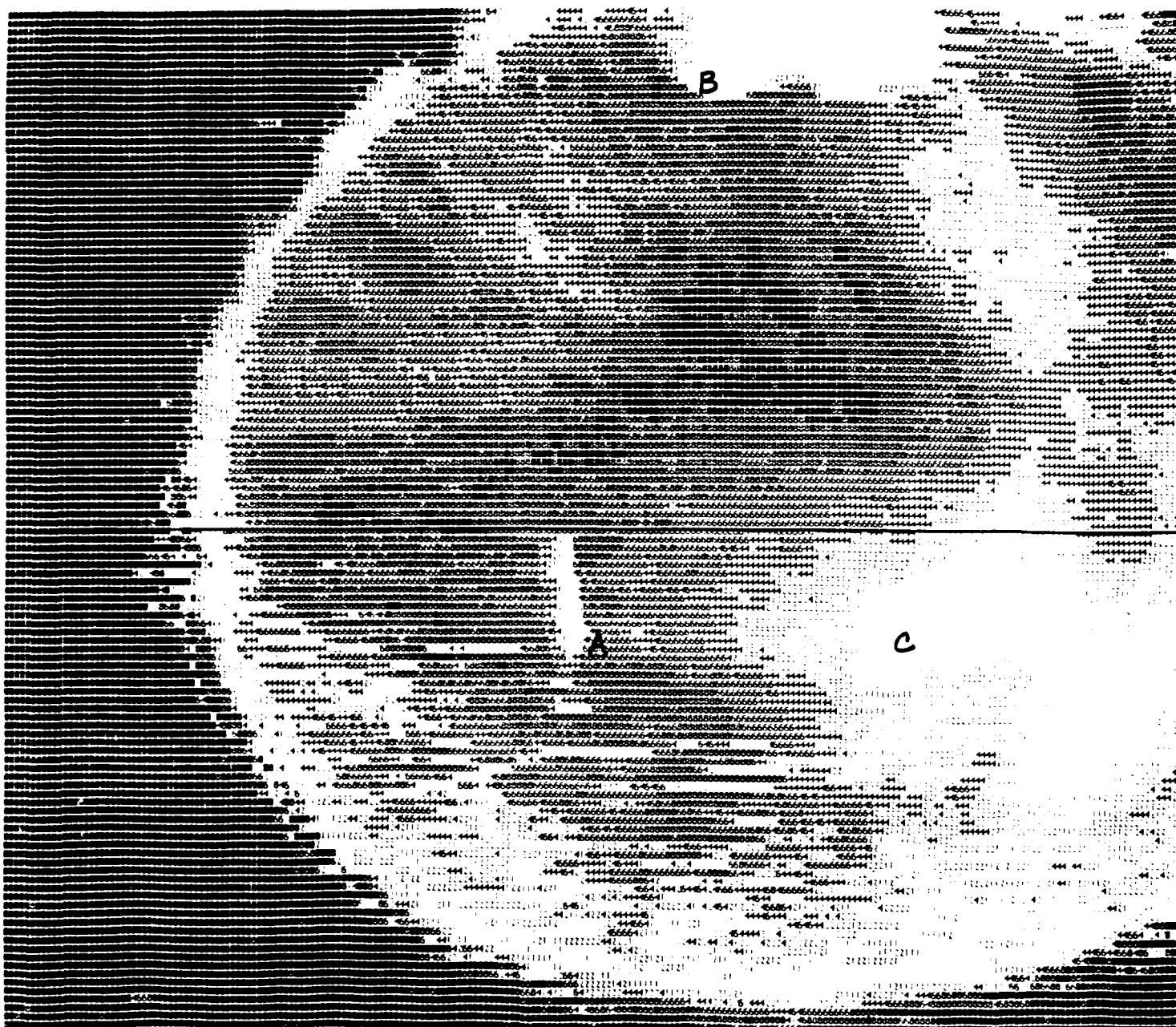
4

5

6

7

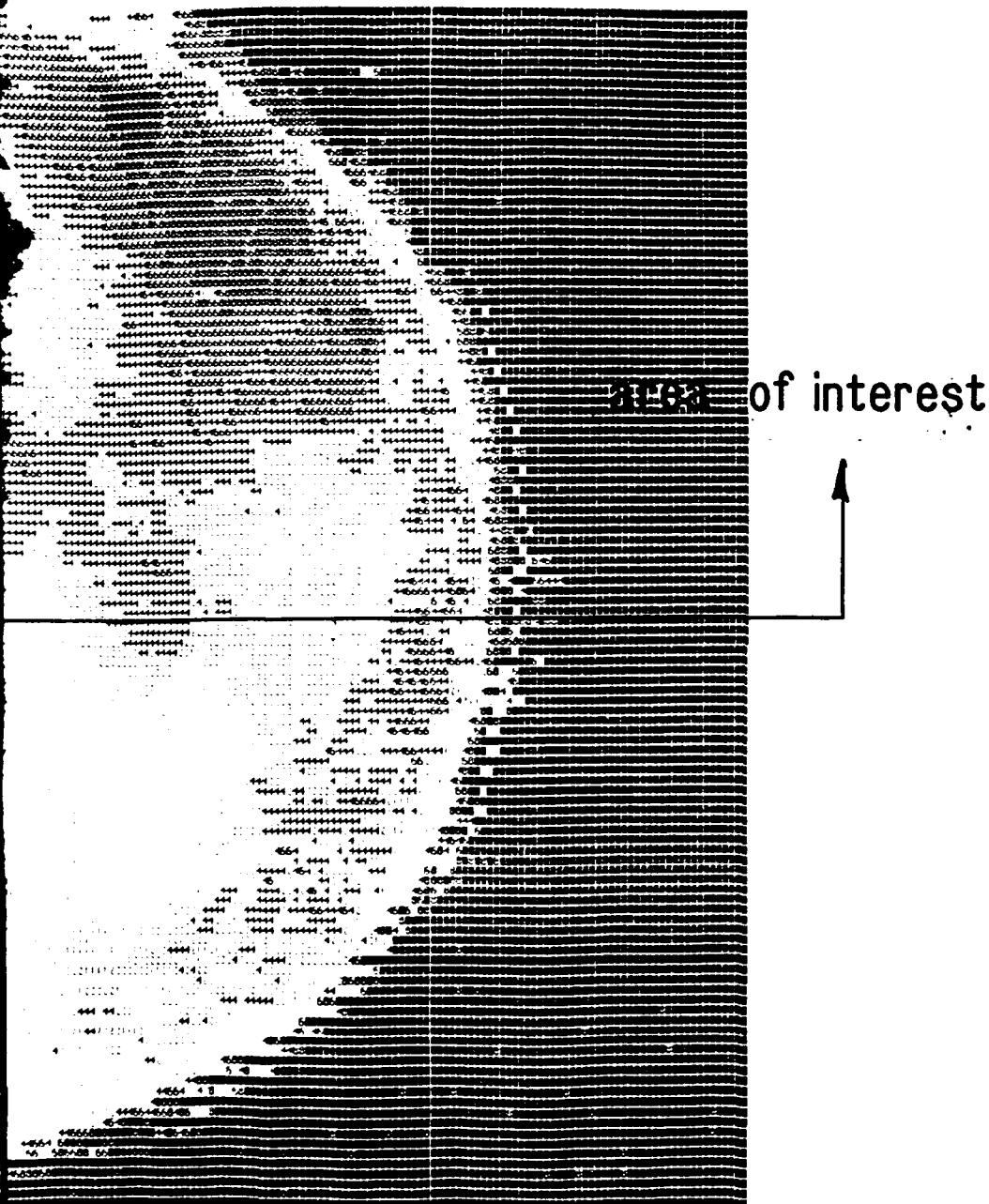
8



SAMPLE NO. 2

2-D

7 8 9 10 11 12 13



SAM



area of interest

13

12

11

10

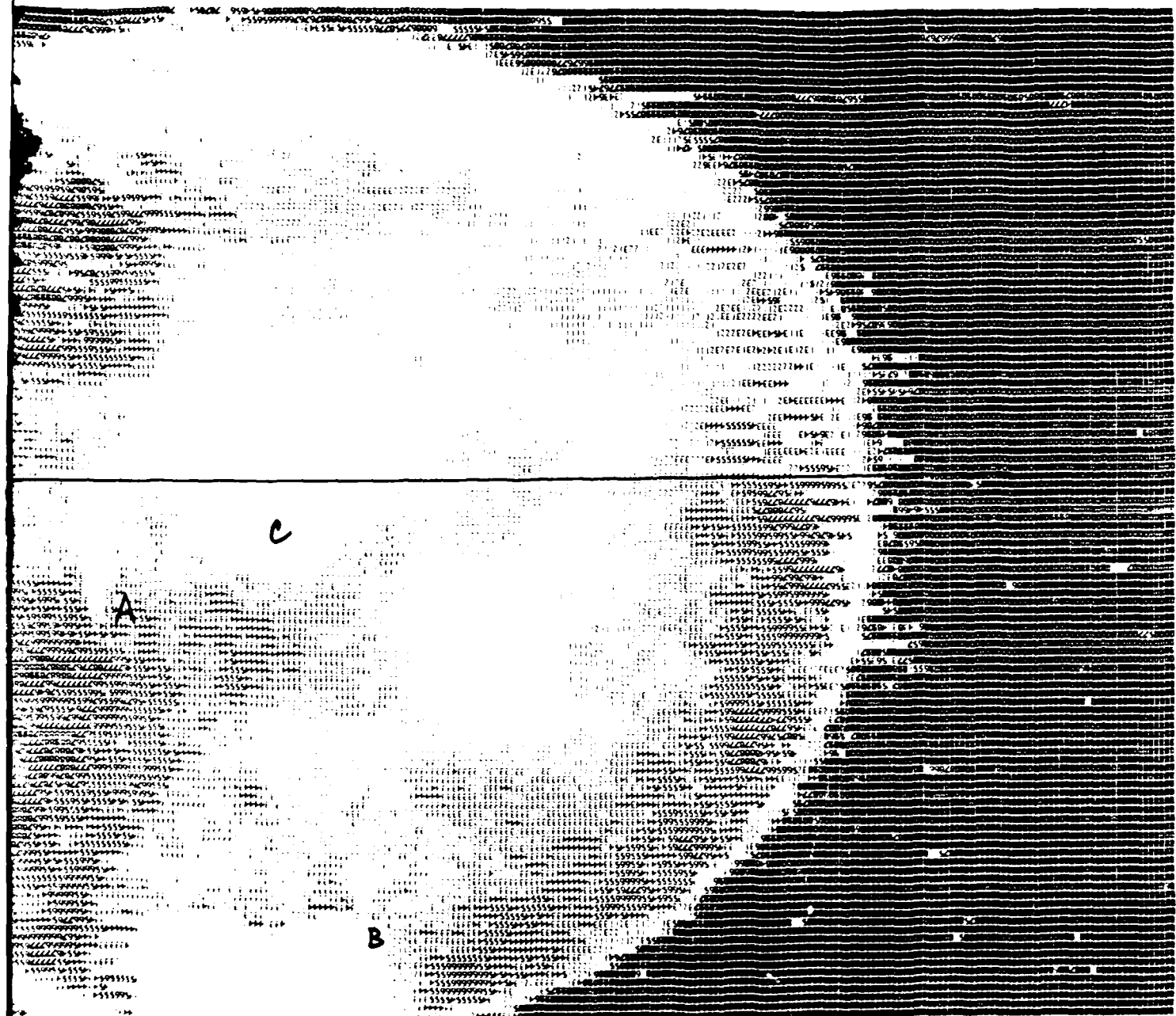
9

8

7

3-A

SAMPLE NO.3



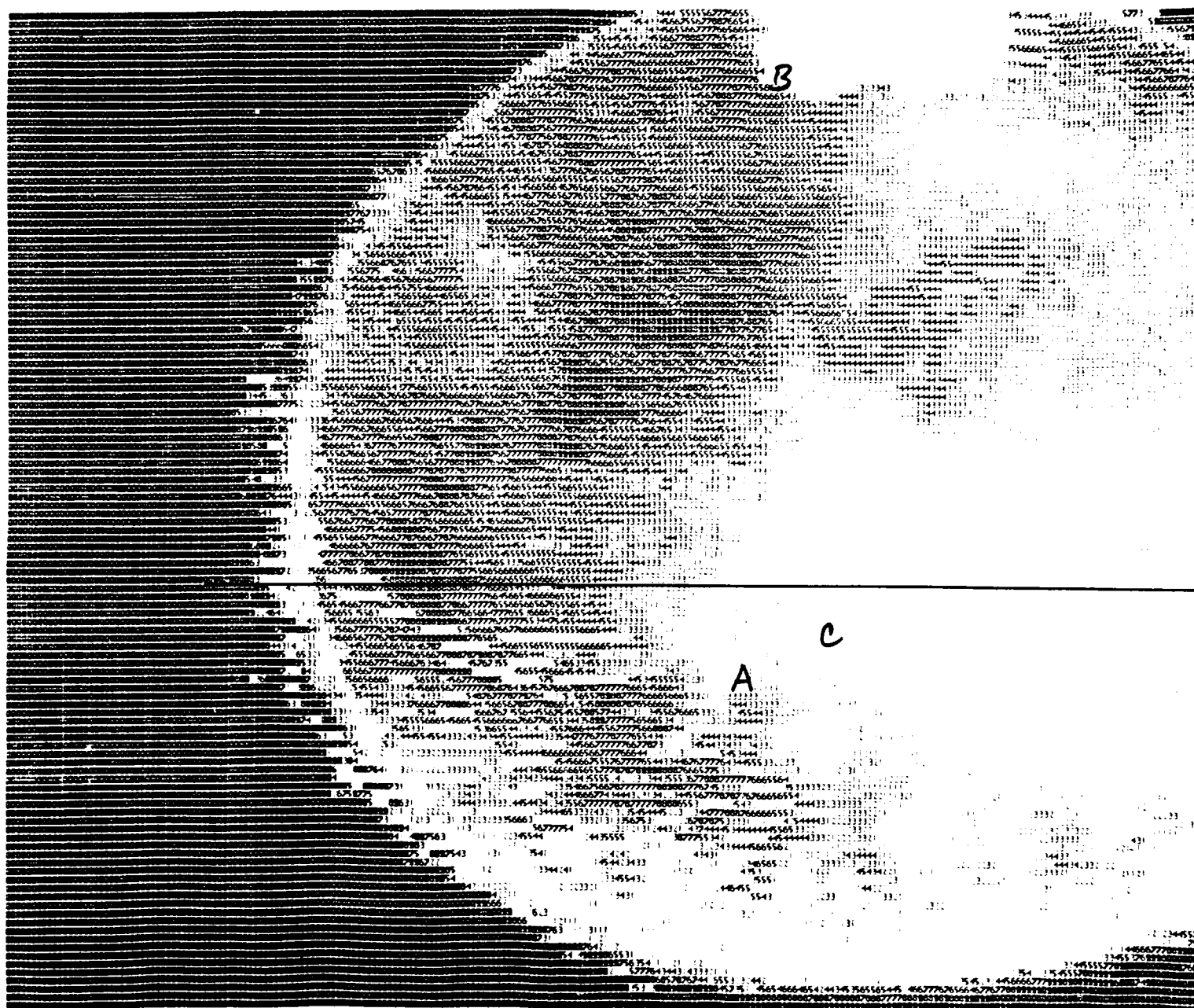
POST SCAN PLOT

DATA FILE = 00013

DATA FILE = D0D10

POST SCAN PLOT

0 inches 1 2 3 4 5 6 7 8



SAMPLE NO.3

3-B

2

SAMI

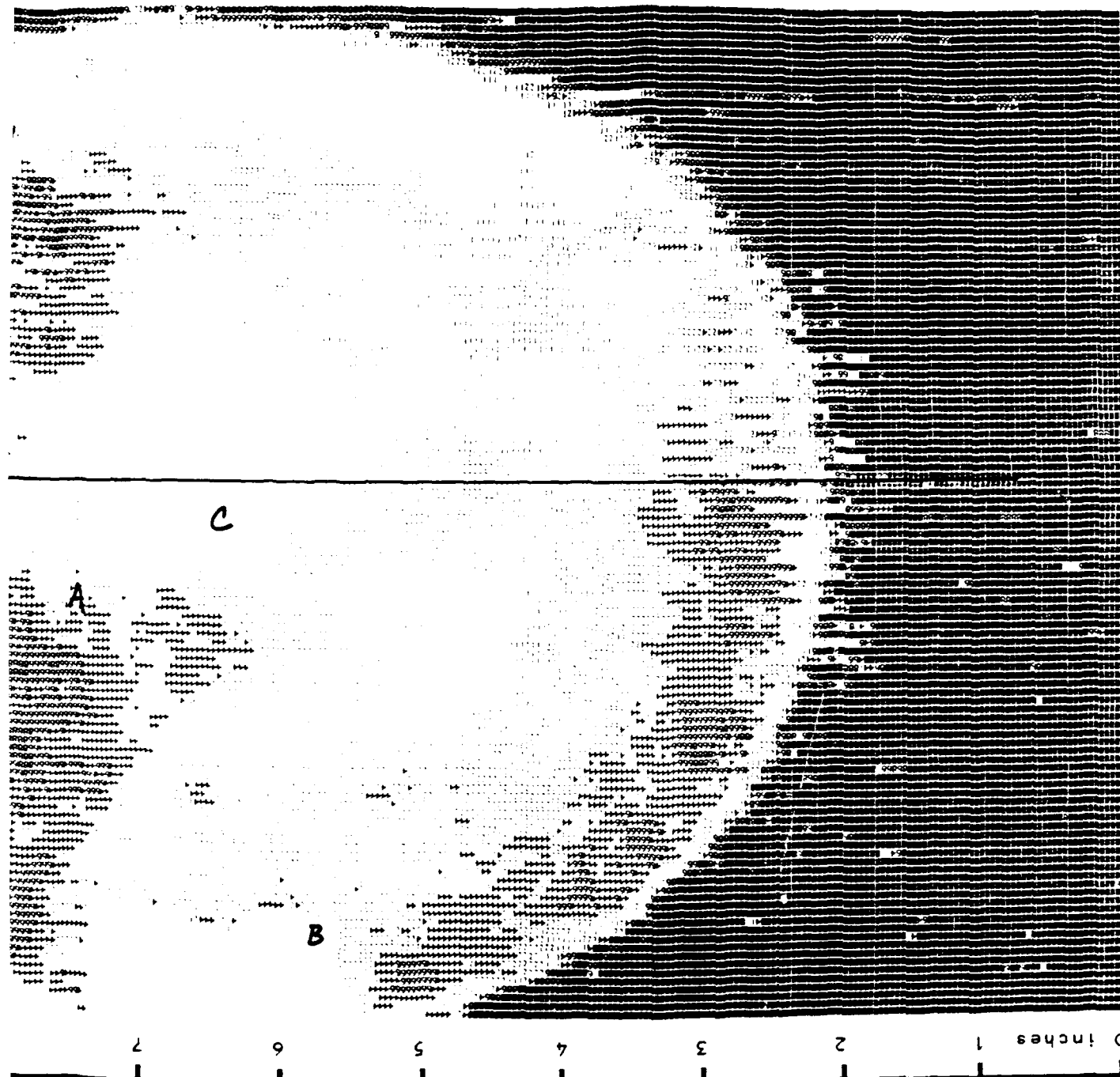


area of interest

7 8 9 10 11 12 13

3-C

SAMPLE NO. 3



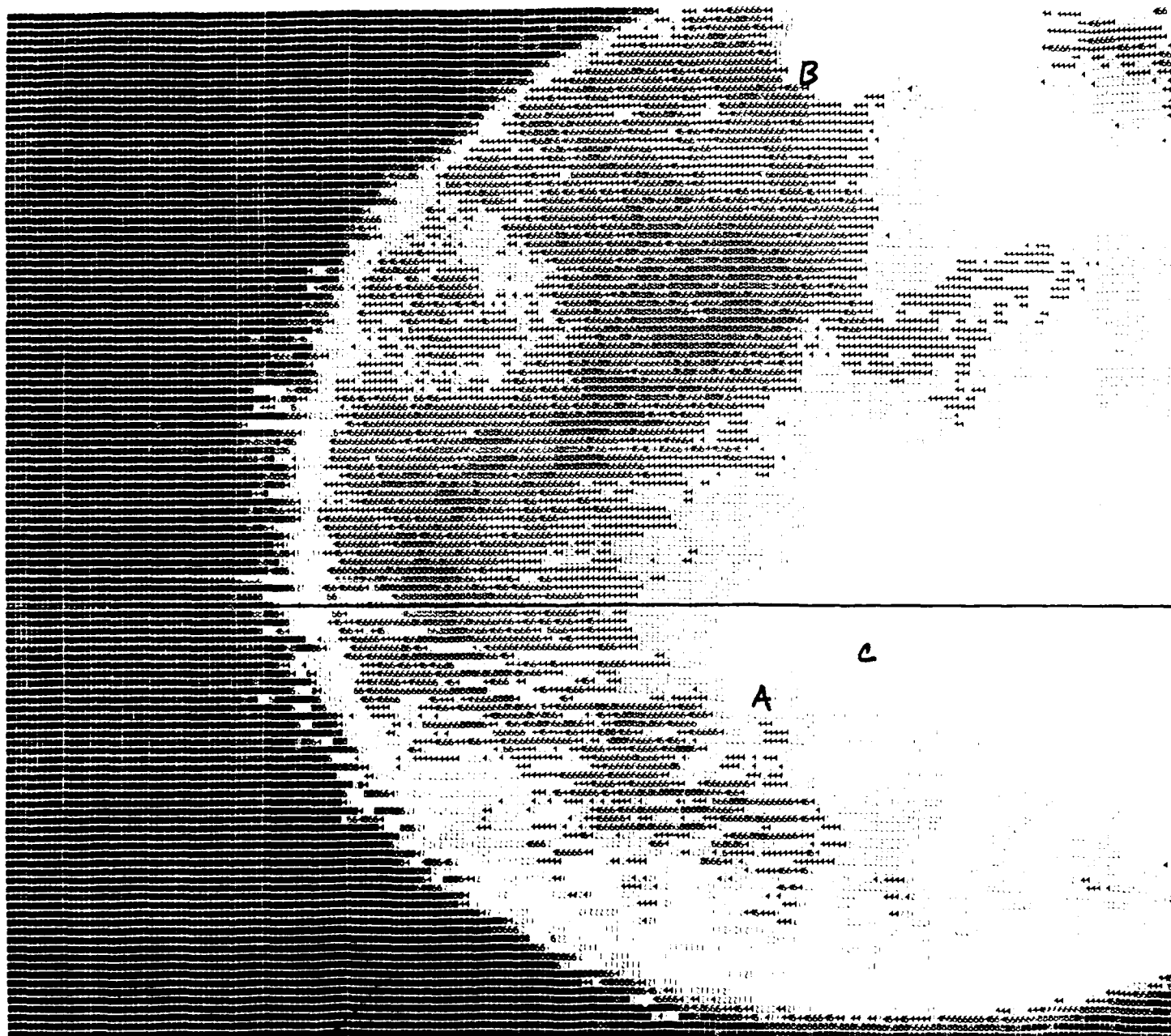
DATA FILE = 00013

POST SCAN PLOT

DATA FILE = DOD10

POST SCAN PLOT

0 inches 1 2 3 4 5 6 7 8



SAMPLE NO. 3

3-D

8	9	10	11	12	13
---	---	----	----	----	----

area of interest

✓

SAMP

area of interest

13

12

11

10

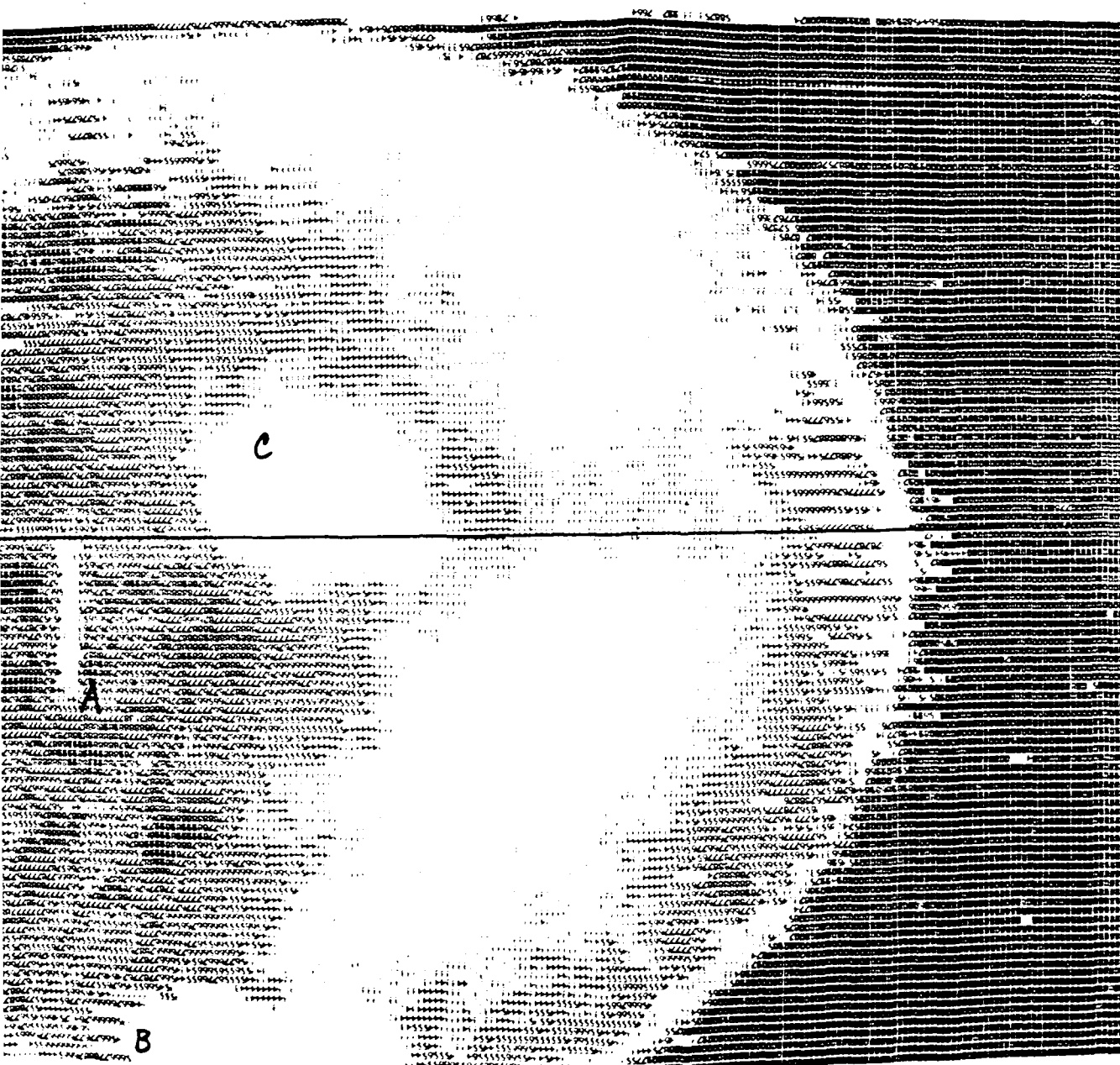
9

8

7

4-A

SAMPLE NO.4



0 inches 1 2 3 4 5 6 7

DATA FILE = D0014

POST SCAN PLOT

DATA FILE = D0D9

POST SCAN PLOT

0 inches

1

2

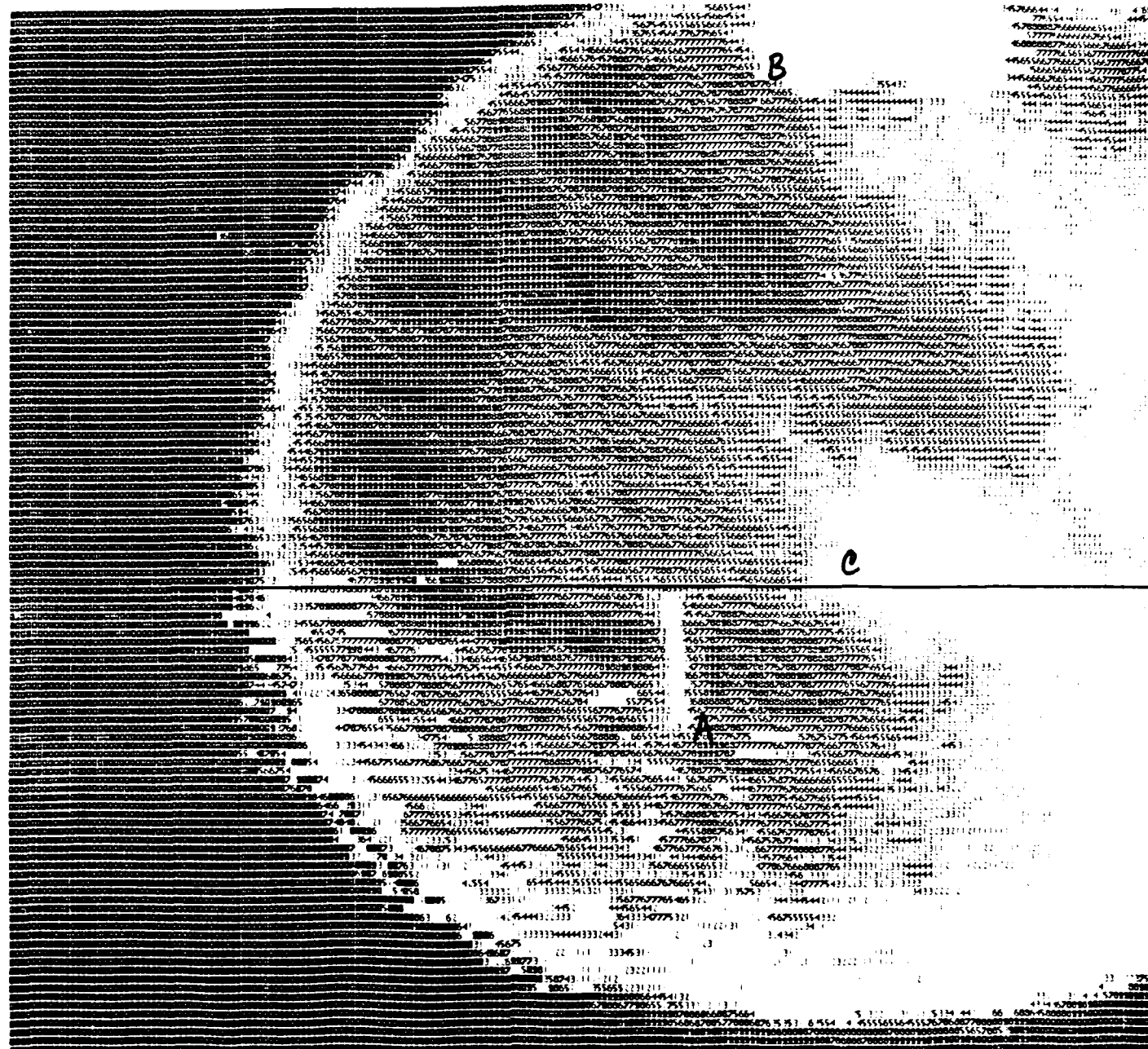
3

4

5

6

7



SAMPLE NO. 4

4-B

7 8 9 10 11 12 13



area of interest



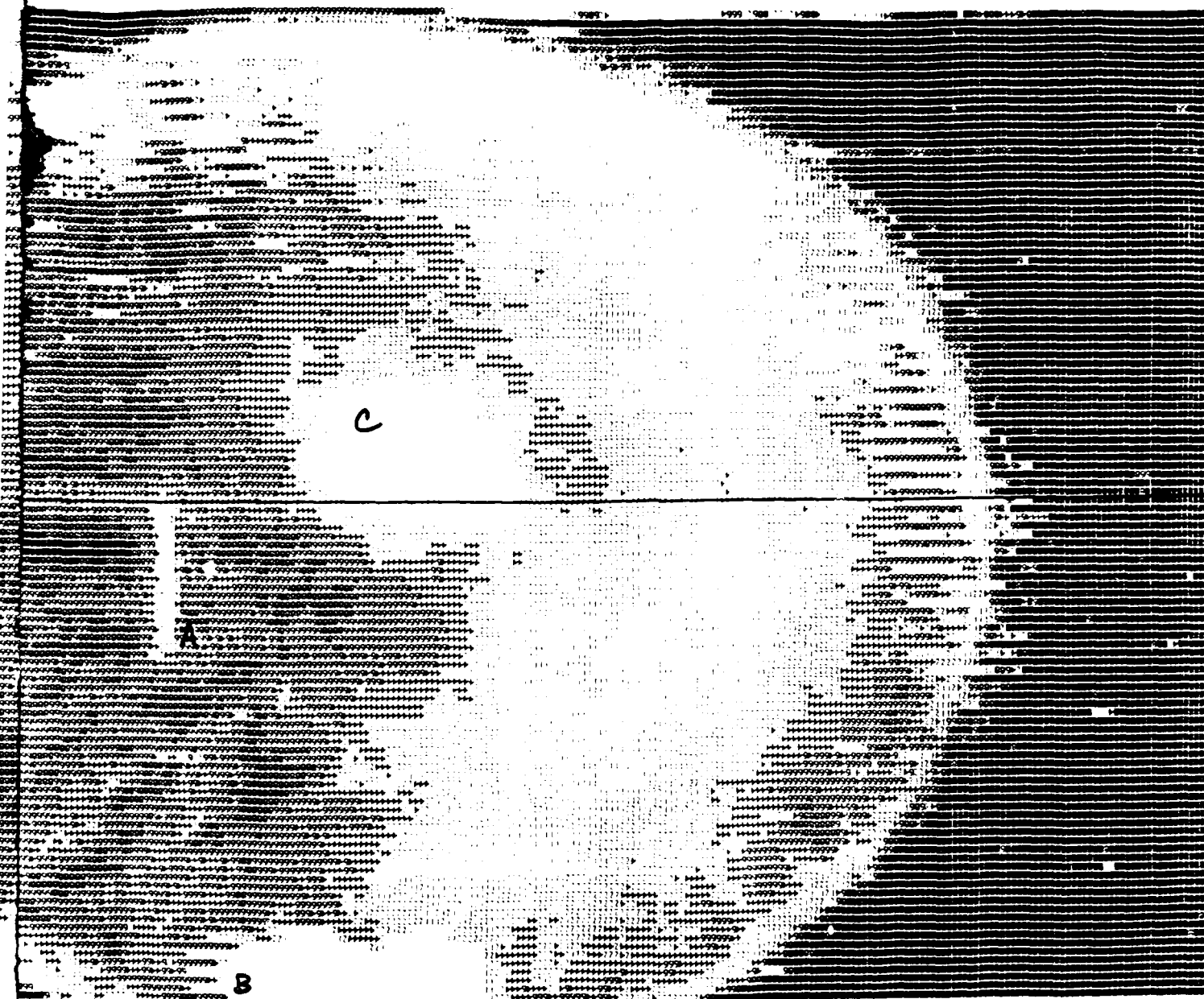


area of interest

7 8 9 10 11 12 13

4-C

SAMPLE NO. 4



POST SCAN PLOT

DATA FILE = 00014

0 inches 1 2 3 4 5 6 7 8

2

DATA FILE = D0D9

POST SCAN PLOT

0 inches

1

2

3

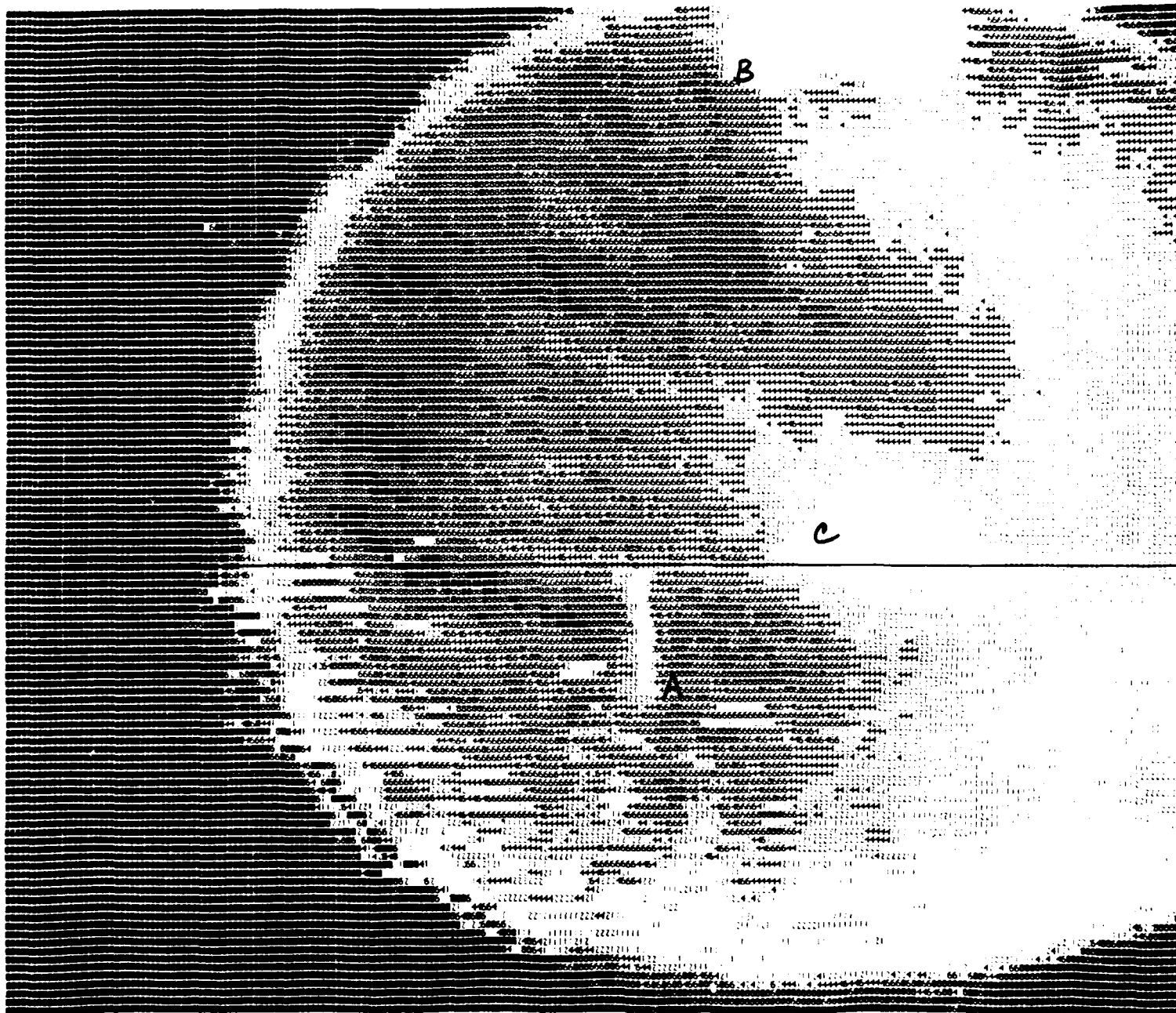
4

5

6

7

8



SAMPLE NO. 4

4-D

8

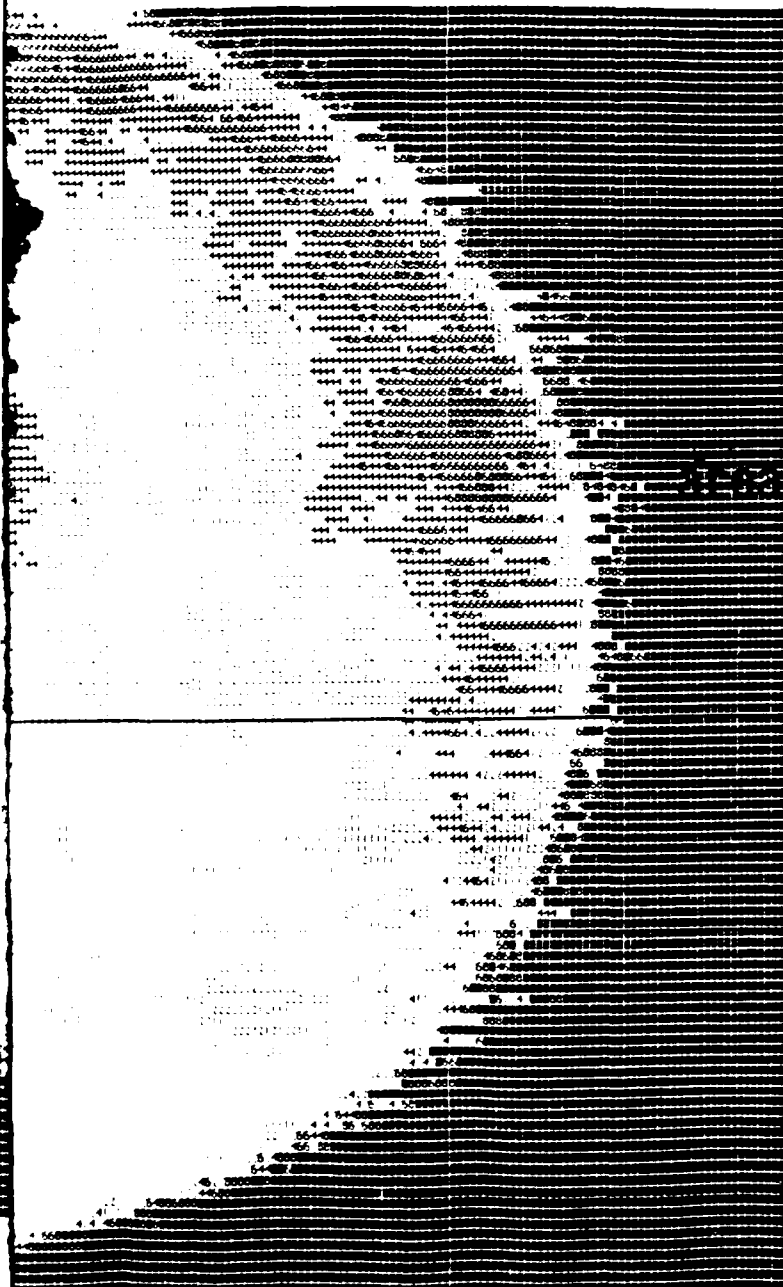
9

10

11

12

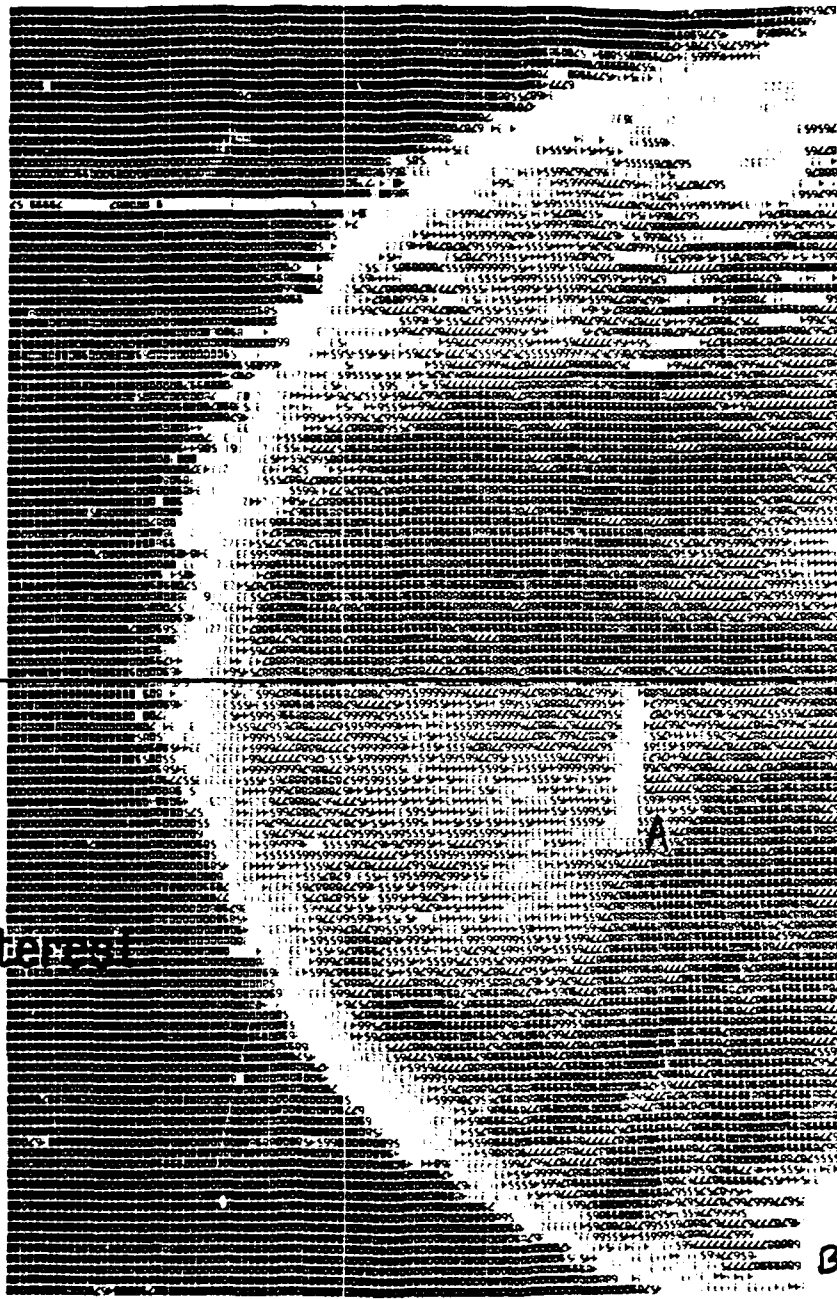
13



of interest



SA

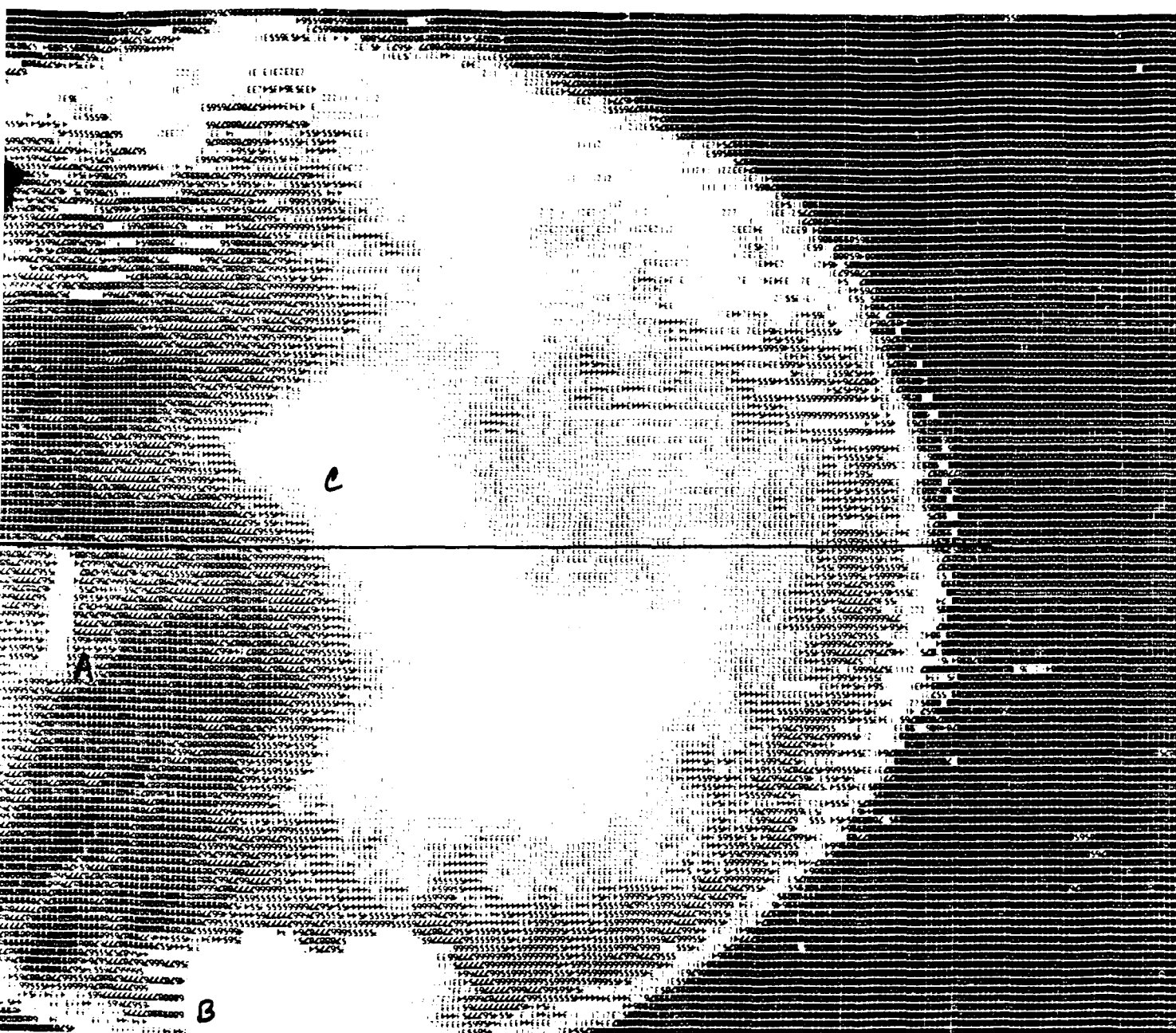


area of interest

7 8 9 10 11 12 13

5-A

SAMPLE NO. 5



8

7

6

5

4

3

2

1

0 inches

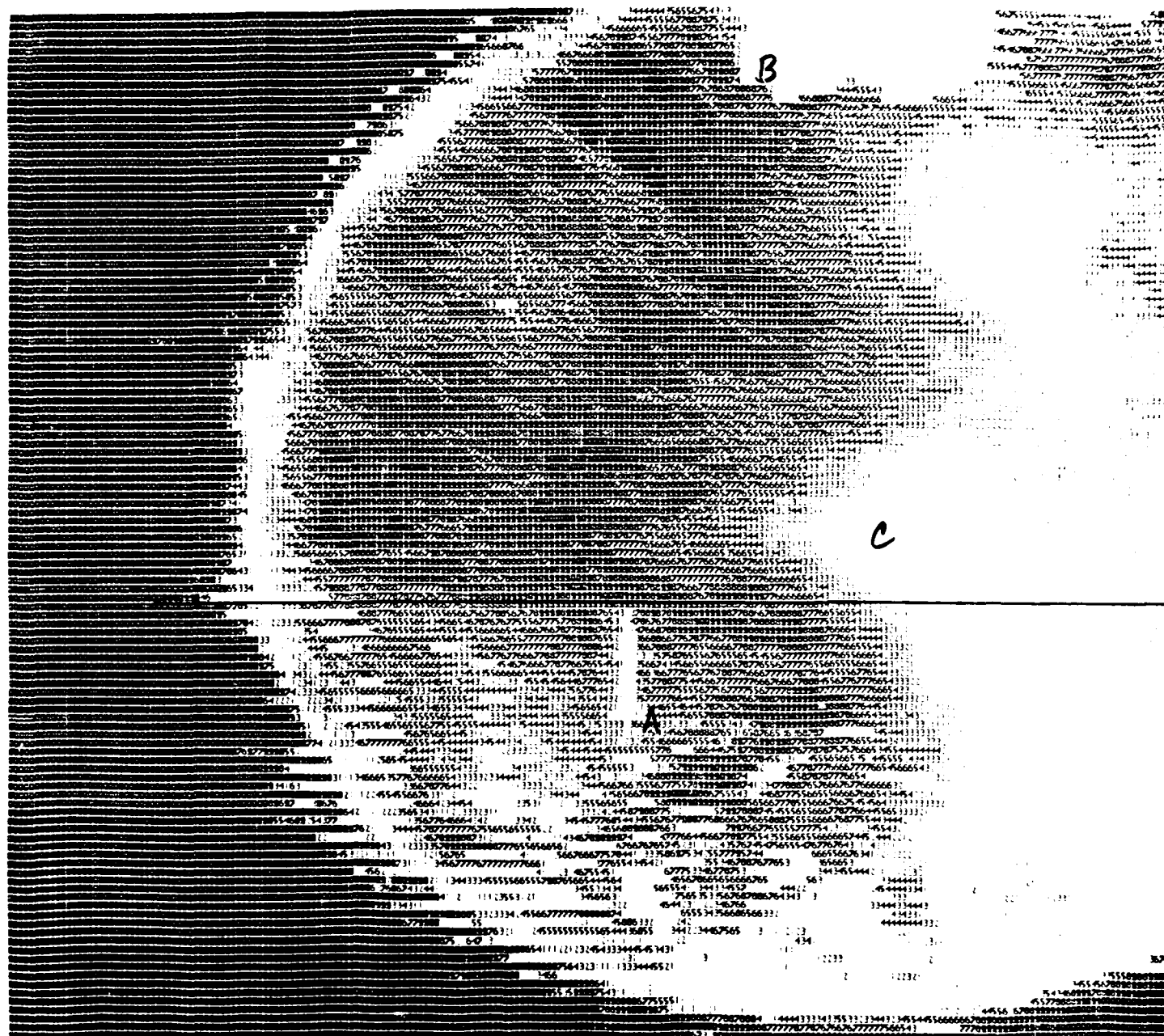
POST SCAN PLOT

DATA FILE = 00015

DATA FILE = D0D8

POST SCAN PLOT

0 inches 1 2 3 4 5 6 7 8



SAMPLE NO.5

5-B

2

SAN



area of interest

13

12

11

10

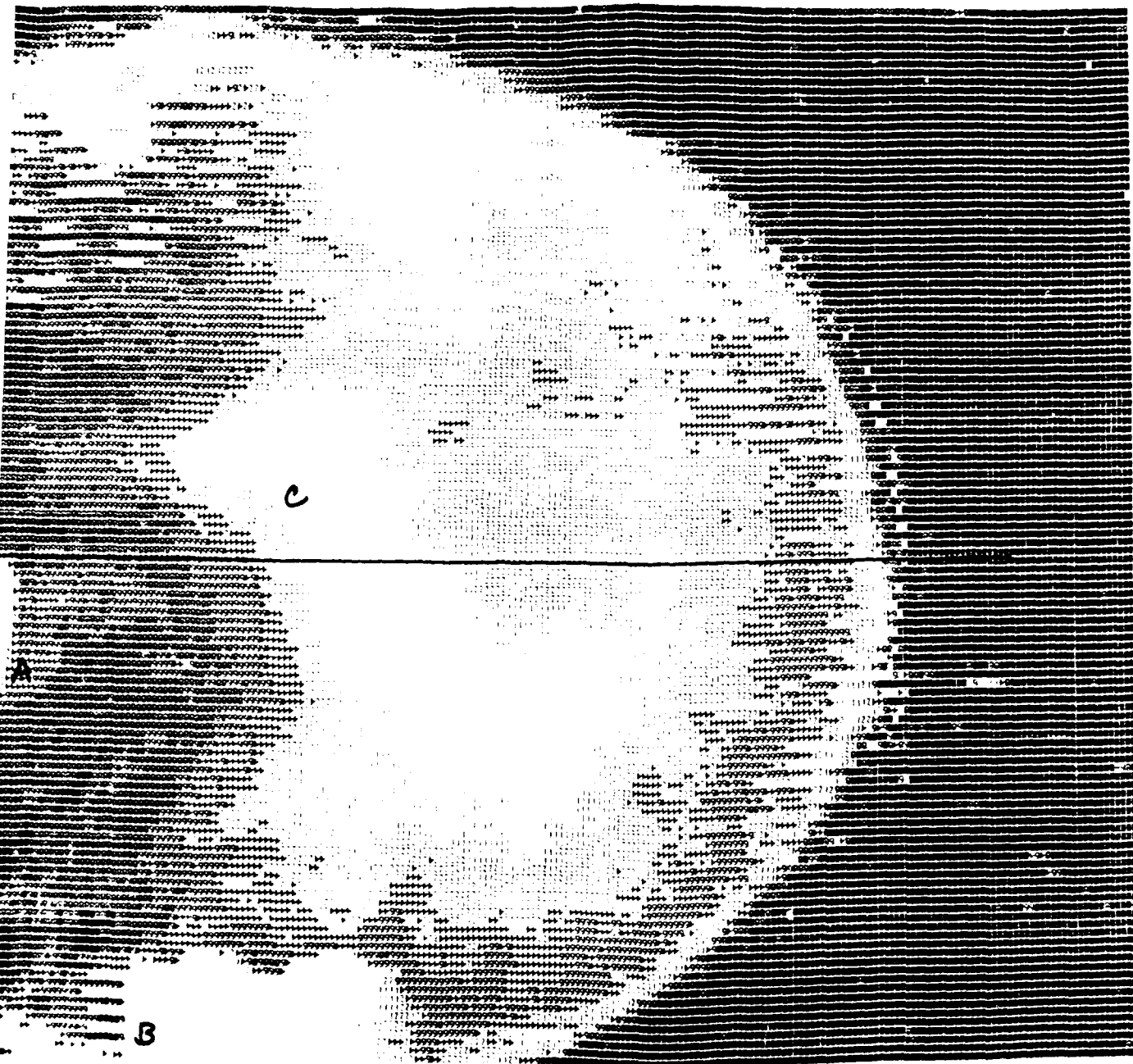
9

8

7

5-C

SAMPLE NO. 5



C

A

B

DATA FILE = D0015
POST SCAN PLOT
0 inches 1 2 3 4 5 6 7

2

DATA FILE = D008

POST SCAN PLOT

0 inches

1

2

3

4

5

6

7

8



SAMPLE NO. 5

5-D

8

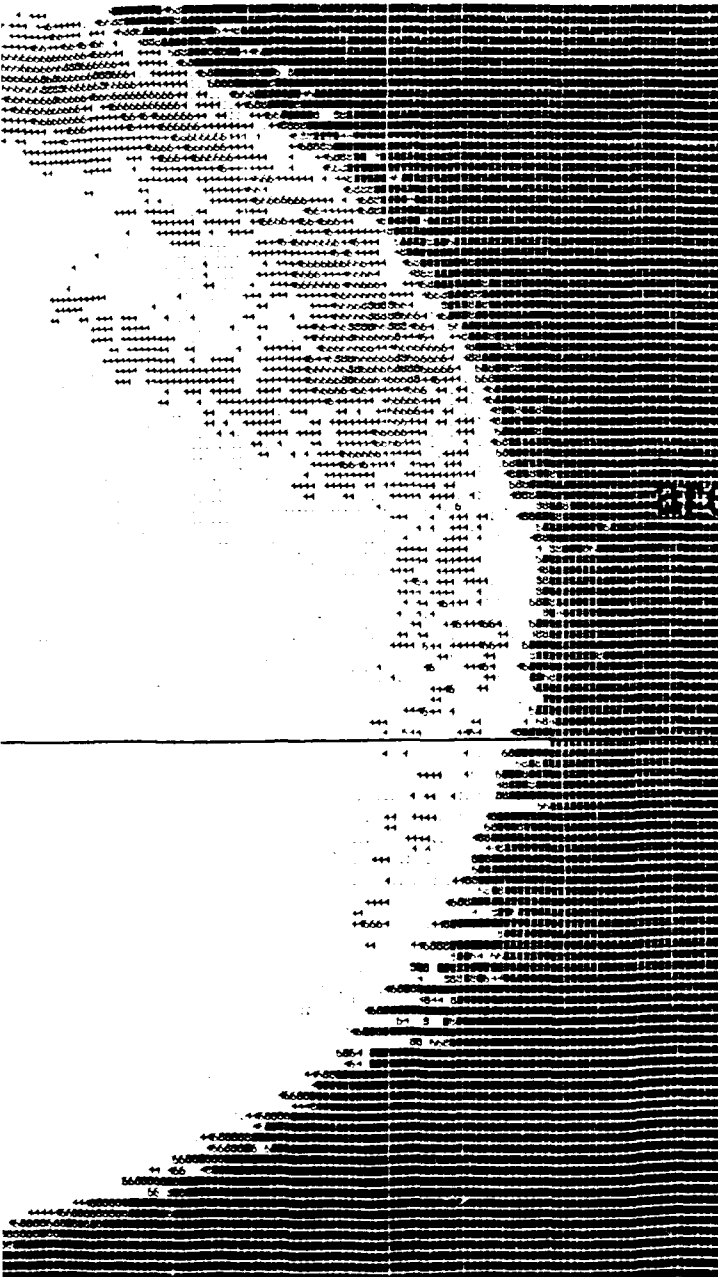
9

10

11

12

13



area of interest



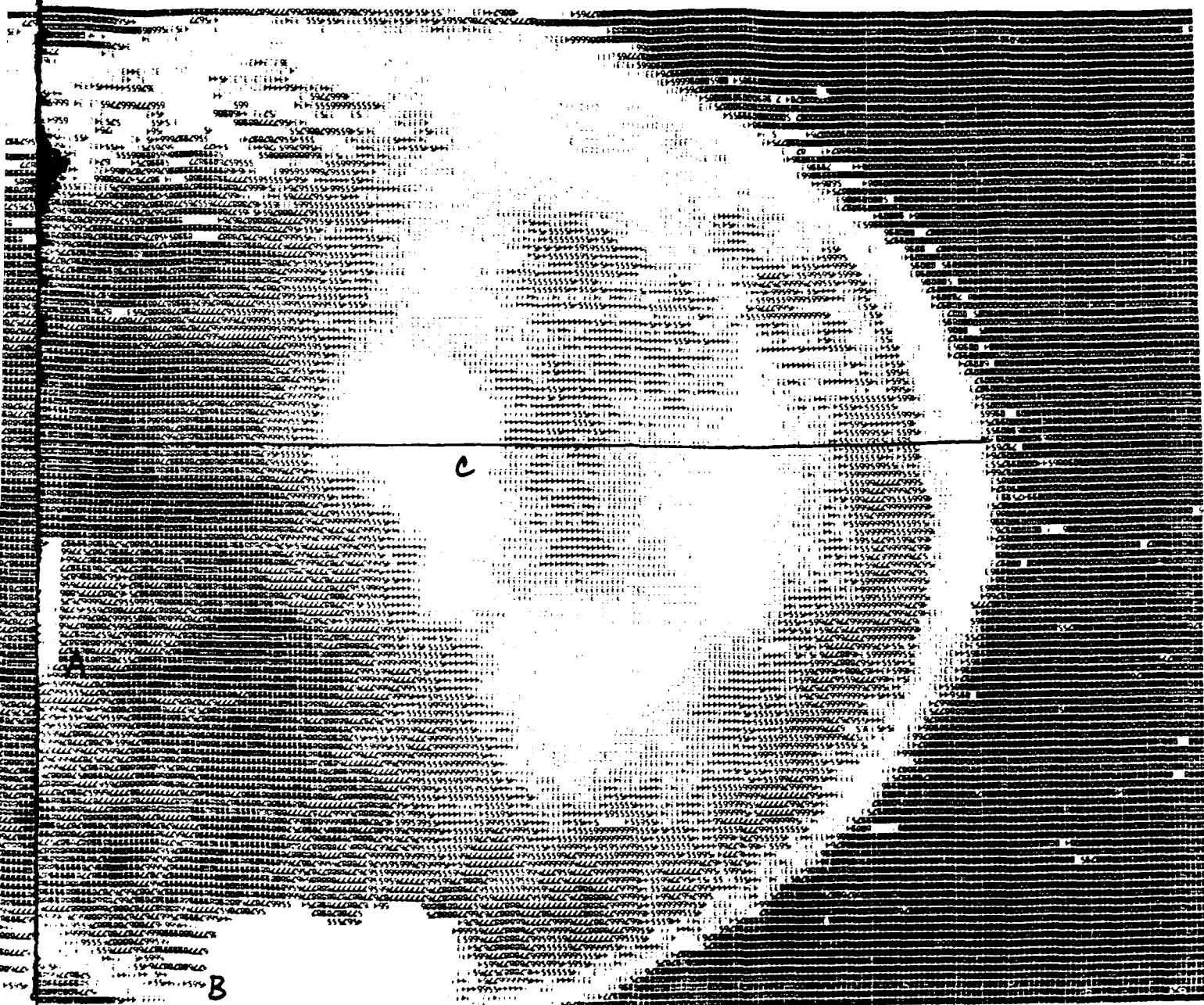
2

encl

PAGE 1 OF 1

6-A

SAMPLE NO.6



C

B

0 inches 1 2 3 4 5 6 7 8

POST SCAN PLOT

DATA FILE = 00016

2

DATA FILE = D007

POST SCAN PLOT

0 inches

1

2

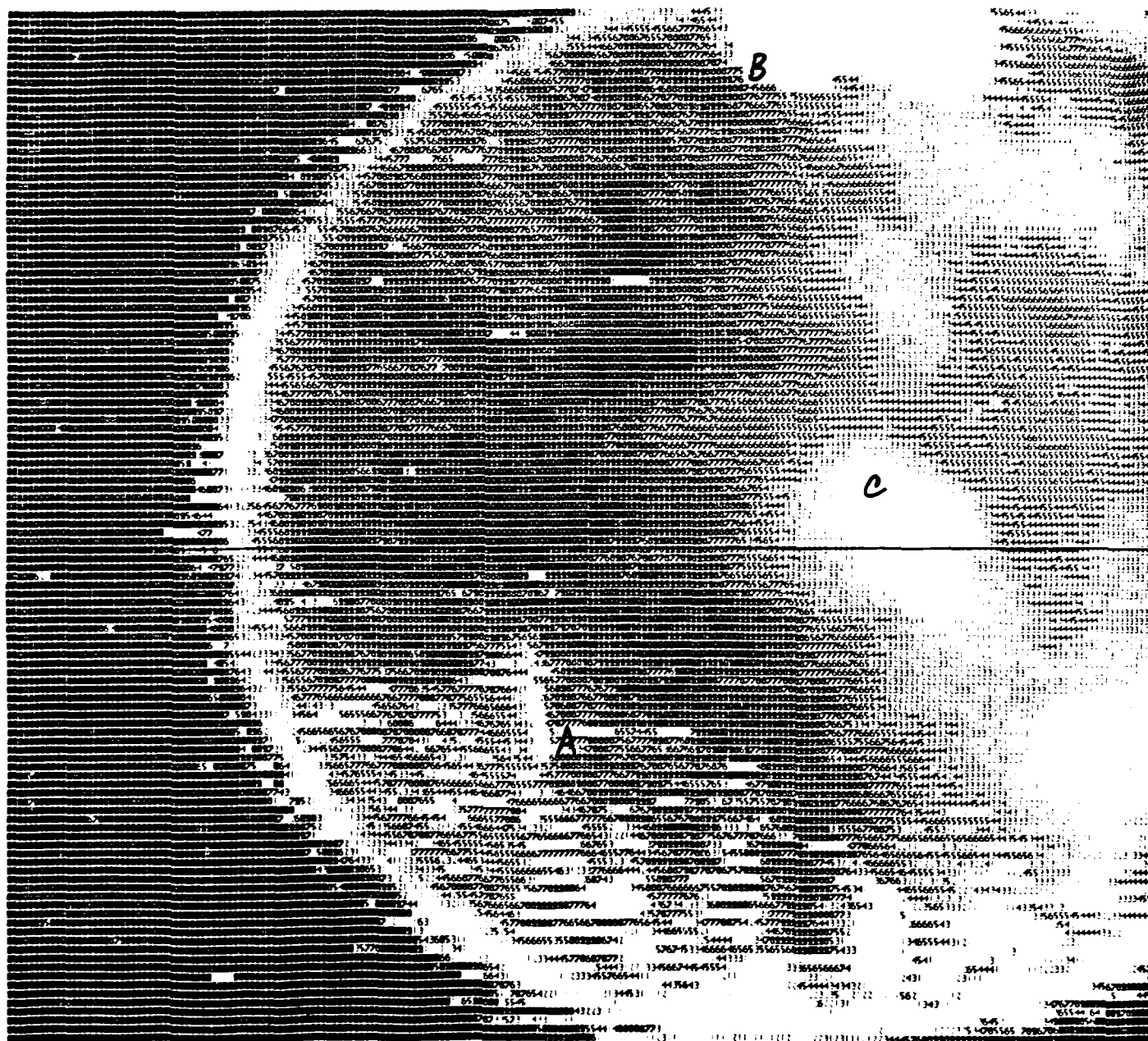
3

4

5

6

7



SAMPLE NO. 6

6-B

8

9

10

11

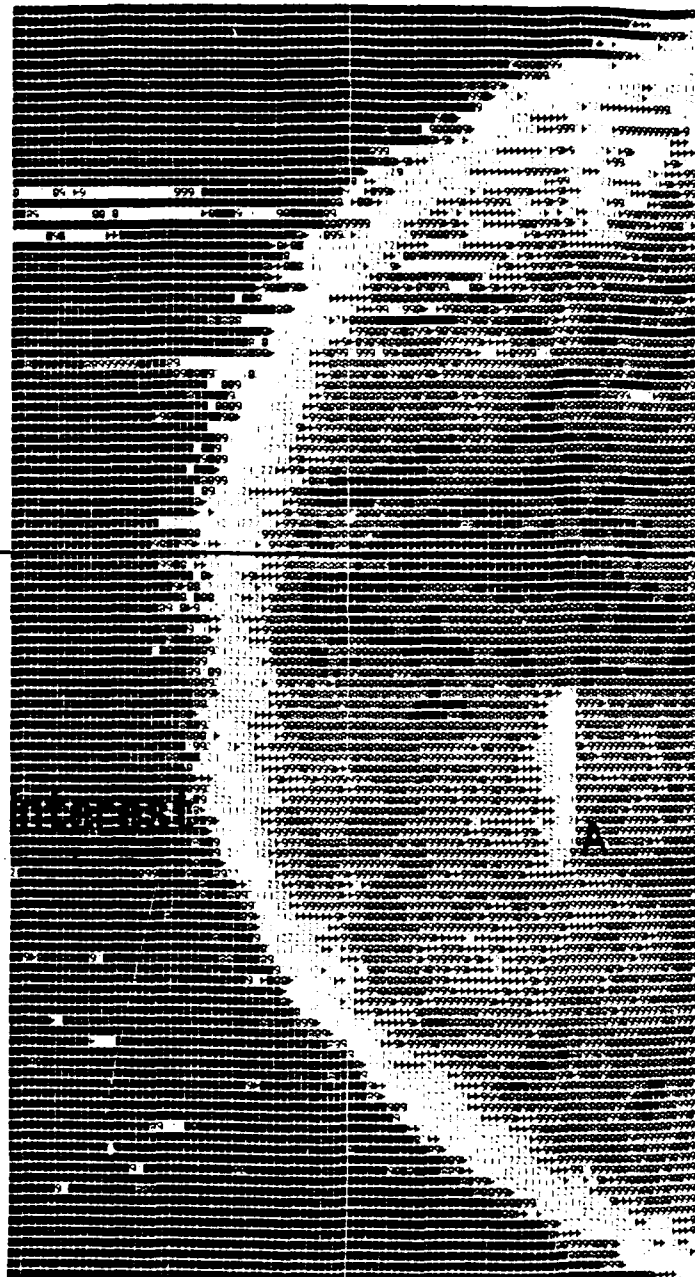
12

13

area of interest



2

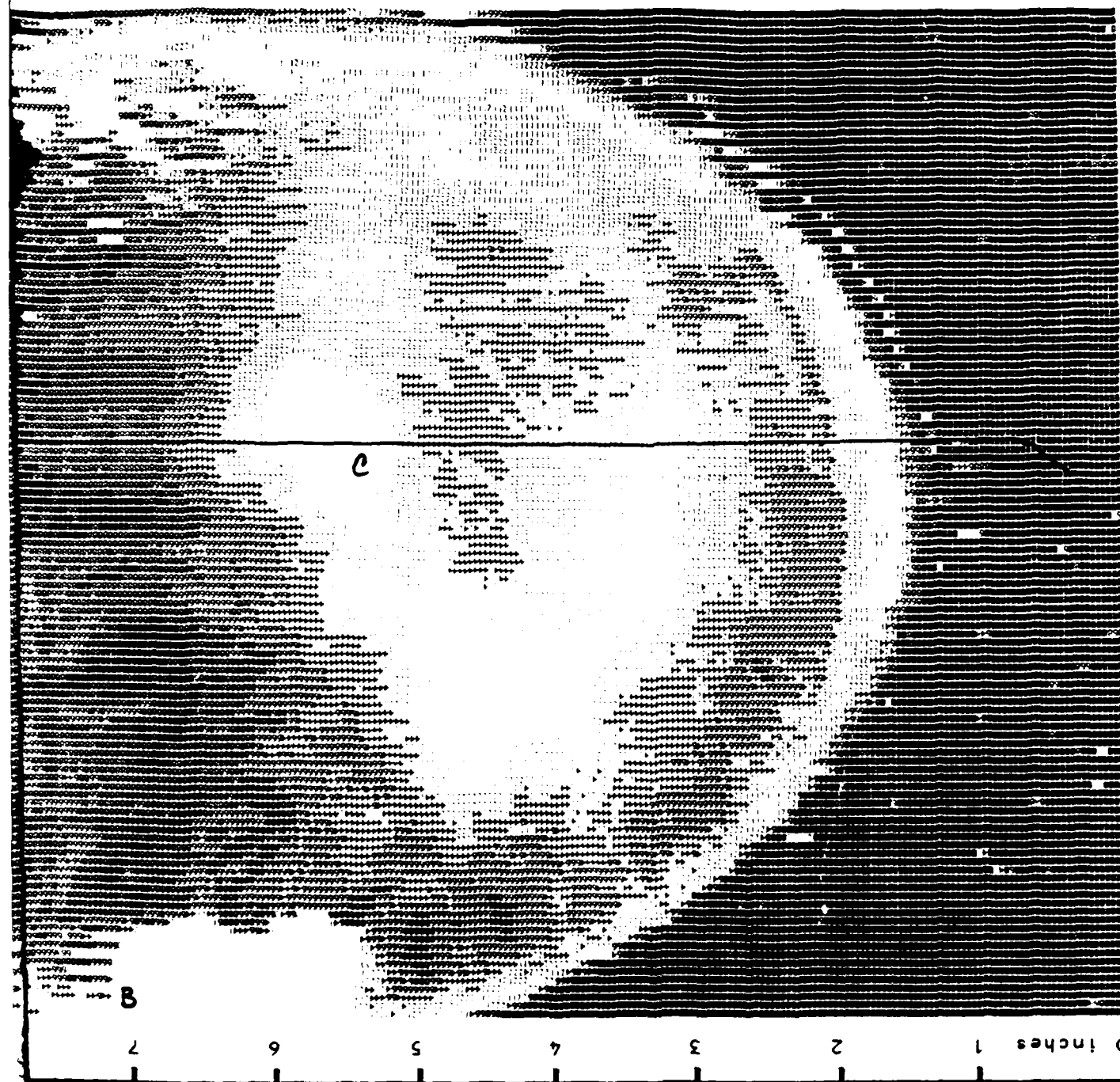


area of interest

8 9 10 11 12 13

6-C

SAMPLE NO. 6



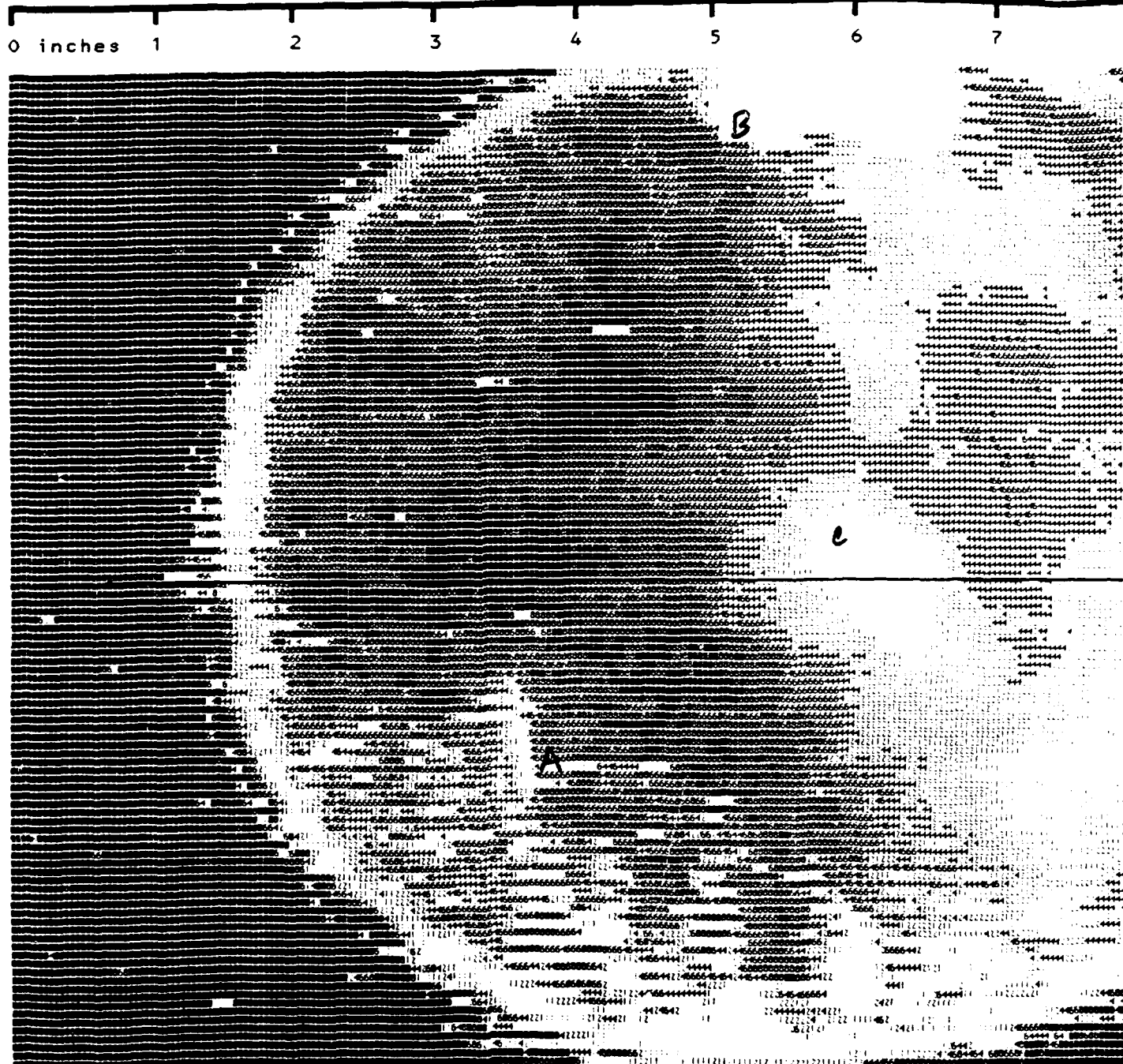
POST SCAN PLOT

DATA FILE = 00016

✓

DATA FILE = D007

POST SCAN PLOT



SAMPLE NO. 6

6-D

8

9

10

11

12

13



area of interest



2

MED
-8