Unites States Department of the Interior
Geological Survey

The distribution of vesicles and olivine phenocrysts in samples from drill hole KI 79-3, Kilauea Iki lava lake, Hawaii

by

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This report is preliminary and has not been reviewed for conformity with the U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

1986

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Introduction

The purpose of this report is to present quantitative modal and size distribution data on vesicles and olivine phenocrysts in drill core from hole KI 79-3, Kilauea Iki lava lake.

Kilauea Iki lava lake formed during the 1959 summit eruption of Hawaii's Kilauea volcano when approximately 40 million cubic meters of picritic basalt filled a pit crater in Kilauea's upper east rift zone (Fig. 1). A detailed description of the eruption can be found in Richter et al. (1970).

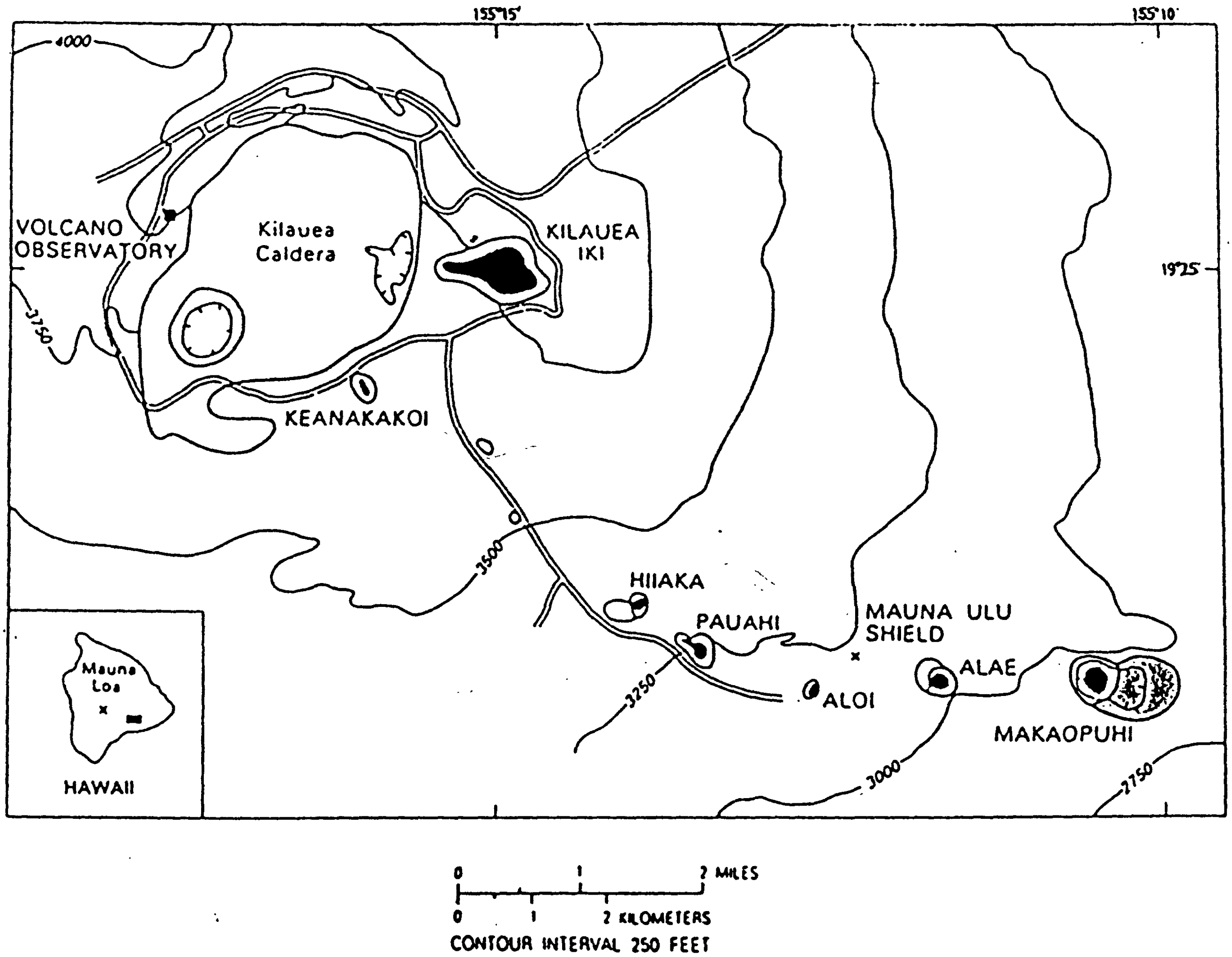

Figure 1. Index map of the summit area of Kilauea volcano. All historic lava lakes formed prior to 1968 are shown. Modified from Wright and others (1976).

Shortly after the eruption ceased and the crust stabilized, petrologic and geophysical investigations of the lava lake began. In 1960-62, 1967, and 1975, a total of 10 holes were drilled through the upper crust of the lake by scientists at the U.S. Geological Survey. The thickening crust of the lake was again drilled in 1976, 1978-79, and 1981 (16 holes) by workers at Sandia

Laboratories in cooperation with the U.S. Geological Survey. Petrographic and chemical data of the core recovered from the 1960-62 drilling is presented in Richter and Moore (1966). Descriptive catalogues for drill core recovered from the subsequent drilling programs are supplied by Helz et al. (1984) and Helz and Wright (1983). The locations of most of the drill holes in cross section are given in Figure 2.

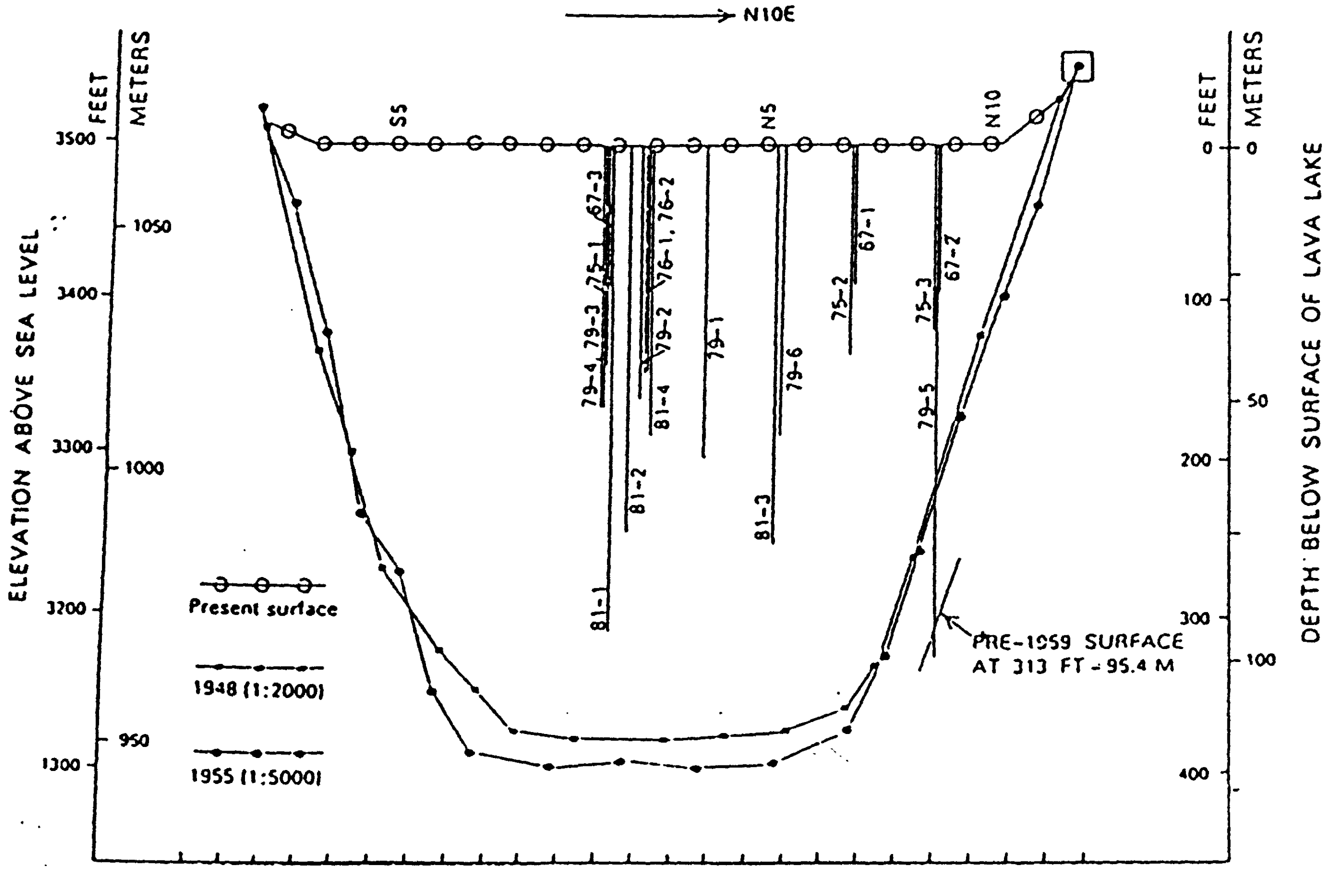

Figure 2. Cross-section of Kilauea Iki lava lake, cutting the center of the main chamber of the lake at a strike of N10E. The present surface of the lake and two pre-eruption profiles, based on two different sets of airphotos, are shown. The actual base of the lake as located in drill hole KI79-5 is significantly different from either pre-eruption profile, as indicated. The vertical exaggeration is 4:1.

The drill holes have been projected onto this cross-section. Several of the drill hole locations have been reoccupied repeatedly. Distances between closely-spaced drill holes are not to scale, but the location of clusters of holes relative to each other is correct.

The core retrieved from the repeated drilling of the crust of the cooling lava lake provides the unique opportunity to study the crystallization history of basalt in a natural environment. Petrologic studies of the core to date include Helz (1980, 1983, 1984, 1987) and Helz and Thornber (1987). Helz (1980) qualitatively observed the presence of an olivine/vesicle rich uppermost crust, an underlying dense olivine-depleted zone and, in the lowermost sections of the core, a diffuse olivine cumulate zone virtually devoid of vesicles. Helz suggests that the formation of these zones reflects the removal of olivine from the upper part of the lake by gravitative settling occurring, for the most part, after the lake degassed. The data contained in this report (see also Mangan and Helz, 1985) represents the preliminary stages of a study aimed at modeling the process of olivine/liquid fractionation in the lava lake.

To quantify the distribution of olivine and vesicles, core from one drill hole located in the center of the lake, KI 79-3, was examined. Description of the sampling and analytical procedures, the tabulated data, and photocopied reproductions of olivine/vesicle "maps" of the core follow.

[Note -- Depth measurements will be reported in feet as well as meters to be consistent with the drill logs in Helz et al. (1984) and Helz and Wright (1983).]

Sampling Procedure

Drill hole KI 79-3 extends 172.8 feet (~50 m) below the surface of the lake (6cm diameter, recovery rate ~100%). The primary data set is from a group of sixteen approximately one-foot (~30 cm) long sections of core from KI 79-3 sampled every ten feet (~3 m) down to the bottom of the hole (samples KI 79-3 #1 through #16). Sample selection avoided the inclusion of localized features such as segregation veins (coarse grained diabasic material produced within the lava lake by a process of internal differentiation) and vertical olivine rich bodies (or "vorbs") which do not represent rock typical of the lava lake.

Three additional samples were chosen to more closely define two key depth intervals -- one from an interval of slightly higher MgO content located about midway through the olivine depleted zone (sample KI 79-3 #17, only olivine data collected) and two from the interval just above the depleted zone where the vesicle content decreases significantly (samples KI 79-3 #18 and #19, only vesicle data collected).

Analytical Procedure

Samples were wrapped in transparent mylar. Vesicles and phenocrysts greater than approximately ½ mm were drawn in by hand with indelible ink. Two such mylar "maps" were produced for each sample. The vesicle maps were made first using whole core sections. Because it was difficult to discern olivines on the rough core surface, the sample was then cut lengthwise and the corresponding phenocryst map was prepared using the flat surface of the halved core. [Exception -- To avoid the inclusion of vorbs, vesicle and phenocryst maps for sample KI 79-3 #14 were made using both faces of halved core.]

Modal and size distribution determinations were obtained using photocopies of the prepared mylar sheets and a Joyce-Loebl MAGICSCAN video imaging system. Photocopies of the original maps were imaged to avoid lighting anomalies which are produced by the highly reflective mylar. The imaging is based on density differences or "grey levels." In its current configuration, the system can discern 64 different grey levels and features down to 0.5 mm across.

The field of view during the imaging consisted of a 23.6 cm^2 frame. A total of six frames per sample map were imaged to produce the size distribution data presented in Tables 2 and 3 (141.6 cm^2 total area analyzed on each vesicle and phenocryst map). The modal determinations of olivine phenocrysts (Table 1) were also made by imaging a total of 141.6 cm^2 per sample. Vesicle modes, which were judged to be more variable over the one foot samples, were determined by imaging an average area of 377.6 cm^2 per sample map. In order to avoid the inclusion of vorbs, only 6 frames were imaged when determining the percent vesicles present in sample KI79-3 #14.

Although the technique described above is somewhat labor intensive (approximately 2 1/2 hours were required to produce each mylar sheet), the use of high contrast vesicle/phenocryst maps reduce the possibility of imaging errors (e.g. counting fractures or diktytaxitic cavities as vesicles). The analytical uncertainty associated with this method is estimated to be less than 4 percent.

The authors would like to acknowledge the use of Edward Chao's imaging system and the technical assistance of Jean Minkin and Judy Back.

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Table 1. Modal data for samples from drill hole KI 79-3

SAMPLE	DEPTH INTERVAL feet	(meters)	% VESICLES[1]		% OLIVINE, total[1]		% OLIVINE, matrix only[2]
KI 79-3 # 1	2.0- 3.0	(0.6- 0.9)	25.3	(3.3)	12.4	(3.0)	16.6
KI 79-3 # 2	15.6- 16.6	(4.7- 5.1)	16.4	(3.2)	5.9	(0.6)	7.15
KI 79-3 # 3	25.7- 26.7	(7.8- 8.1)	25.1	(4.2)	5.8	(1.0)	7.9
KI 79-3 # 4	37.0- 38.0	(11.2-11.5)	9.6	(1.4)	6.3	(1.5)	7.5
KI 79-3 # 5	47.2- 48.2	(14.3-14.6)	7.9	(1.9)	4.5	(1.4)	5.1
KI 79-3 # 6	58.9- 59.9	(18.0-18.3)	6.9	(1.3)	4.8	(0.4)	5.4
KI 79-3 # 7	71.0- 72.0	(21.6-21.9)	6.3	(1.4)	5.8	(1.1)	6.2
KI 79-3 # 8	83.6- 84.6	(25.5-25.8)	0.9	(0.8)	1.4	(0.4)	1.4
KI 79-3 # 9	93.7- 94.7	(28.5-28.8)	2.0	(1.0)	2.3	(1.2)	2.3
KI 79-3 #10	104.5-105.5	(31.9-32.2)	1.6	(0.6)	2.2	(0.5)	2.2
KI 79-3 #11	116.9-117.9	(35.6-35.9)	0.7	(0.4)	1.1	(0.6)	1.1
KI 79-3 #12	127.9-128.9	(39.0-39.3)	1.2	(0.5)	7.3	(1.4)	7.4
KI 79-3 #13	138.8-139.8	(42.3-42.6)	1.2	(1.2)	6.2	(3.7)	6.3
KI 79-3 #14	150.7-151.1	(45.9-46.0)	0.0		5.2	(1.3)	5.2
KI 79-3 #15	161.3-162.3	(49.2-49.5)	0.8	(0.4)	15.8	(1.5)	15.9
KI 79-3 #16	170.6-171.6	(52.0-52.3)	2.4	(3.0)	24.6	(1.0)	25.2
KI 79-3 #17	95.7- 96.7	(29.1-29.4)	N.D.[3]		4.3	(1.4)	4.3
KI 79-3 #18	30.2- 31.2	(9.2- 9.5)	12.7		N.D.		N.D.
KI 79-3 #19	32.9- 33.6	(10.0-10.2)	15.9[4]		N.D.		N.D.

[1] Each entry is the average of several imaging frames, the standard deviation associated with the average is given in parentheses.
[2] The volume contribution of vesicles removed.
[3] Not determined.
[4] Normal matrix only.

Table 2. Olivine grain size in samples from drill hole KI79-3

SIZE, mm^2	NUMBER OF OBSERVATIONS								
	KI79-3 #1	KI79-3 #2	KI79-3 #3	KI79-3 #4	KI79-3 #5	KI79-3 #6	KI79-3 #7	KI79-3 #8	KI79-3 #9
feet	2.0- 3.0	15.6-16.6	25.7-26.7	37.0-38.0	47.2- 8.2	58.9-59.9	71.0-72.0	83.6-84.6	93.7-94.7
meters	0.6- 0.9	4.7- 5.1	7.8- 8.1	11.2-11.5	14.3-14.6	18.0-18.3	21.6-21.9	25.5-25.8	28.5-28.8
0.2- 3.0	565	515	348	519	424	384	779	198	248
3.1- 6.0	103	47	62	48	41	37	28	10	13
6.1- 9.0	40	11	11	12	3	6	3	1	2
9.1-12.0	15	2	7	2	0	1	1	1	0
12.1-15.0	9	0	1	4	0	0	1	0	0
15.1-18.0	6	0	4	1	0	1	0	0	0
18.1-21.0	2	0	0	0	0	0	1	0	0
21.1-24.0	1	0	0	0	0	0	0	0	0
24.1-27.0	1	0	0	1	0	1	0	0	0
27.1-30.0	1	0	0	0	0	0	0	0	0
30.1-33.0	0	0	0	0	0	0	0	0	0
33.1-36.0	1	0	0	0	0	0	0	0	0
36.1-39.0	1	0	0	0	0	0	0	0	0
39.1-42.0	0	0	0	1	0	0	0	0	0
42.1-45.0	0	0	0	0	0	0	0	0	0
45.1-48.0	0	0	0	0	0	0	0	0	0
48.1-51.0	0	0	0	0	0	0	0	0	0
51.6-54.0	1	0	0	0	0	0	0	0	0
54.1-57.0	0	0	0	0	0	0	0	0	0
57.1-60.0	0	0	0	0	0	0	0	0	0

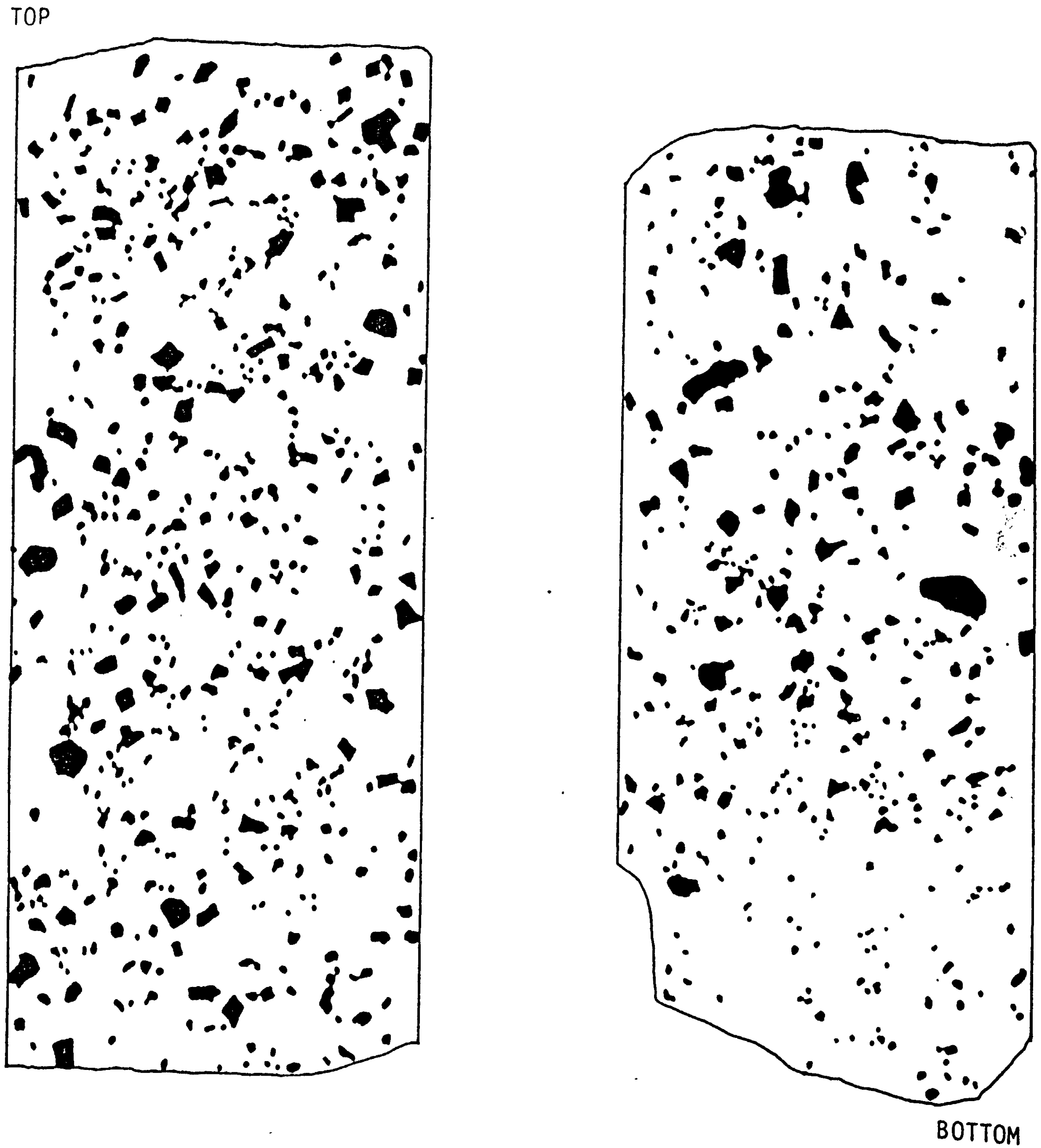
	KI79-3 #10	KI79-3 #11	KI79-3 #12	KI79-3 #13	KI79-3 #14	KI79-3 #15	KI79-3 #16	KI79-3 #17
feet	104.5-105.5	116.9-117.9	127.9-128.9	138.8-139.8	150.7-151.1	161.3-162.3	170.6-171.6	95.7- 96.7
meters	31.9- 32.2	35.6- 35.9	39.0- 39.3	42.3- 42.6	45.9- 46.0	49.2- 49.5	52.0- 52.3	29.1- 29.4
0.2- 3.0	292	181	782	508	822	1301	1732	463
3.1- 6.0	12	5	50	50	33	106	157	5
6.1- 9.0	1	0	13	19	2	33	57	6
9.1-12.0	0	0	2	3	1	17	39	2
12.1-15.0	0	0	3	2	0	11	16	0
15.1-18.0	0	0	1	0	0	5	3	0
18.1-21.0	0	0	0	0	0	2	6	0
21.1-24.0	0	0	0	0	0	3	6	0
24.1-27.0	0	0	0	0	0	1	1	0
27.1-30.0	0	0	0	0	0	0	1	0
30.1-33.0	0	0	0	0	0	0	0	0
33.1-36.0	0	0	0	0	0	1	3	0
36.1-39.0	0	0	0	0	0	0	0	0
39.1-42.0	0	0	0	0	0	0	0	0
42.1-45.0	0	0	0	0	0	0	0	0
45.1-48.0	0	0	0	0	0	0	0	0
48.1-51.0	0	0	0	0	0	0	0	0
51.6-54.0	0	0	0	0	0	0	0	0
54.1-57.0	0	0	0	0	0	0	0	0
57.1-60.0	0	0	0	0	0	0	0	0

Table 3. Vesicle size in samples from drill hole KI79-3

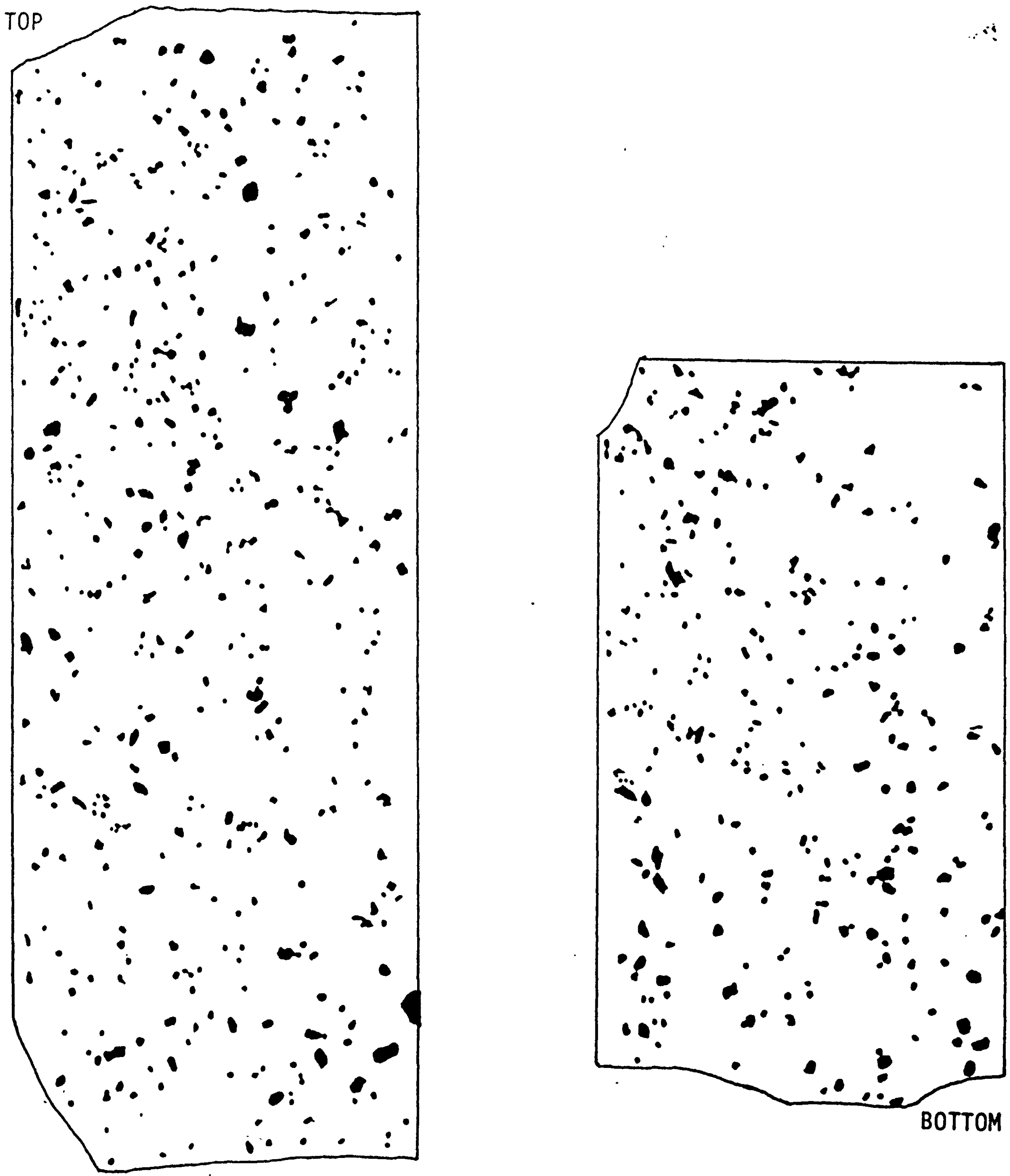
SIZE, mm^2	NUMBER OF OBSERVATIONS								
	KI79-3 #1	KI79-3 #2	KI79-3 #3	KI79-3 #4	KI79-3 #5	KI79-3 #6	KI79-3 #7	KI79-3 #8	KI79-3 #9
feet	2.0- 3.0	15.6-16.6	25.7-26.7	37.0-38.0	47.2-48.2	58.9-59.9	71.0-72.0	83.6-84.6	93.7-94.7
meters	0.6- 0.9	4.7- 5.1	7.8- 8.1	11.2-11.5	14.3-14.6	18.0-18.3	21.6-21.9	25.5-25.8	28.5-28.8
0.2- 3.0	756	889	1043	1593	465	993	698	116	424
3.1- 6.0	97	164	172	100	70	59	16	26	6
6.1- 9.0	39	51	36	26	26	17	3	0	2
9.1-12.0	23	23	32	8	2	6	5	0	0
12.1-15.0	25	16	22	6	2	4	1	0	0
15.1-18.0	13	7	12	1	1	0	0	0	0
18.1-21.0	13	5	10	1	0	1	0	0	0
21.1-24.0	8	4	7	1	0	1	1	0	0
24.1-27.0	6	0	2	1	0	2	0	0	0
27.1-30.0	4	2	4	0	1	1	0	0	0
30.1-33.0	5	2	2	0	1	0	0	0	0
33.1-36.0	6	0	5	0	1	0	0	0	0
36.1-39.0	3	1	1	0	0	0	0	0	0
39.1-42.0	3	0	2	0	0	0	0	0	0
42.1-45.0	4	0	0	0	0	1	0	0	0
45.1-48.0	0	0	0	1	0	0	0	0	0
48.1-51.0	0	0	0	0	0	1	0	0	0
51.6-54.0	0	0	2	0	0	0	0	0	0
54.1-57.0	0	0	2	0	0	0	0	0	0
57.1-60.0	2	0	0	0	0	0	0	0	0

	KI79-3 #10	KI79-3 #11	KI79-3 #12	KI79-3 #13	KI79-3 #14	KI79-3 #15	KI79-3 #16	KI79-3 #18	KI79-3 #19
feet	104.5-105.5	116.9-117.9	127.9-128.9	138.8-139.8	150.7-151.1	161.3-162.3	170.6-171.6	30.2- 31.2	32.9- 33.6
meters	31.9- 32.2	35.6- 35.9	39.0- 39.3	42.3- 42.6	45.9- 46.0	49.2- 49.5	52.0- 52.3	9.2- 9.5	10.0- 10.2
0.2- 3.0	684	238	264	203	5	93	187	2026	2228
3.1- 6.0	0	1	1	1	0	3	5	67	99
6.1- 9.0	0	0	0	0	0	3	2	30	31
9.1-12.0	0	0	0	0	0	0	1	12	19
12.1-15.0	0	0	0	0	0	0	1	8	6
15.1-18.0	0	0	0	0	0	0	0	6	1
18.1-21.0	0	0	0	0	0	0	1	5	1
21.1-24.0	0	0	0	0	0	1	0	6	2
24.1-27.0	0	0	0	0	0	1	0	4	0
27.1-30.0	0	0	0	0	0	0	0	1	1
30.1-33.0	0	0	0	0	0	0	0	0	1
33.1-36.0	0	0	0	0	0	0	0	0	2
36.1-39.0	0	0	0	0	0	0	0	0	0
39.1-42.0	0	0	0	0	0	0	0	2	0
42.1-45.0	0	0	0	0	0	0	0	1	0
45.1-48.0	0	0	0	0	0	0	0	0	2
48.1-51.0	0	0	0	0	0	0	0	0	0
51.6-54.0	0	0	0	0	0	0	0	0	1
54.1-57.0	0	0	0	0	0	0	0	0	0
57.1-60.0	0	0	0	0	0	0	0	0	3

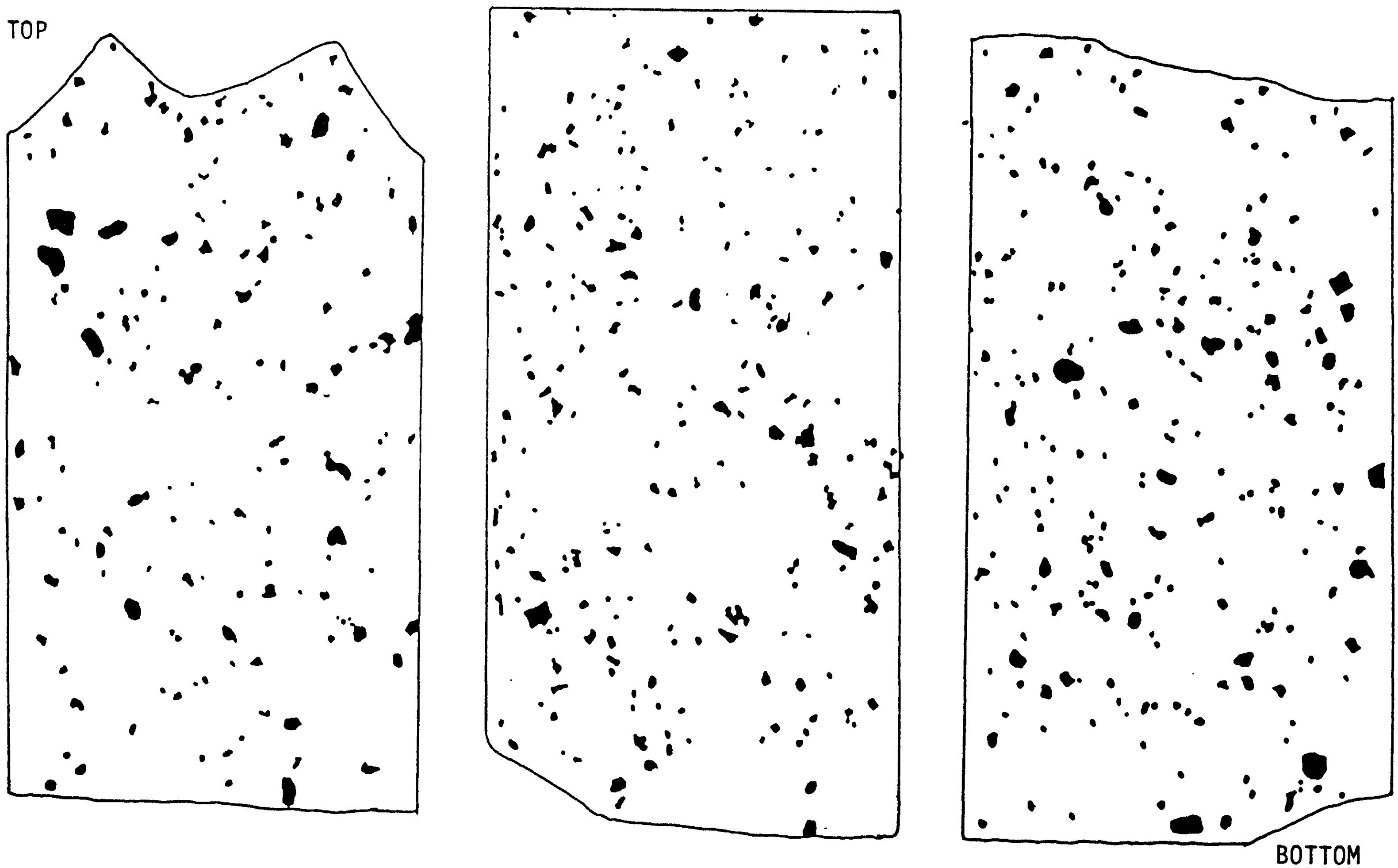
KI 79-3 #1 OLIVINE
2'-3' depth interval
(0.6-0.9 meters)



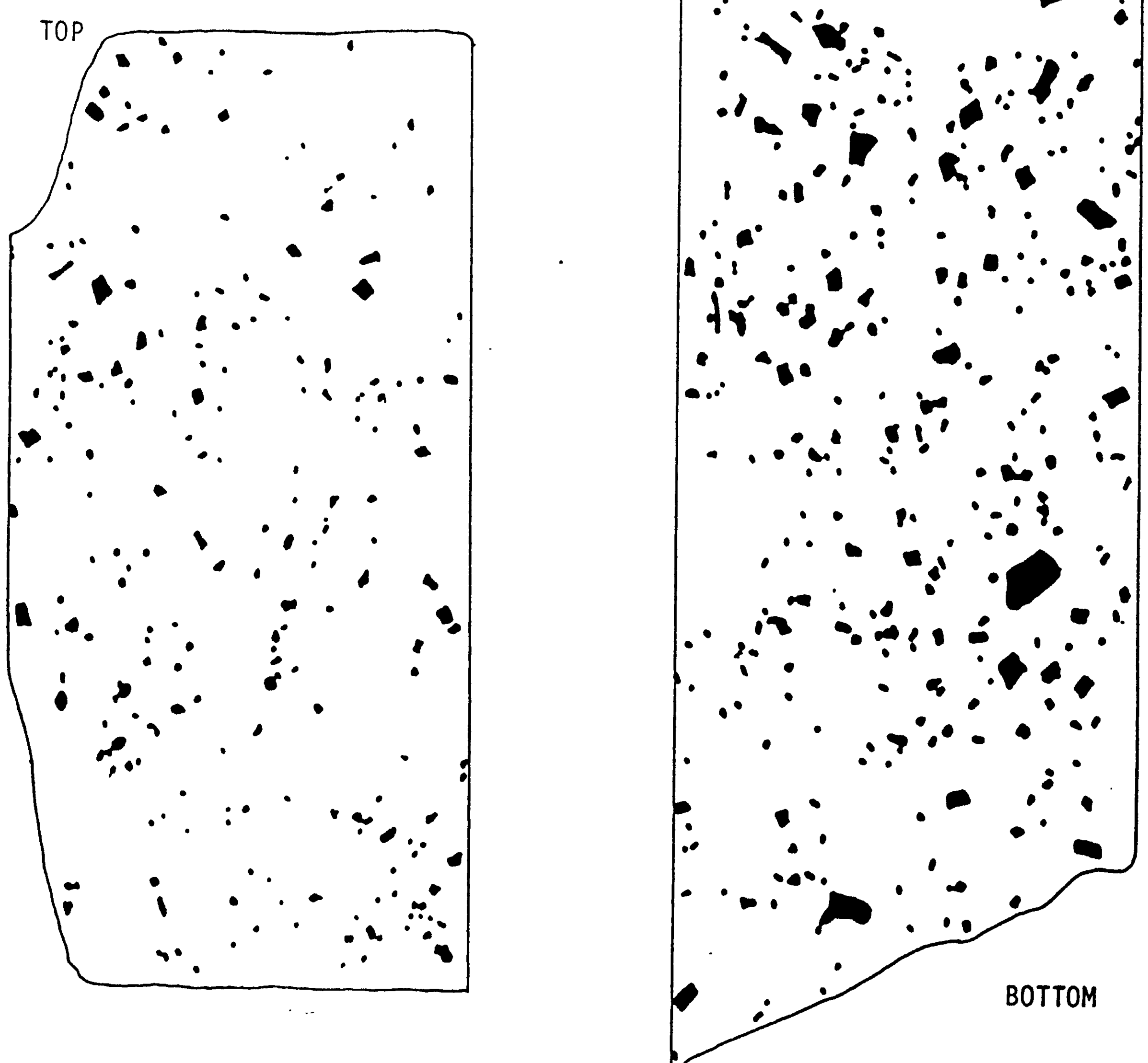
KI 79-3 #2 OLIVINE
15.6'-16.6' depth interval
(4.7-5.1 meters)



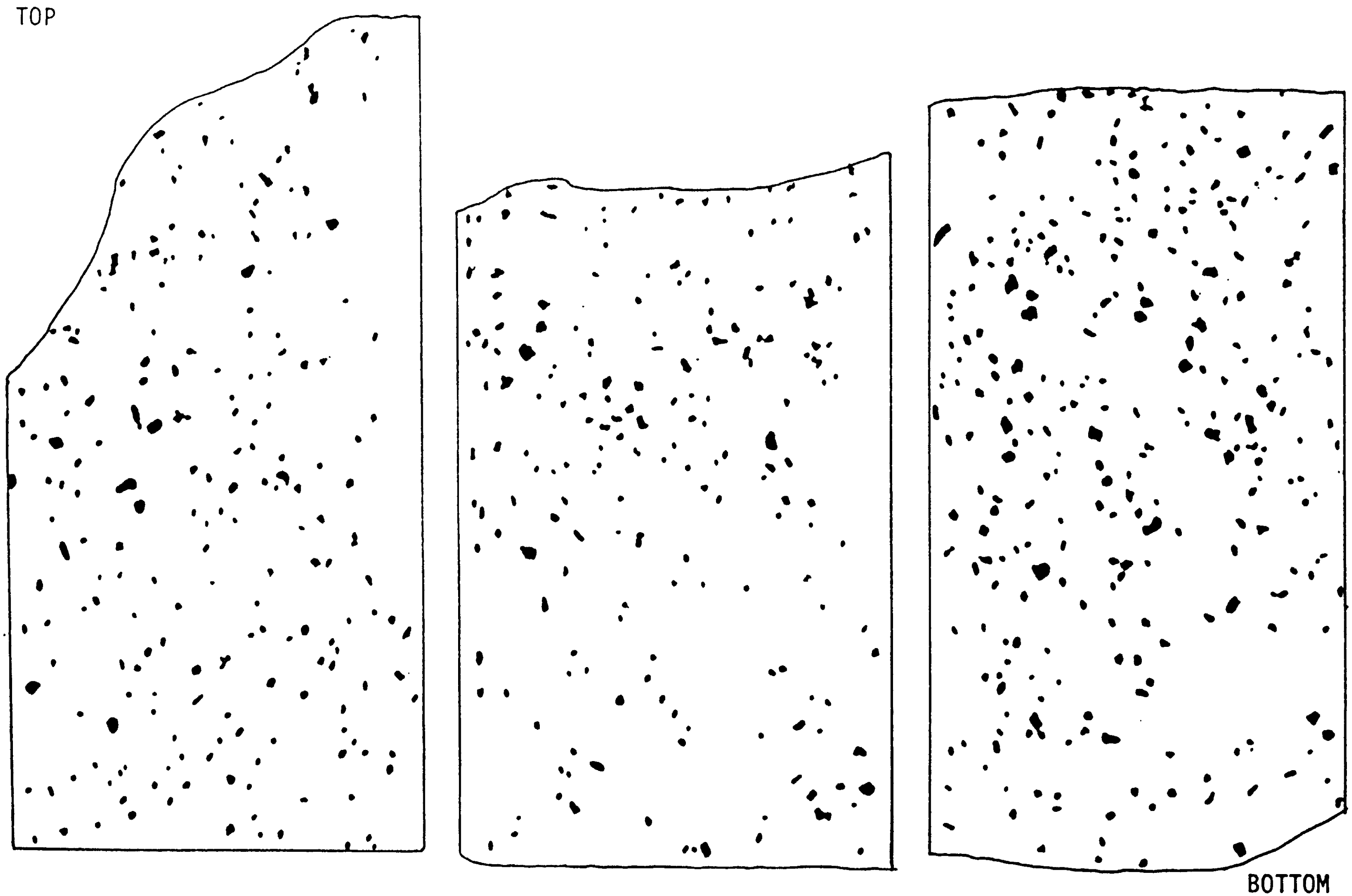
KI 79-3 #3 OLIVINE
25.7'-26.7' depth interval
(7.8-8.1 meters)



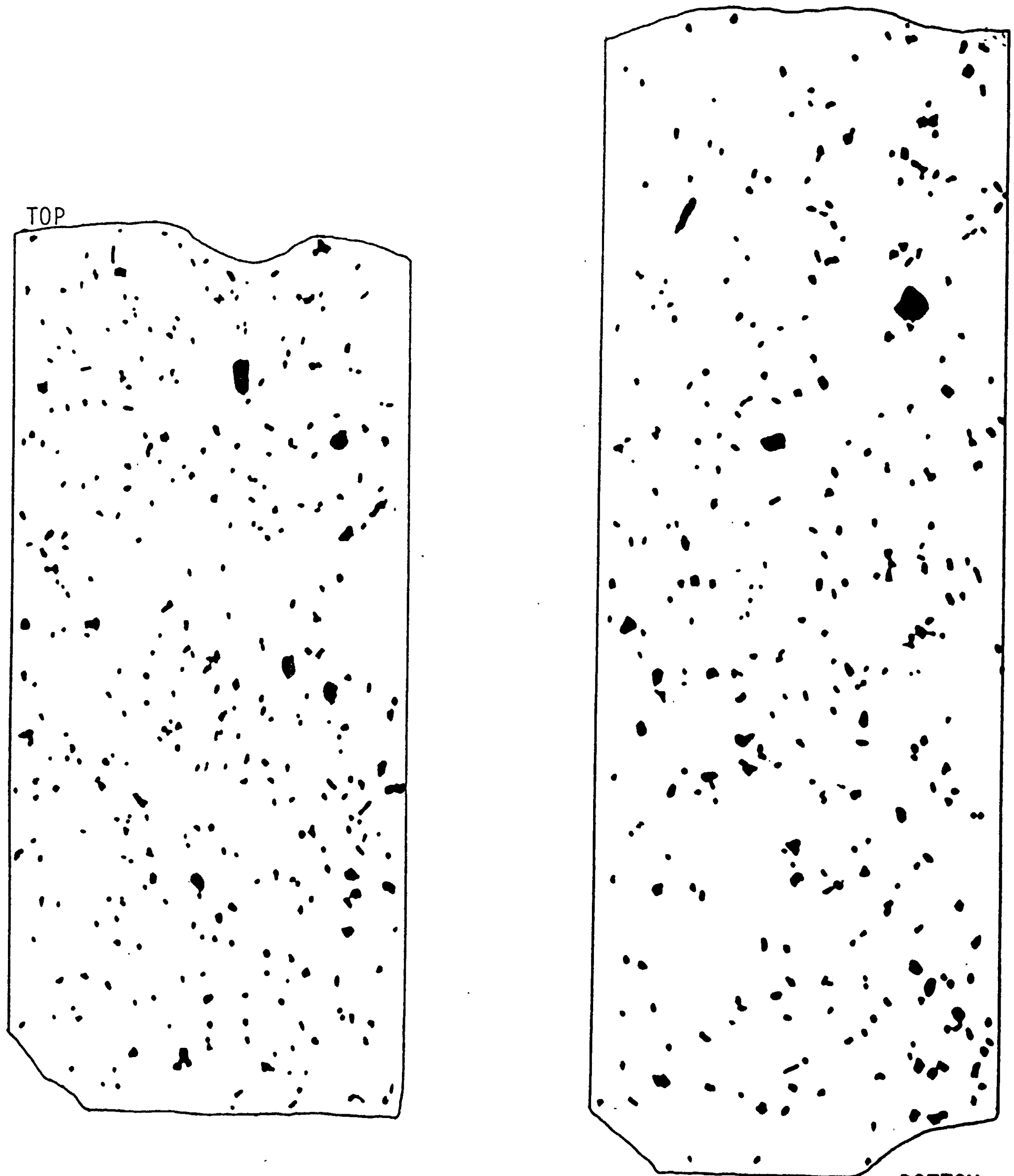
KI 79-3 #4 OLIVINE
37'-38' depth interval
(11.2-11.5 meters)



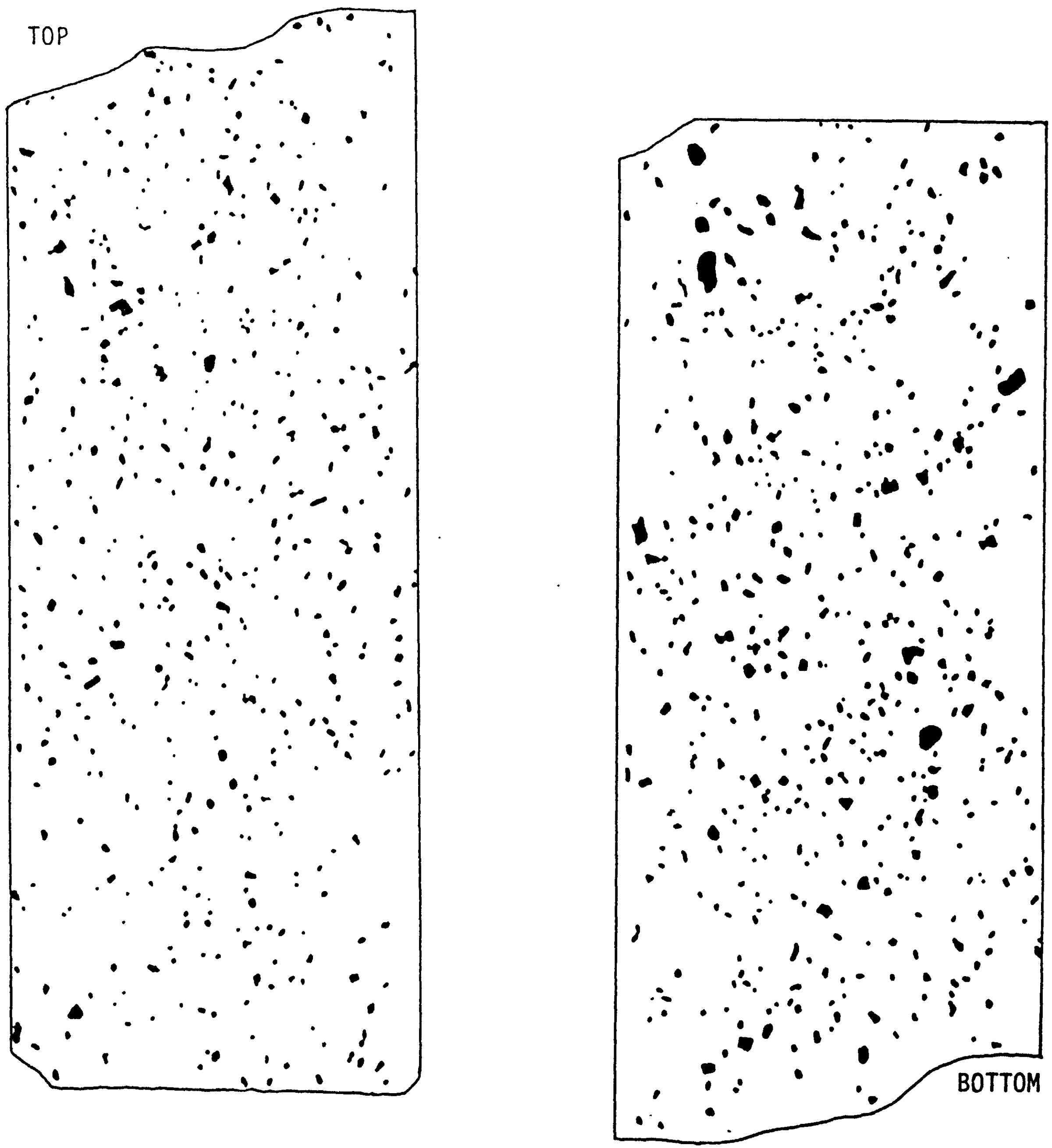
KI 79-3 #5 OLIVINE
47.2'-48.2' depth interval
(14.3-14.6 meters)



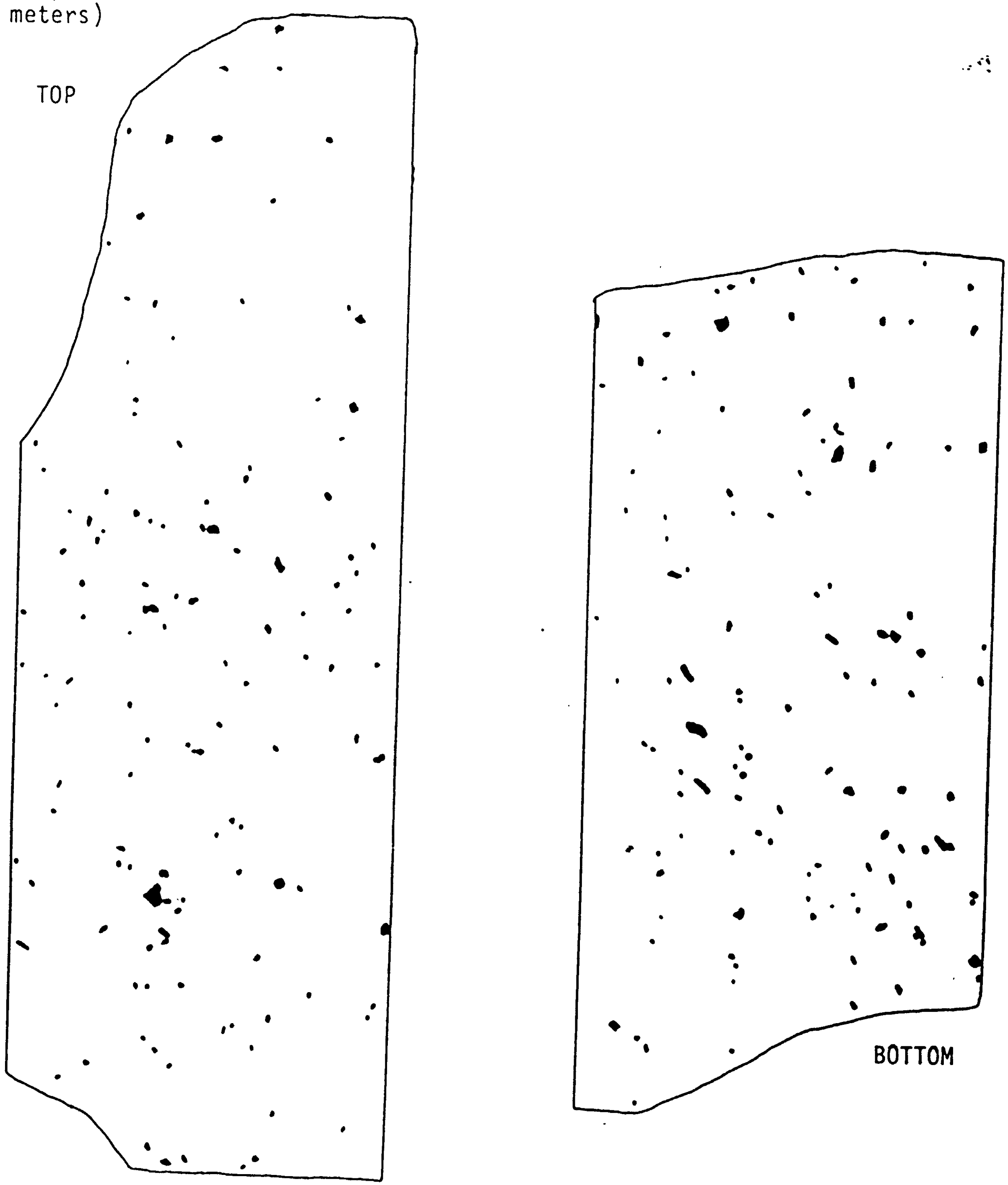
Ki 79-3 #6 OLIVINE
58.9'-59.9' depth interval
(18.0-18.3 meters)



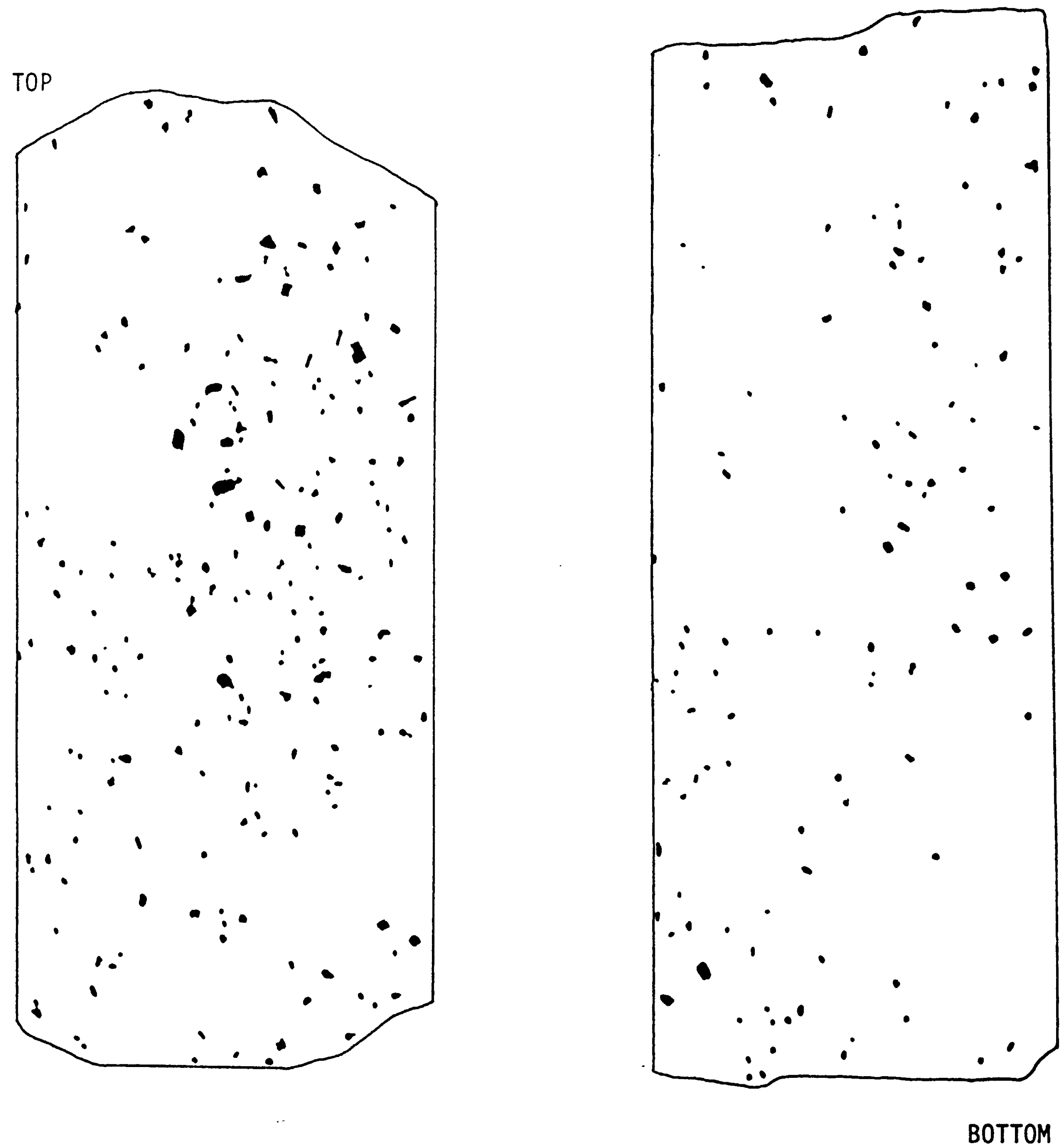
KI 79-3 #7 OLIVINE
71'-72' depth interval
(21.6-21.9 meters)



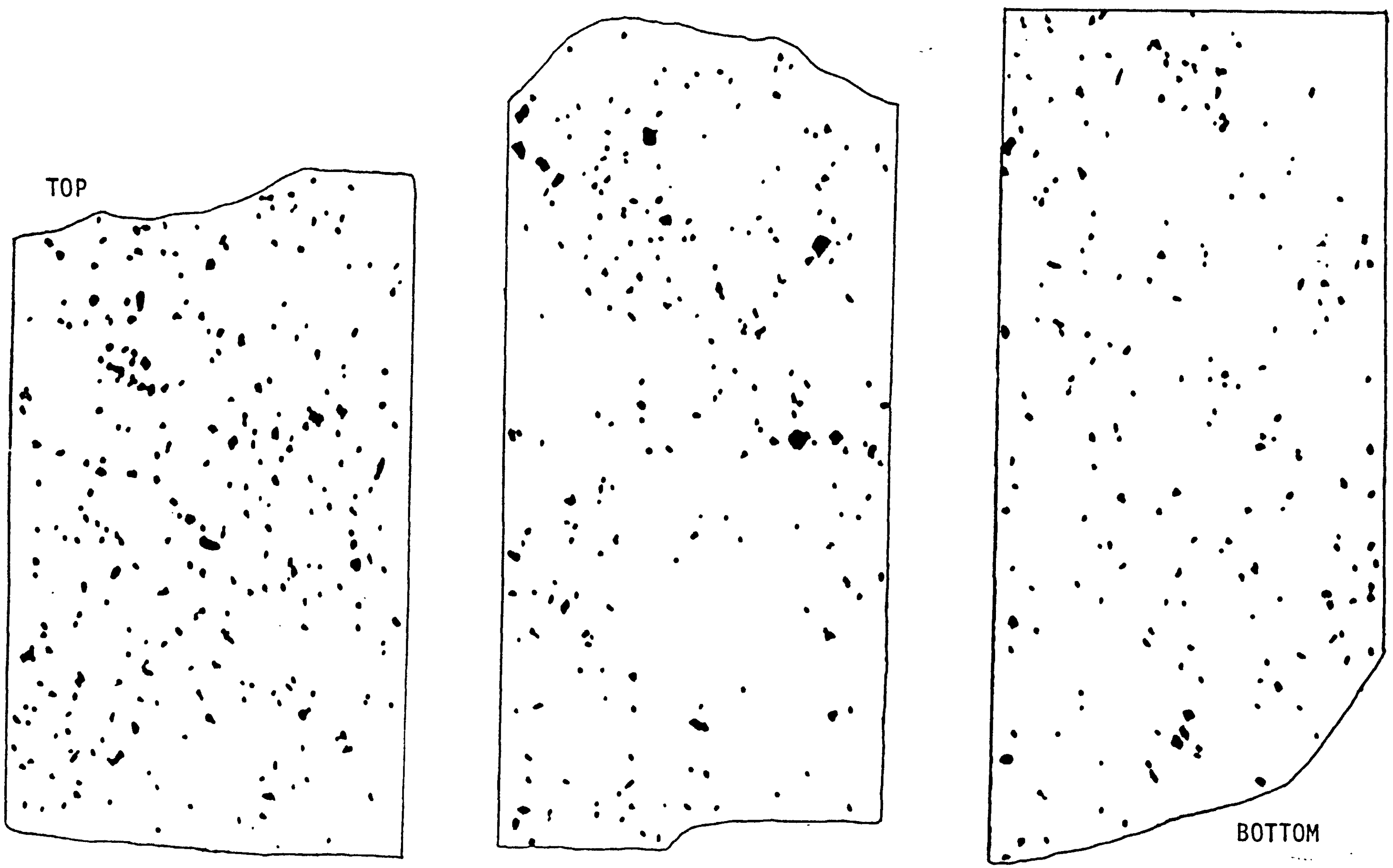
KI 79-3 #8 OLIVINE
83.6'-84.6' depth interval
(25.5-25.8 meters)



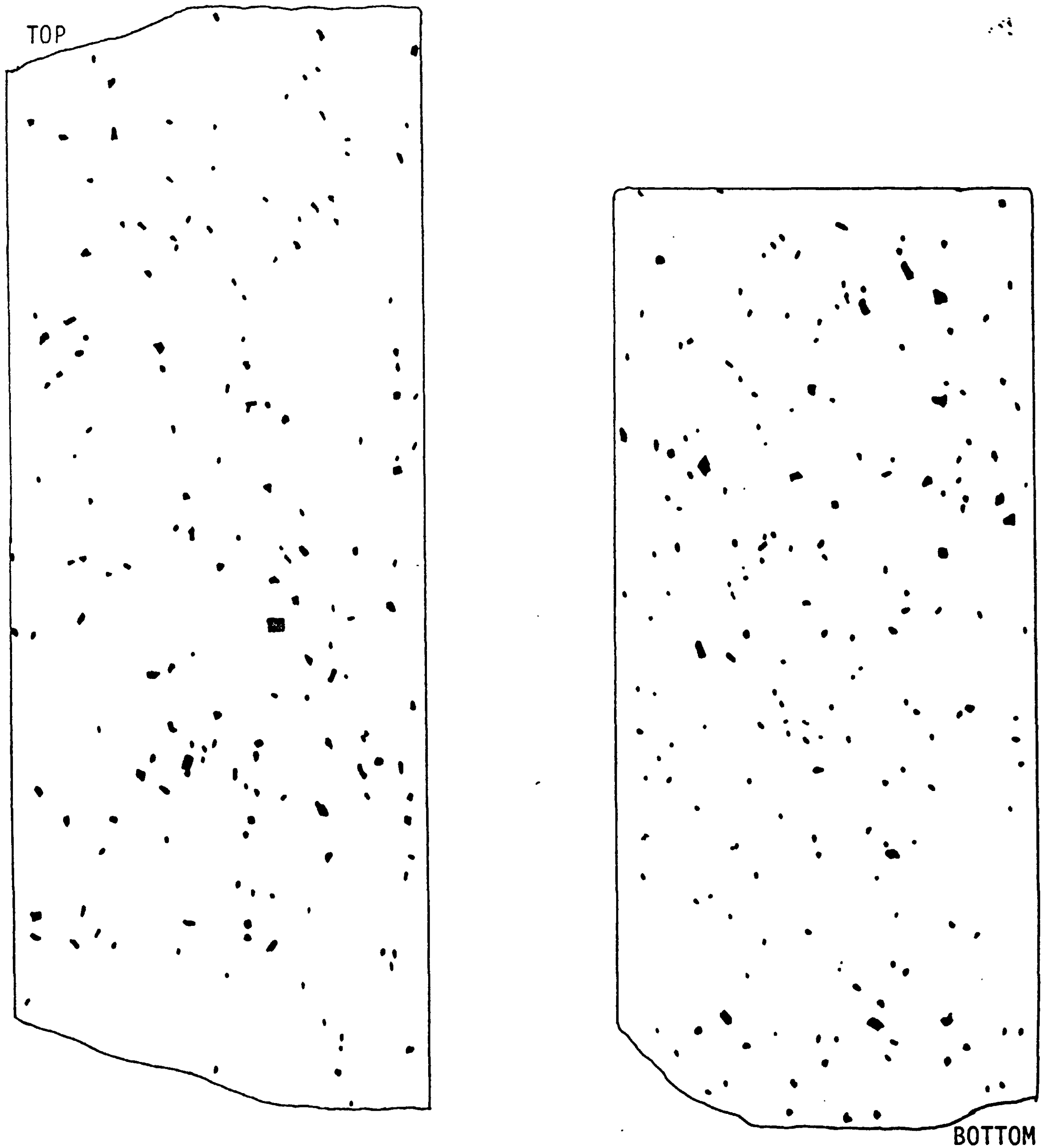
KI 79-3 #9 OLIVINE
93.7'-94.7' depth interval
(28.5-28.8 meters)



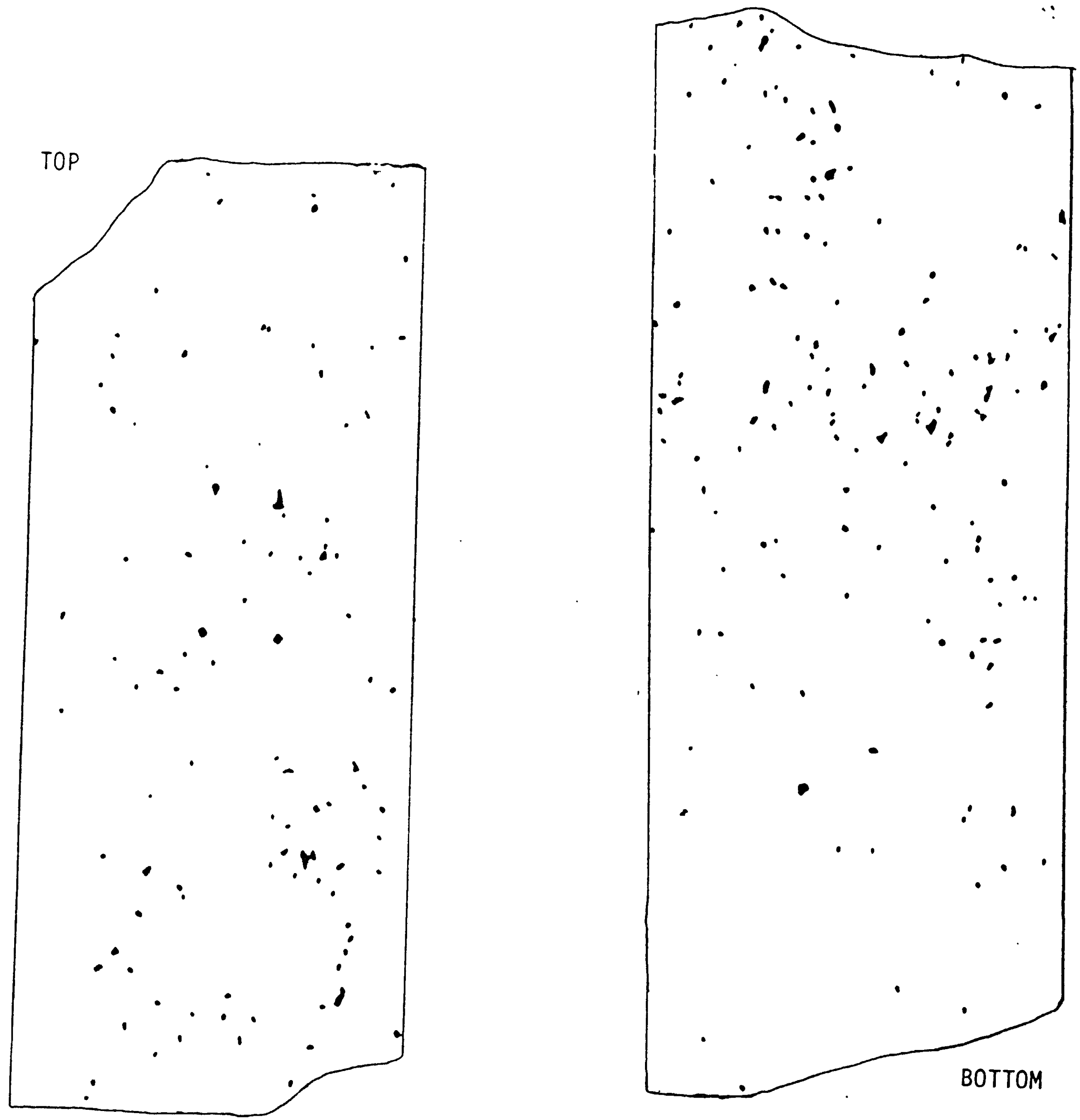
KI 79-3 #17 OLIVINE
95.7'-96.7' depth interval
(29.1-29.4 meters)



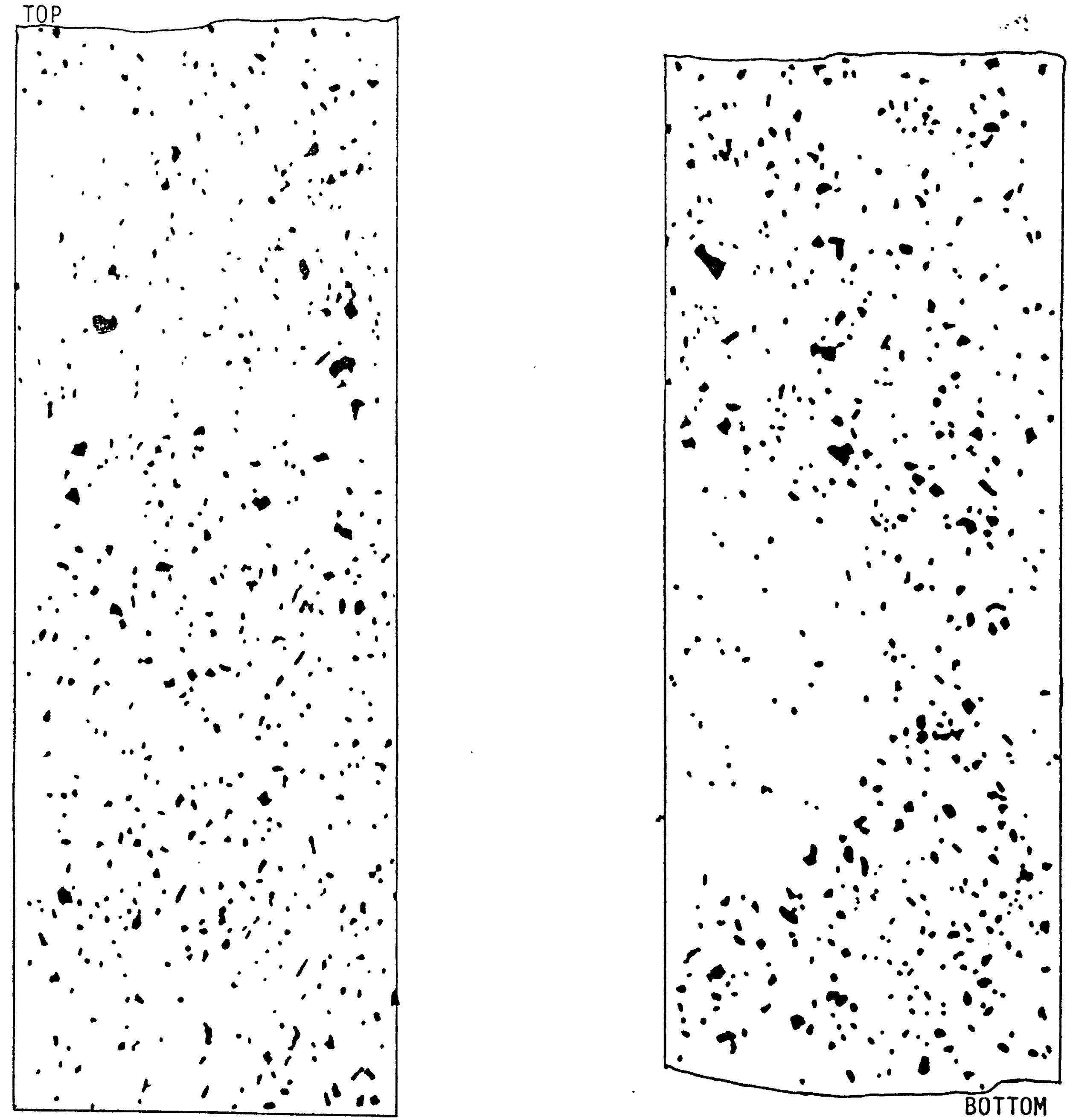
KI 79-3 #10 OLIVINE
104.5'-105.5' depth interval
(31.9-32.2 meters)



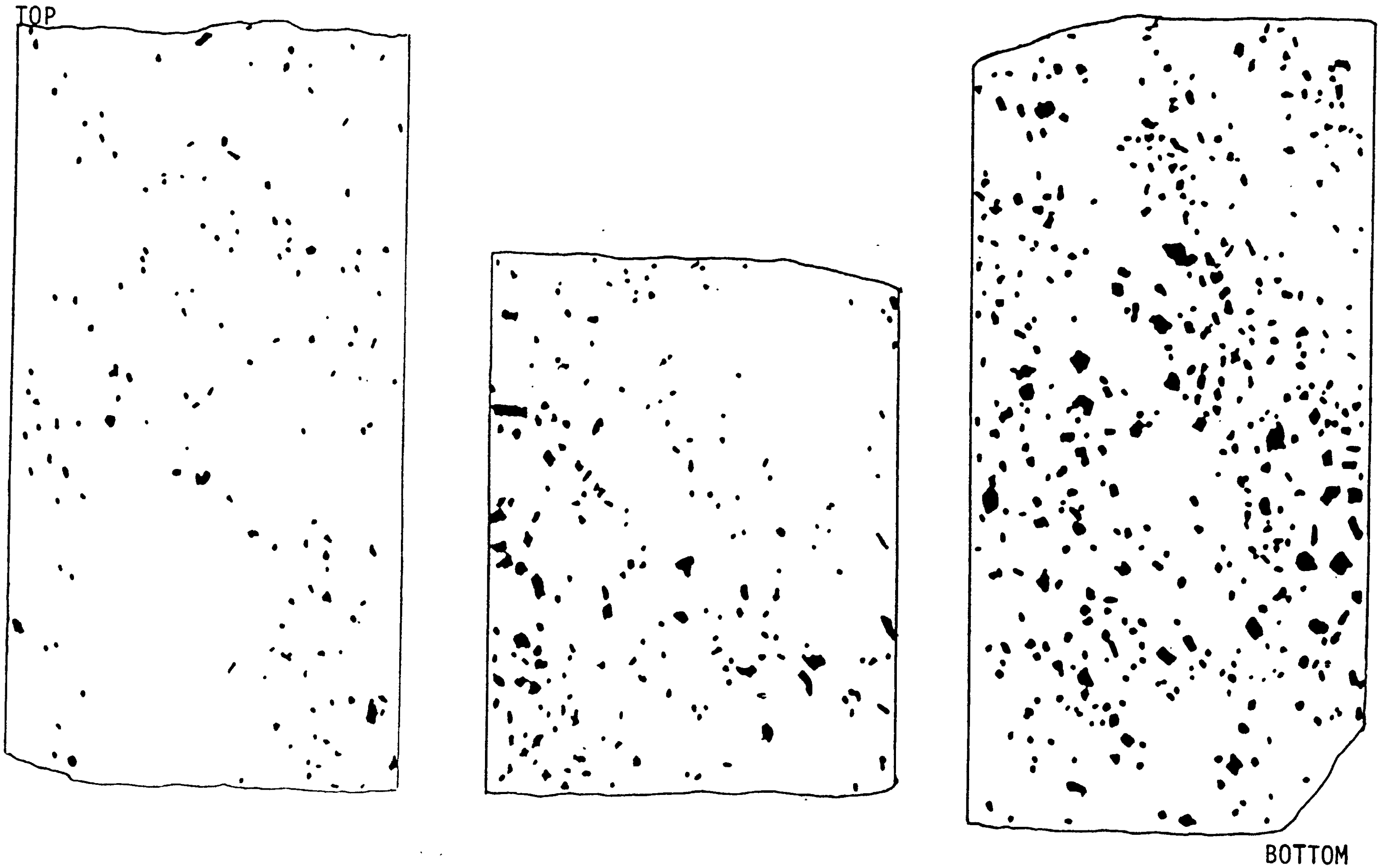
KI 79-3 #11 OLIVINE
116.9'-117.9' depth interval
(35.6-35.9 meters)



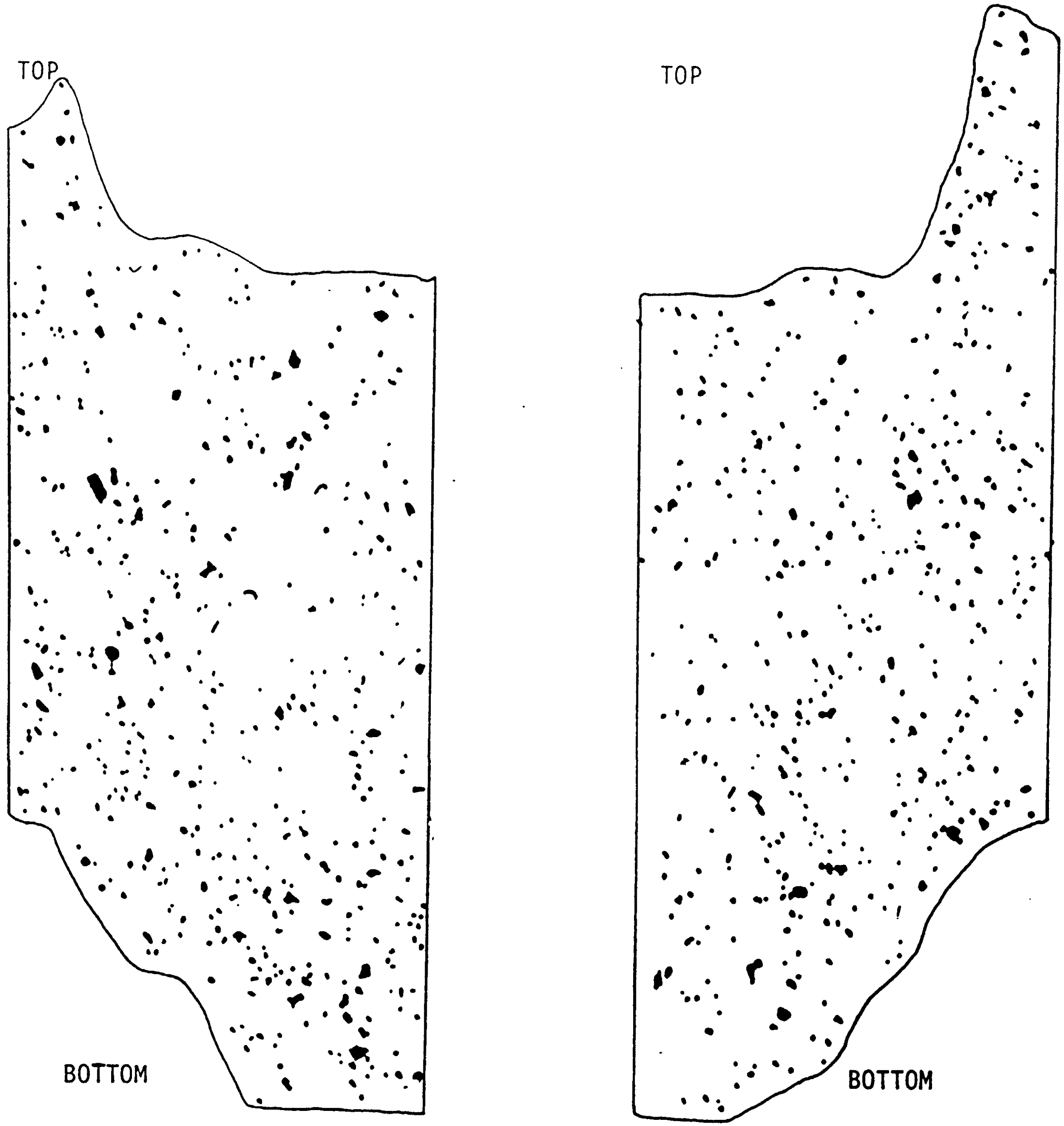
KI 79-3 #12 OLIVINE
127.9'-128.9' depth interval
(39.0-39.3 meters)



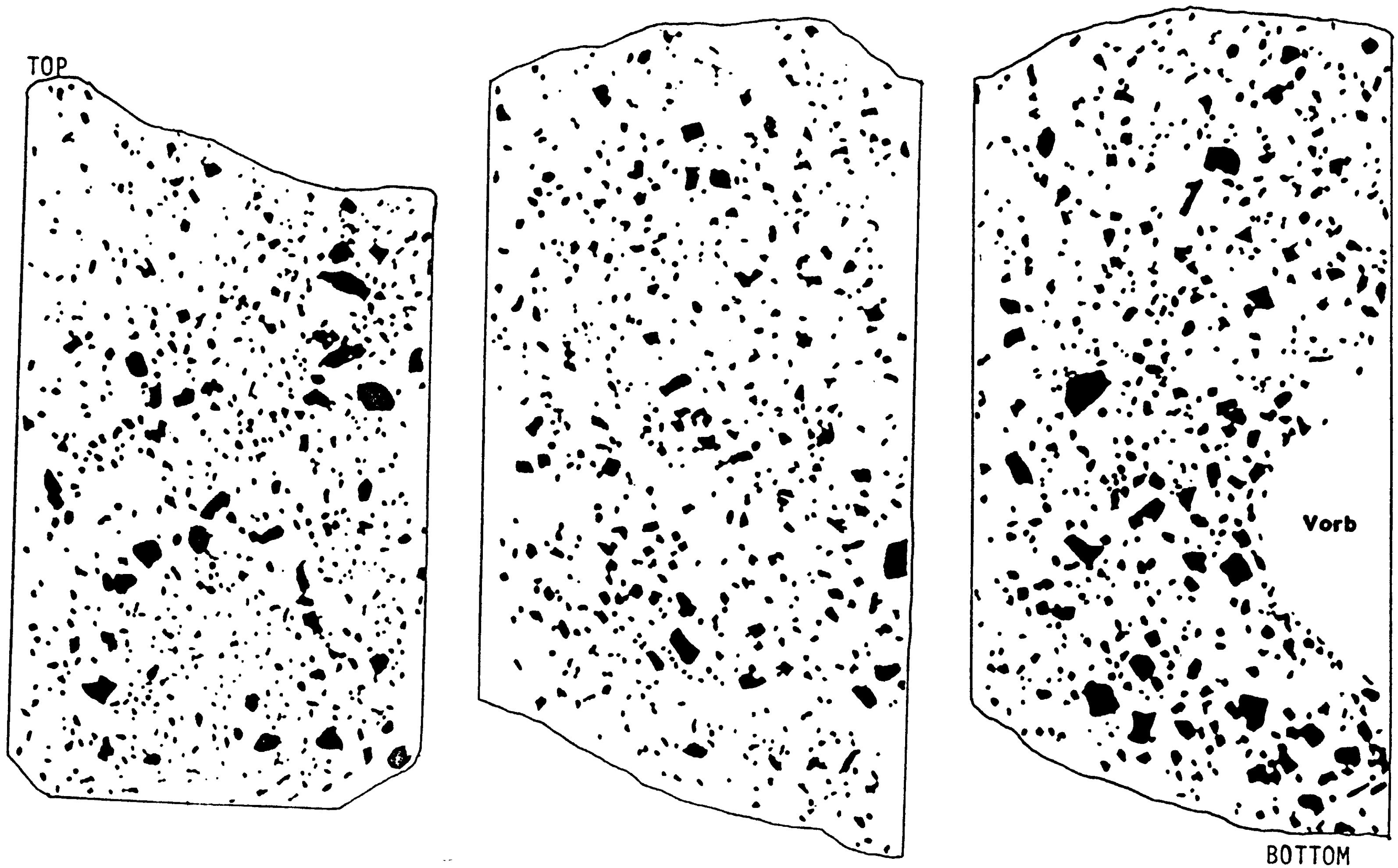
KI 79-3 #13 OLIVINE
138.8'-139.8' depth interval
(42.3-42.6 meters)



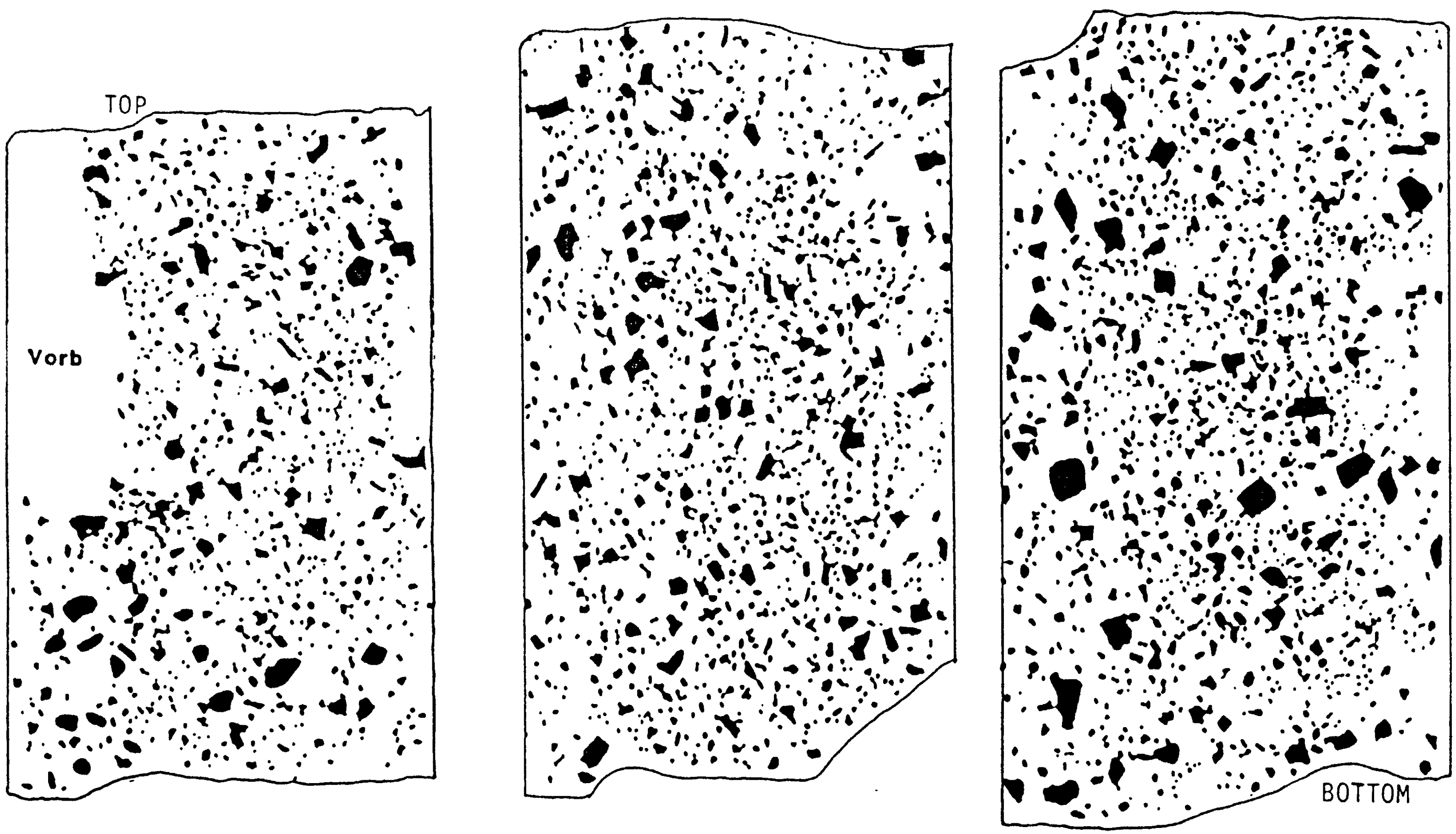
KI 79-3 #14 OLIVINE
150.7'-151.1' depth interval
(45.9-46.0 meters)



KI 79-3 #15 OLIVINE
161.3'-162.3' depth interval
(49.2-49.5 meters)

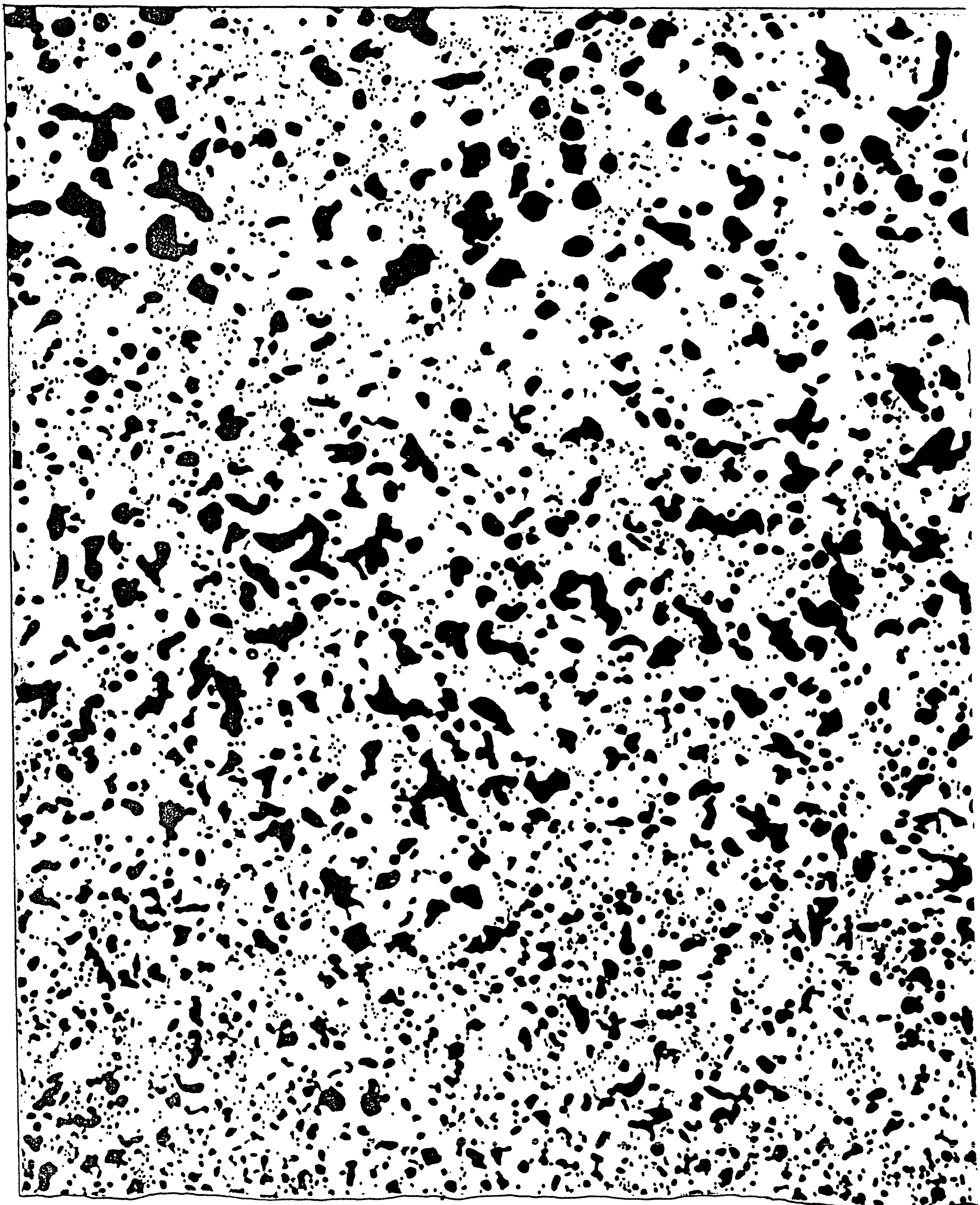


Kl 79-3 #16 OLIVINE
170.6'-171.6' depth interval
(52.0-52.3 meters)



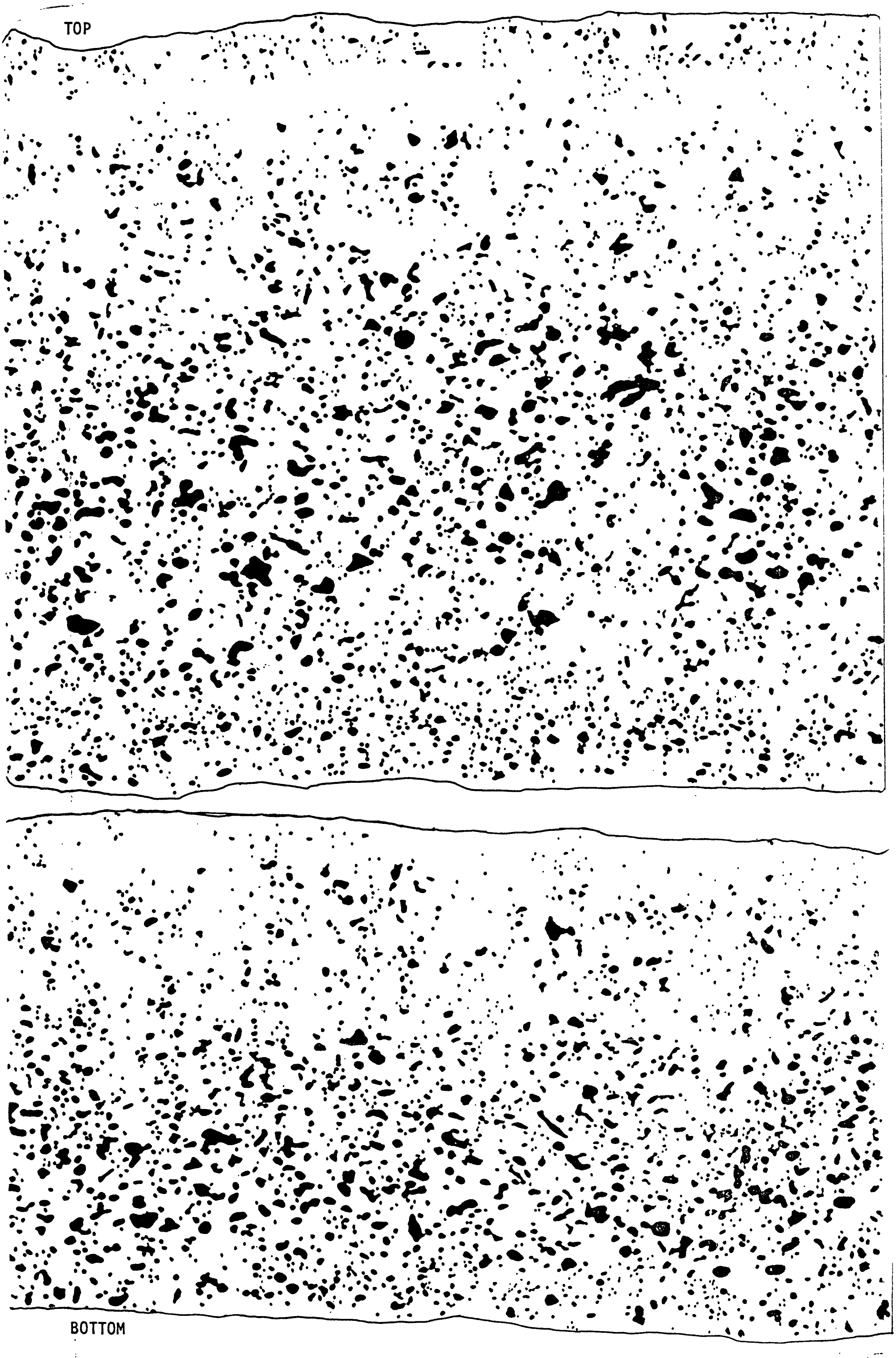
KI 79-3 #1 VESICLES
2.0'-3.0' depth interval
(0.6-0.9 meters)

TOP



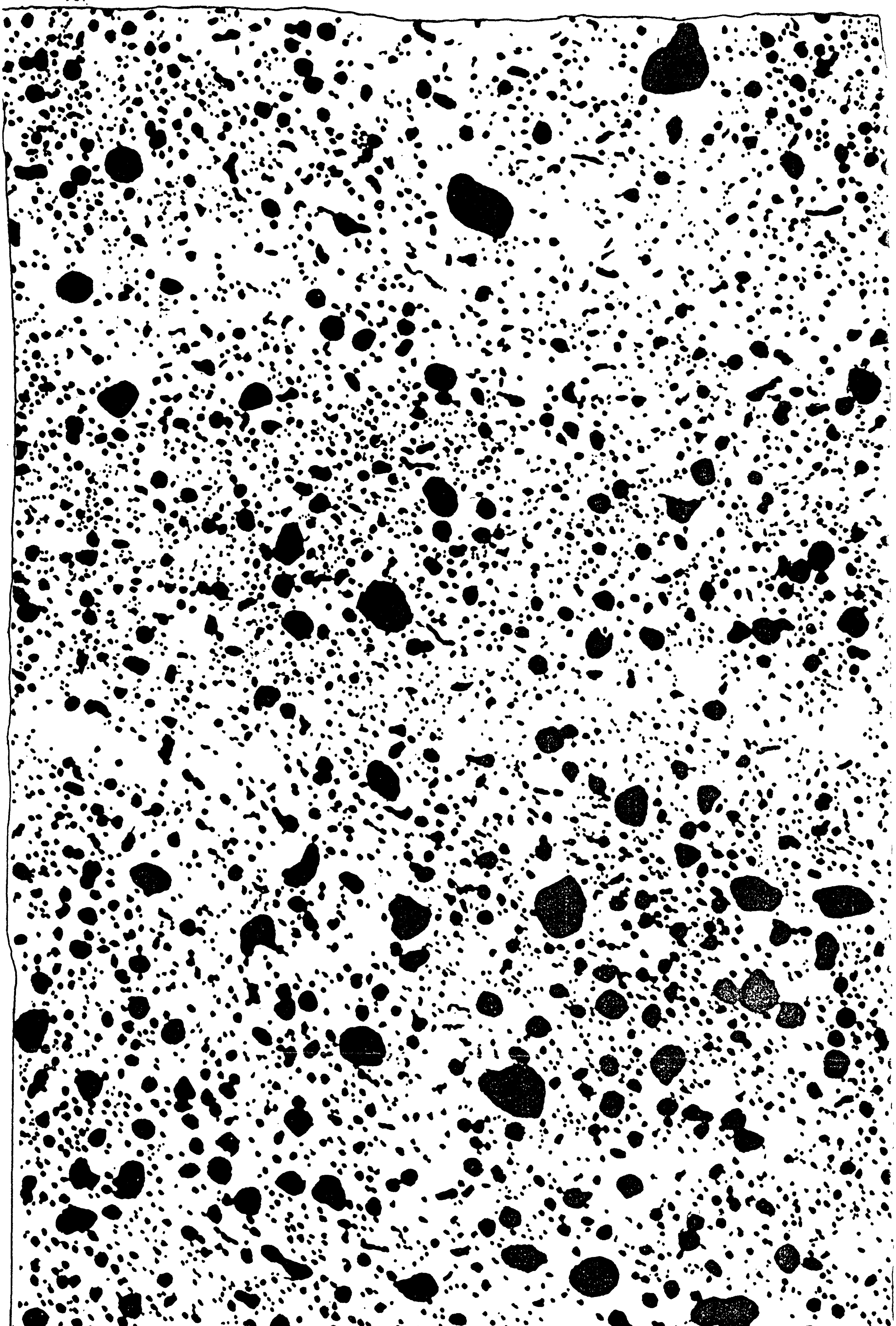
BOTTOM

KI 79-3 #2 VESICLES
15.6'-16.6' depth interval
(4.7-5.1 meters)



KI 79-3 #3 VESICLES
25.7'-26.7' depth interval
(7.8-8.1 meters)

TOP



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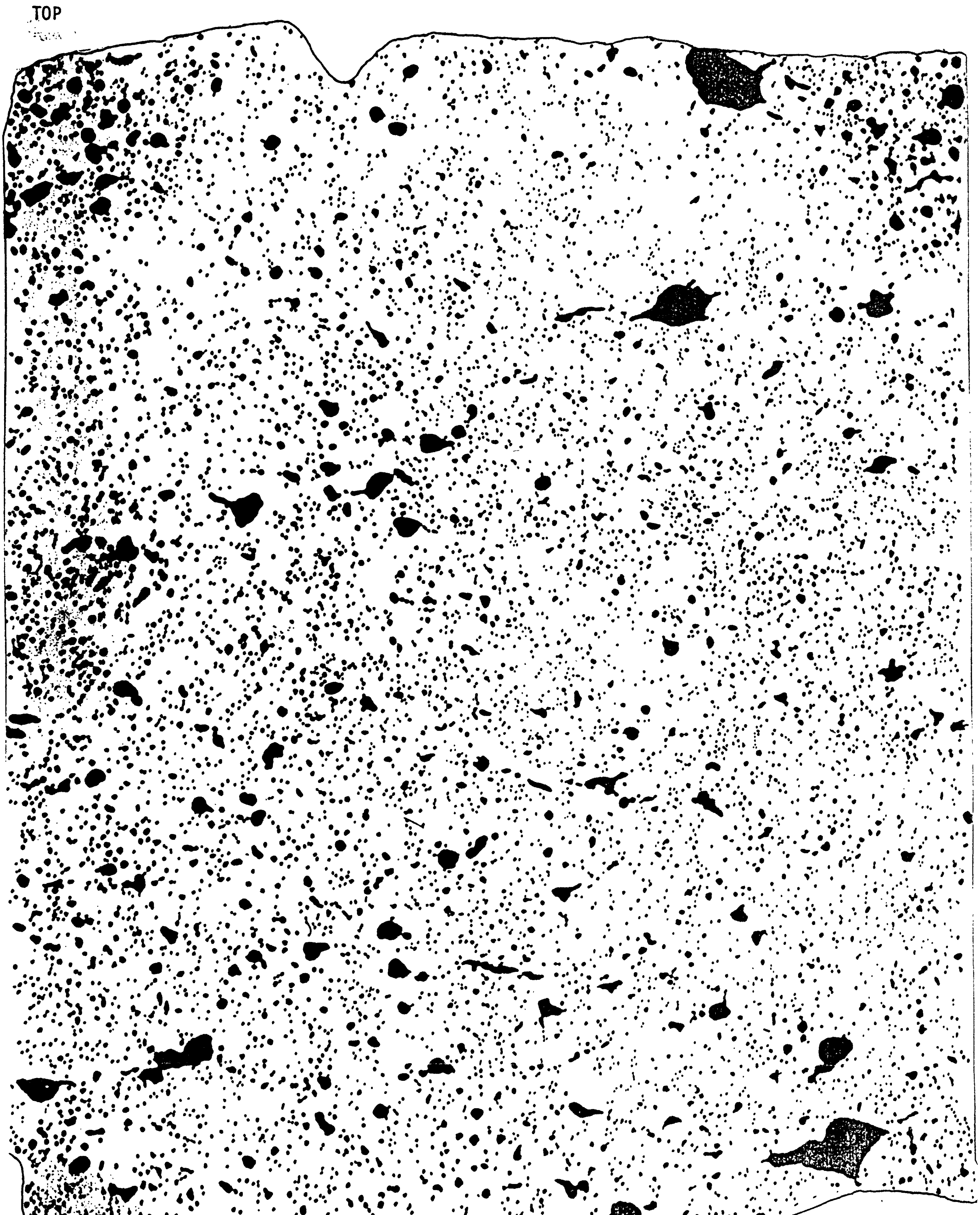
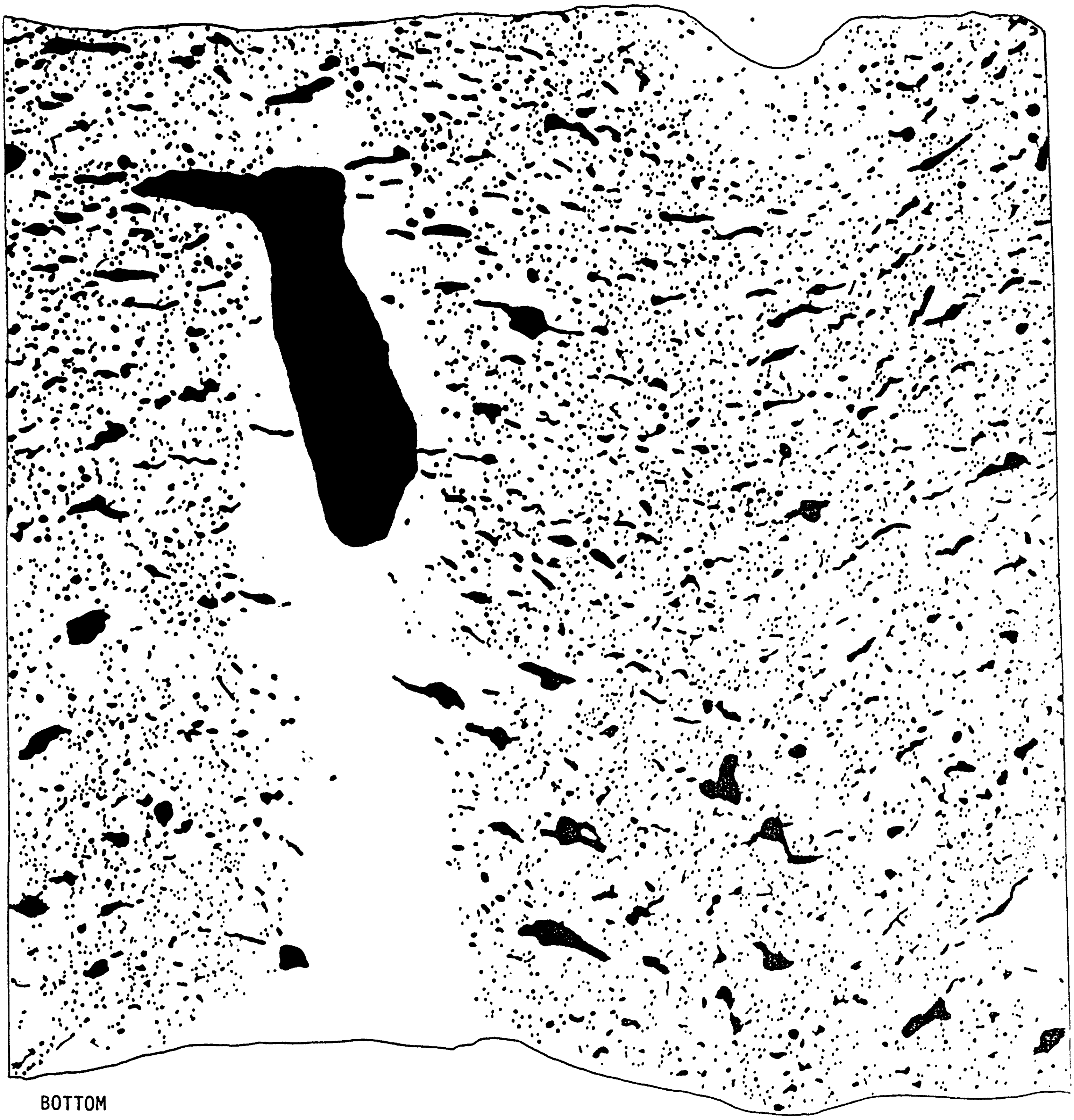
KI 79-3 #18 VESICLES
30.2'-31.1' depth interval
(9.2-9.4 meters)



KI 79-3 #19 VESICLES
32.9'-33.6' depth interval
(10.0-10.2 meters)

TOP



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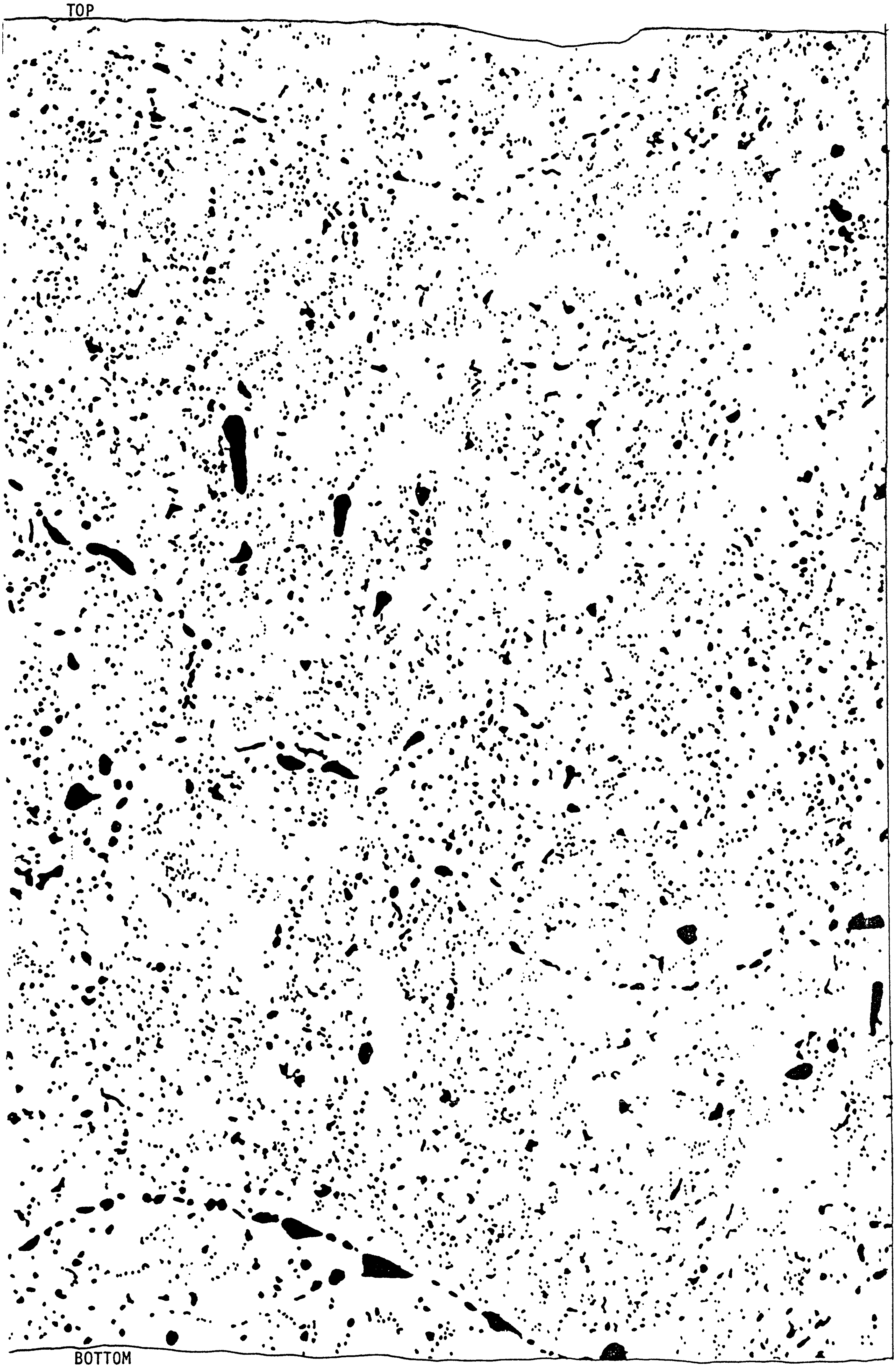
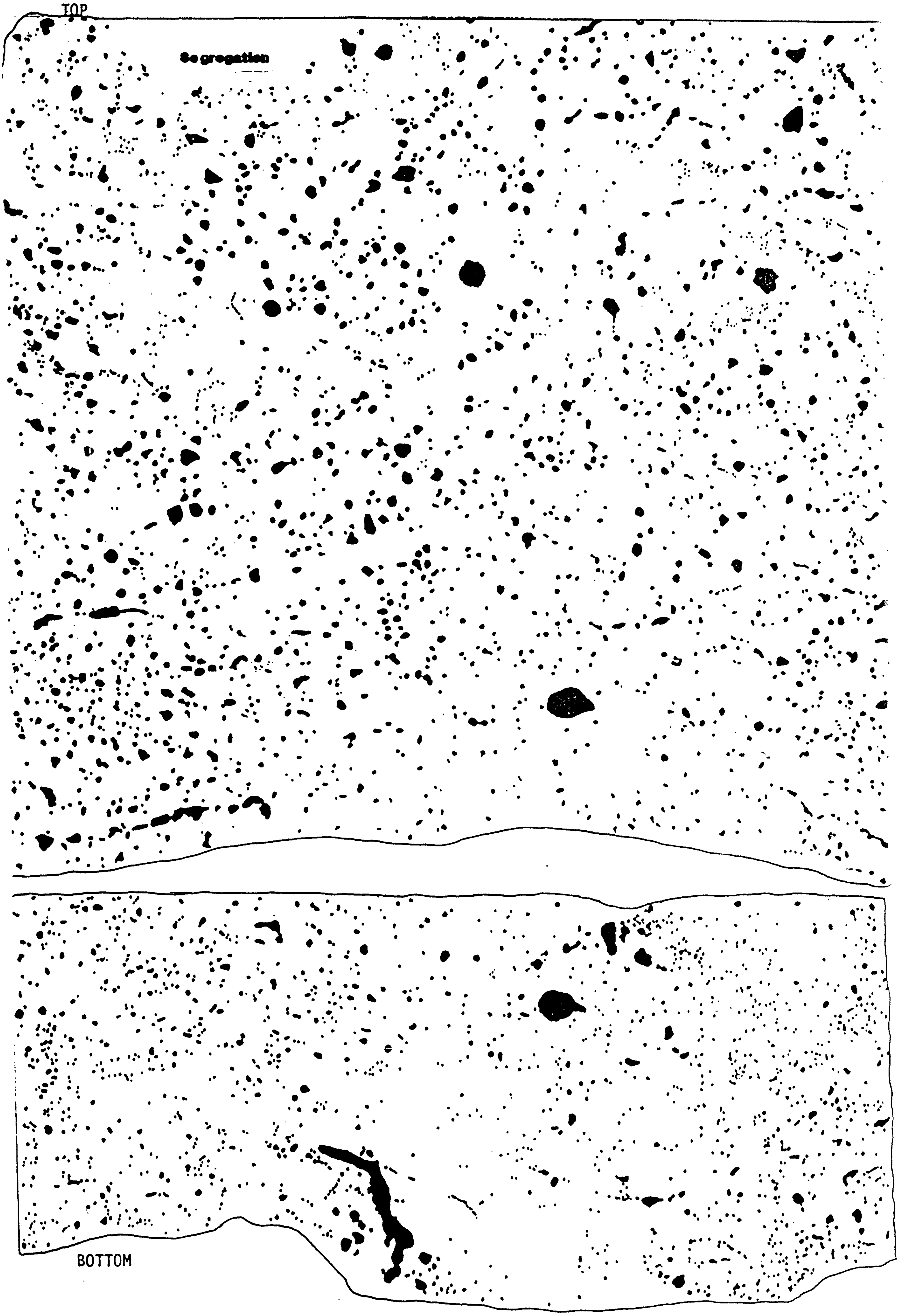
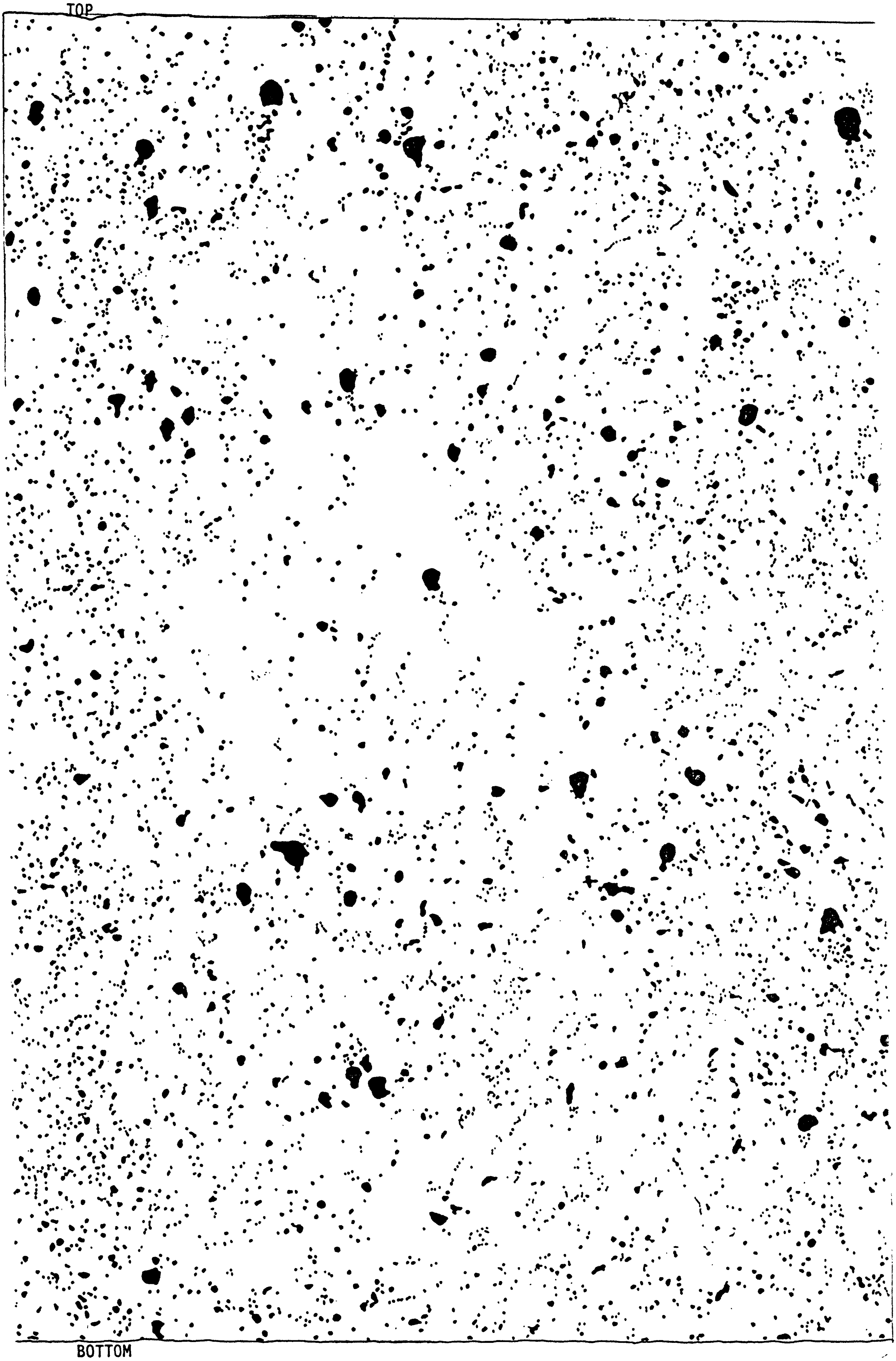
KI 79-3 #4 VESICLES
37.0'-38.0' depth interval
(11.2-11.5 meters)



KI 79-3 #5 VESICLES
47.2'-48.2' depth interval
(14.3-14.6 meters)

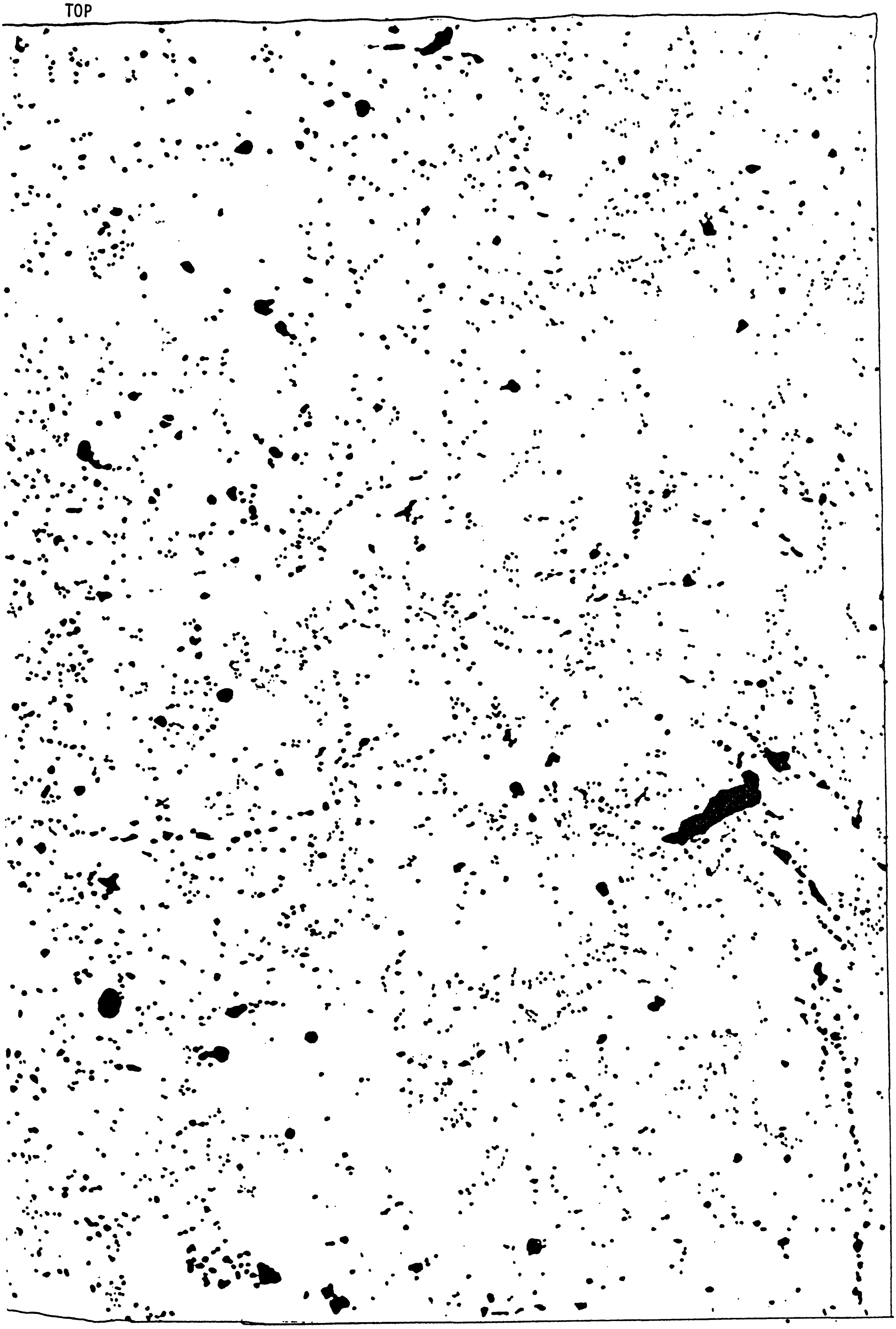


KI 79-3 #6 VESICLES
58.9'-59.9' depth interval
(18.0-18.3 meters)



KI 79-3 #7 VESICLES
71.0'-72.0' depth interval
(21.6-21.9 meters)

TOP



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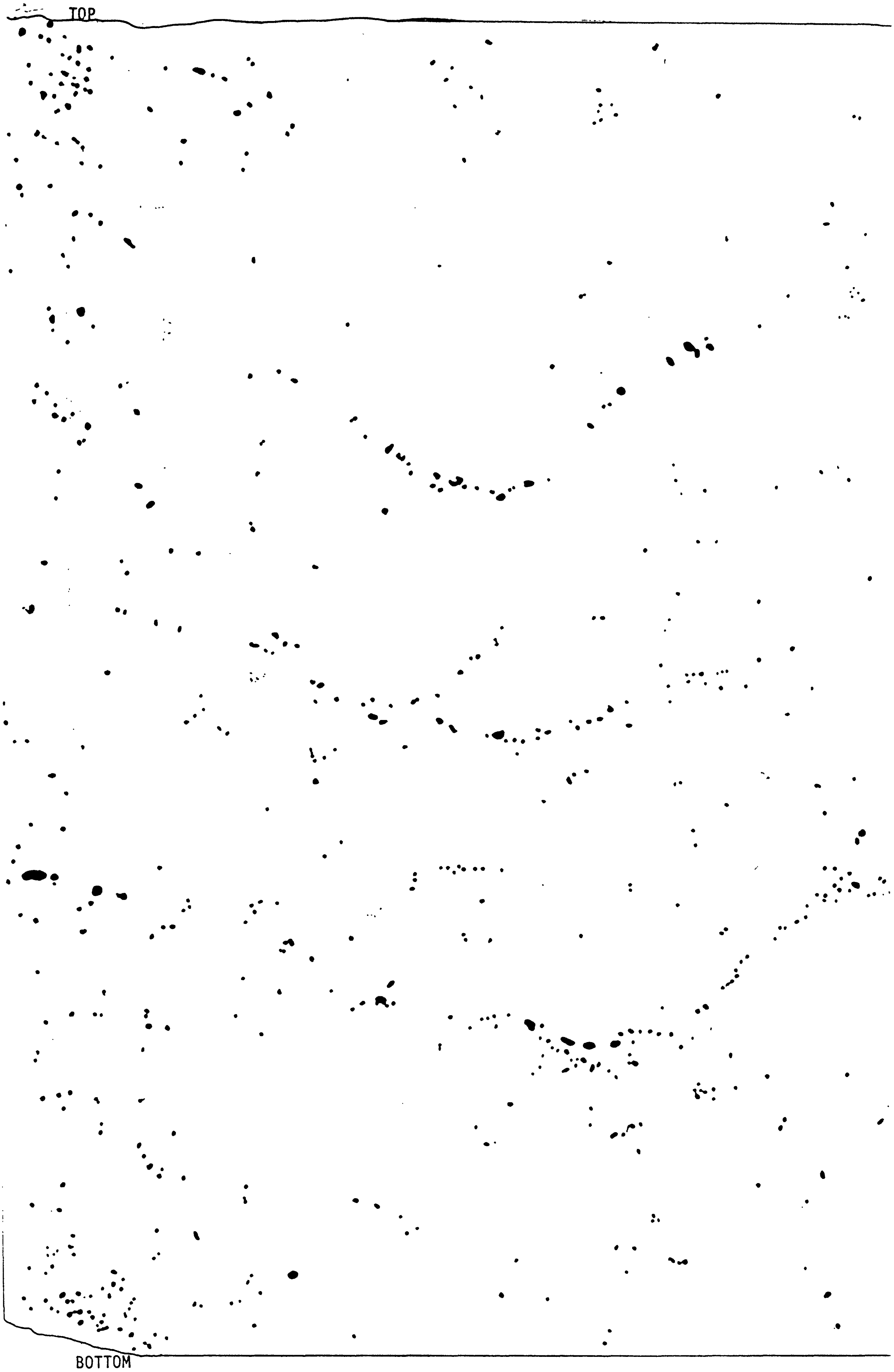
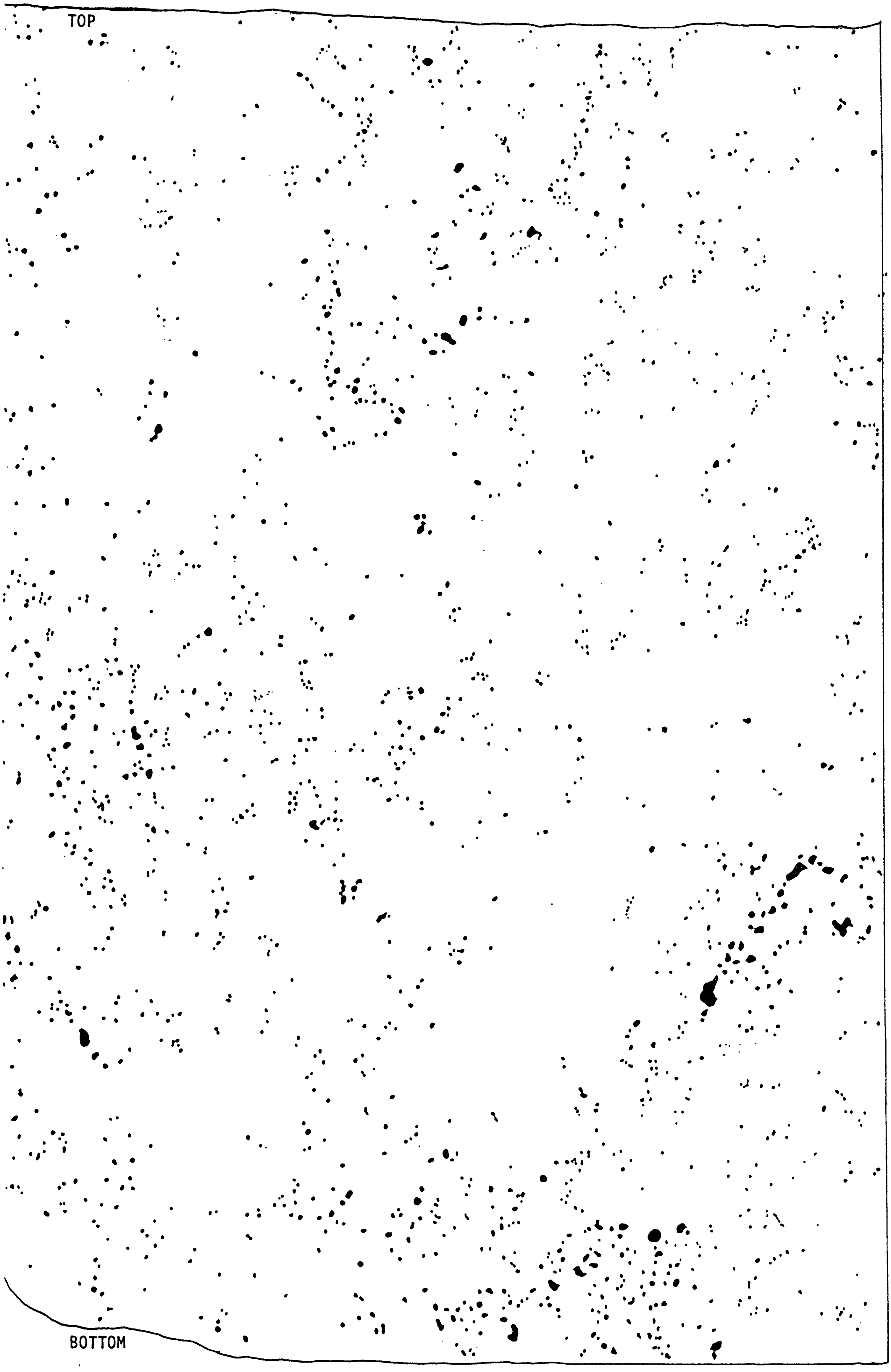
KI 79-3 #8 VESICLES
83.6'-84.6' depth interval
(25.5-25.8 meters)

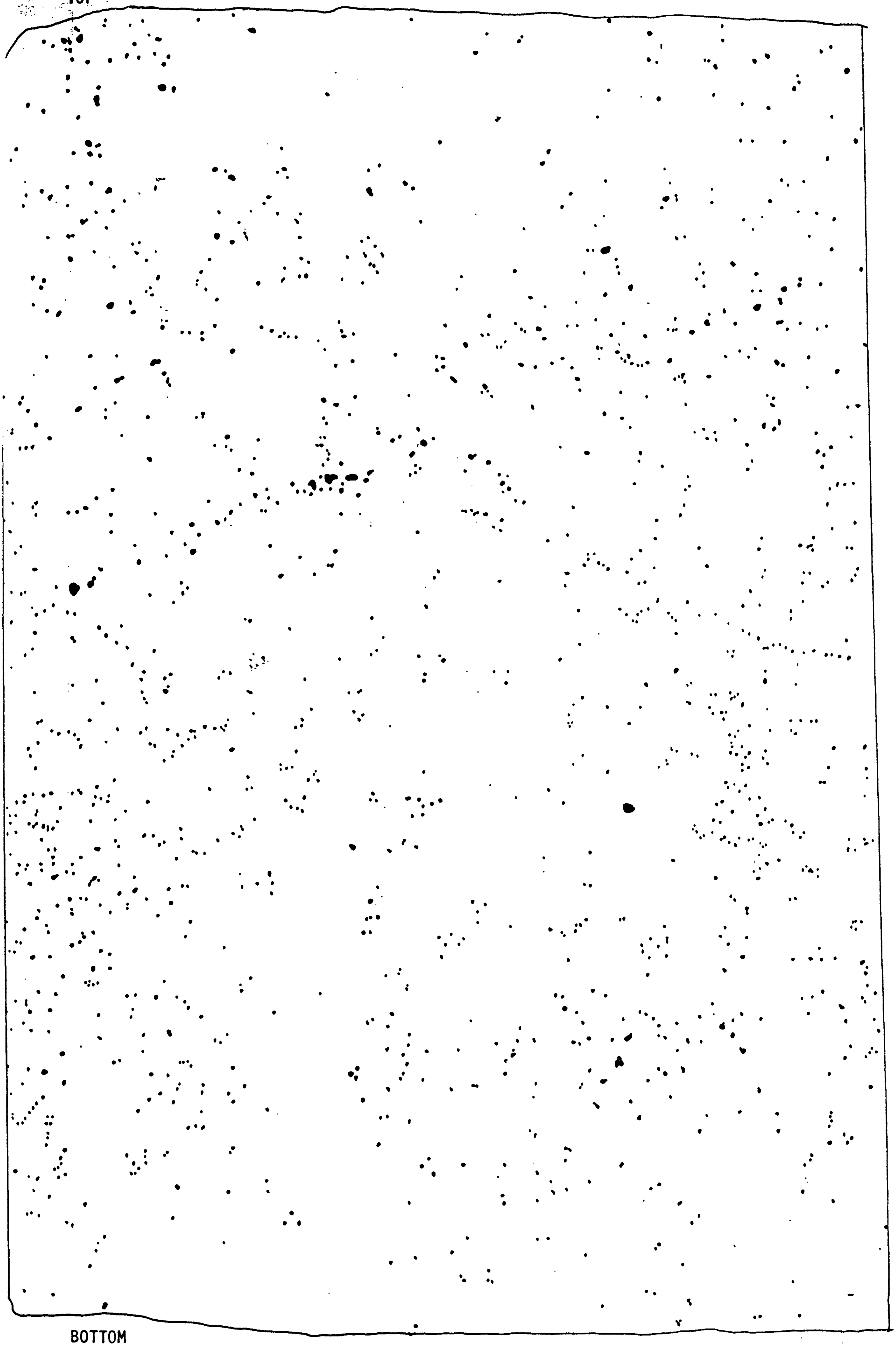


KI 79-3 #9 VESICLES
93.7'-94.7' depth interval
(28.5-28.8 meters)



KI 79-3 #10 VESICLES
104.5'-105.5' depth interval
(31.9-32.2 meters)

TOP



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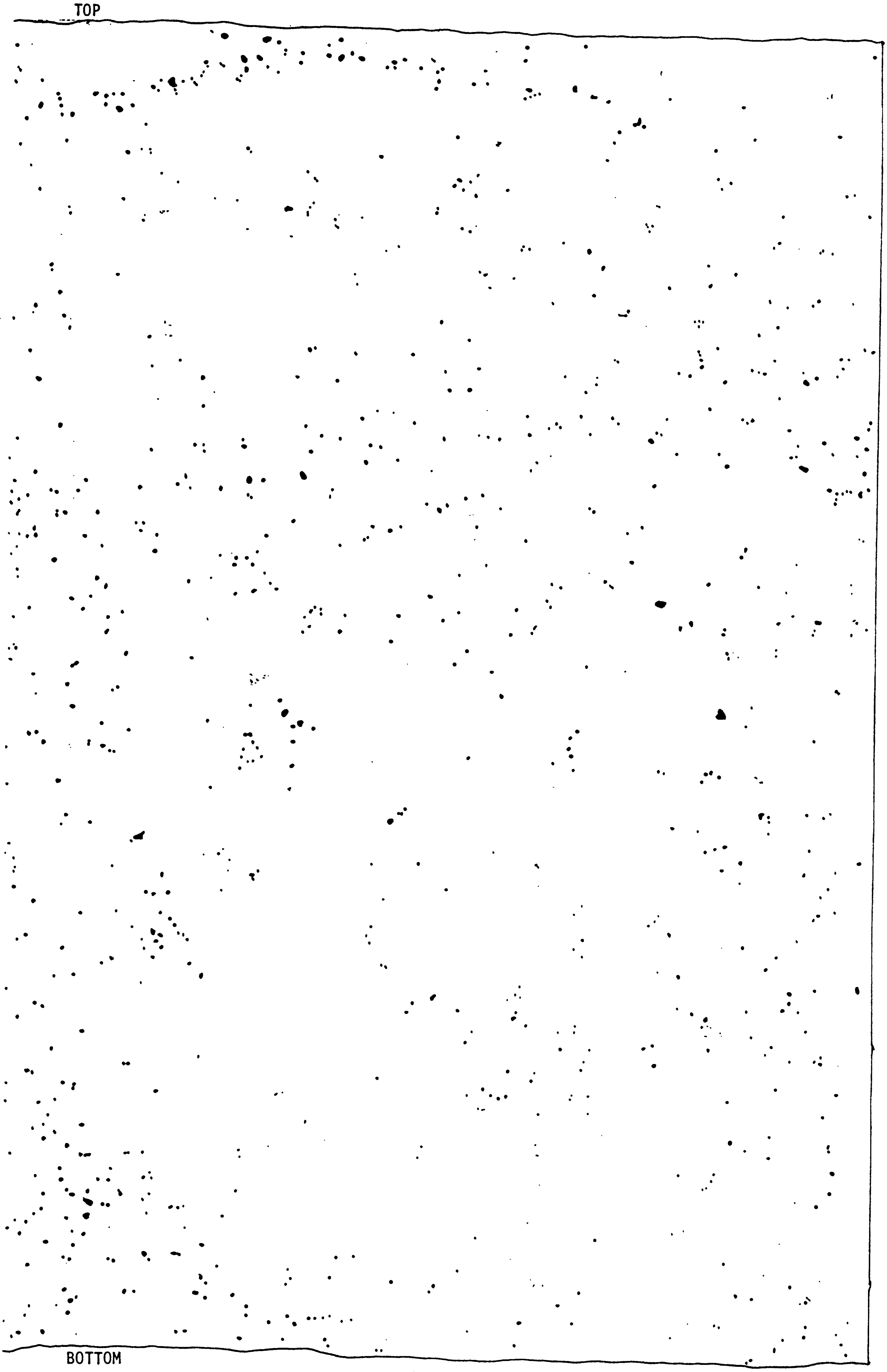
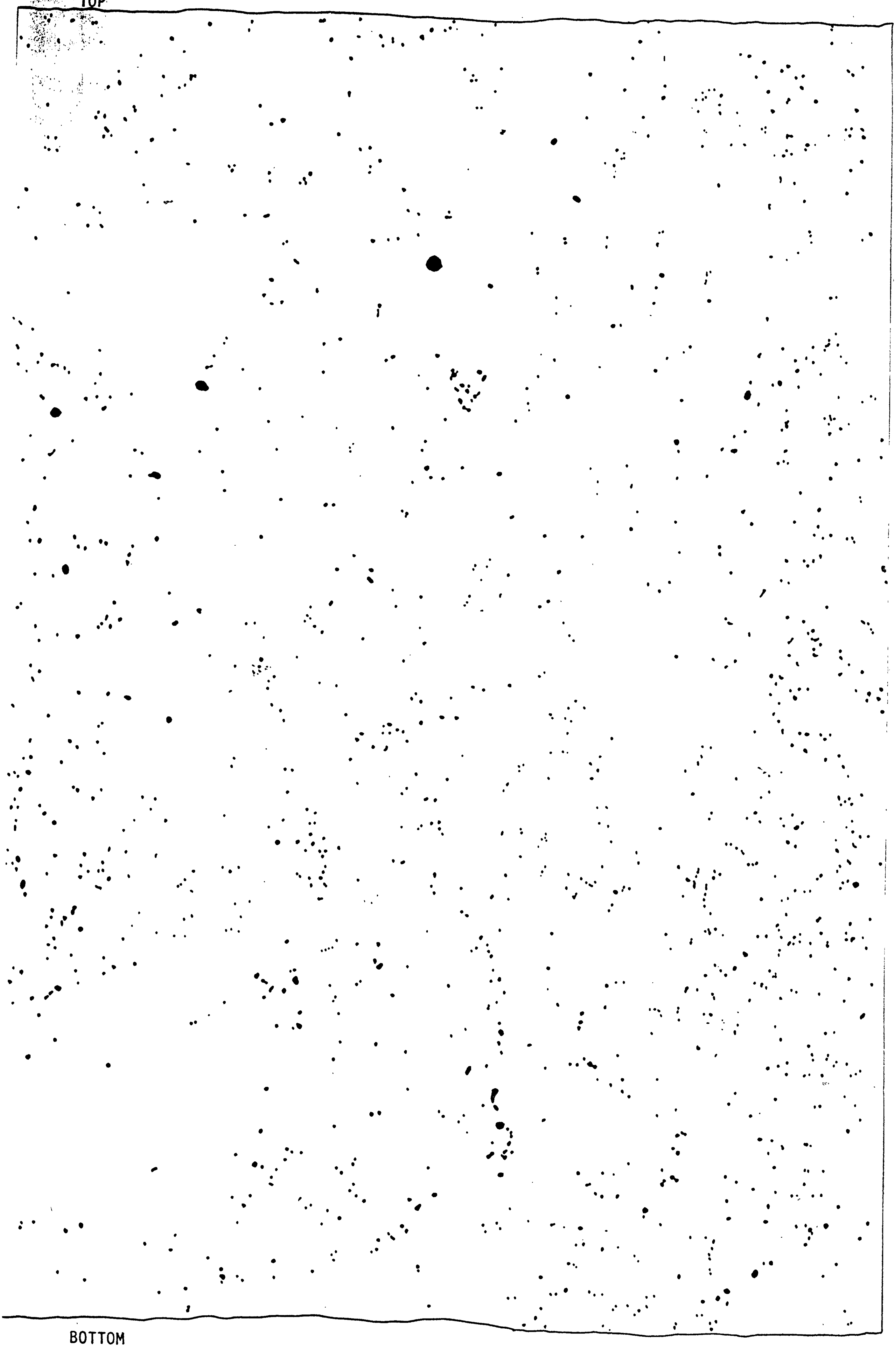
KI 79-3 #11 VESICLES
116.9'-117.9' depth interval
(35.6-35.9 meters)



KI 79-3 #12 VESICLES
127.9'-128.9' depth interval
(39.0-39.3 meters)

TOP



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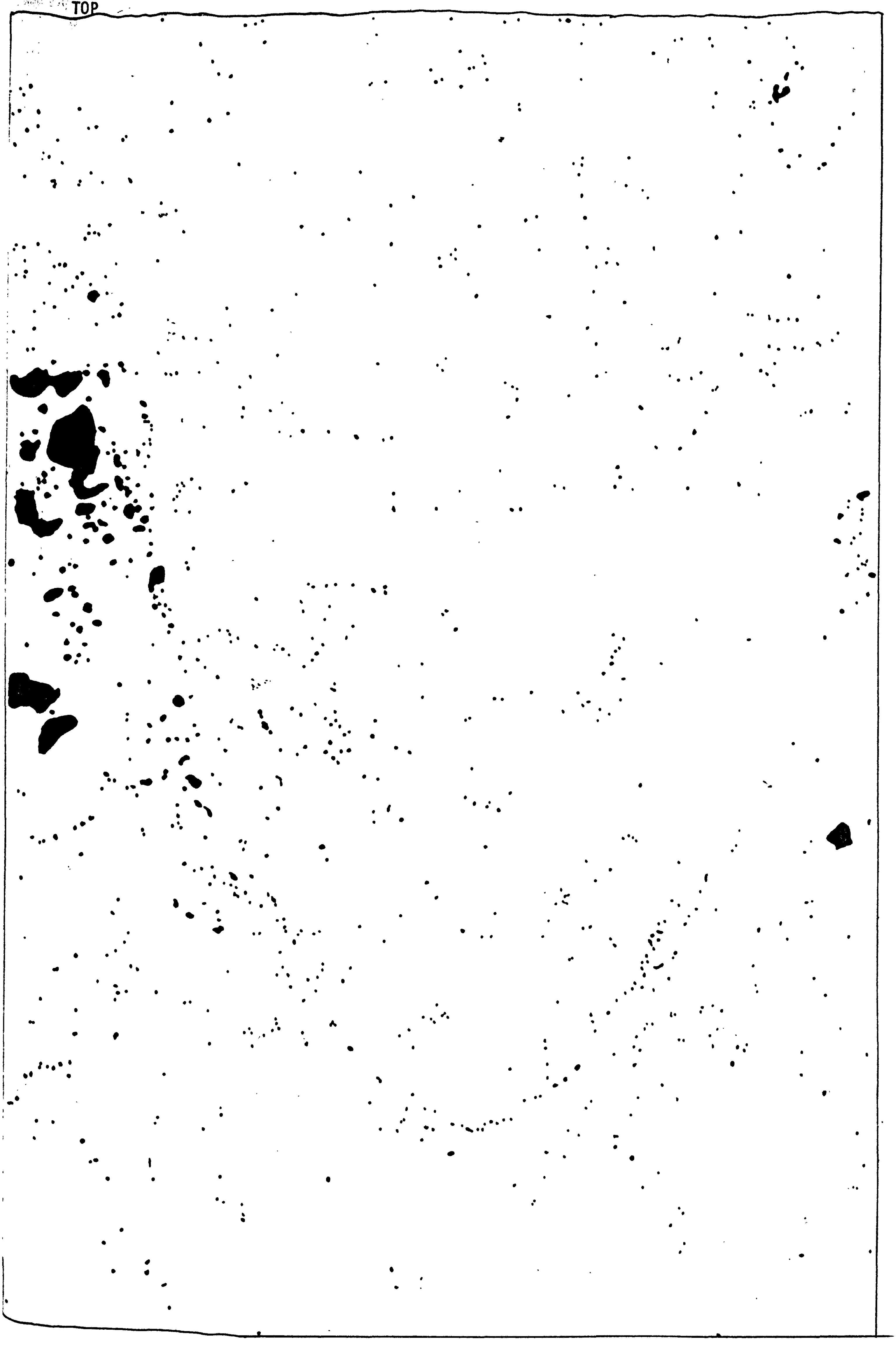
KI 79-3 #13 VESICLES
138.8'-139.8' depth interval
(42.3-42.6 meters)

TOP



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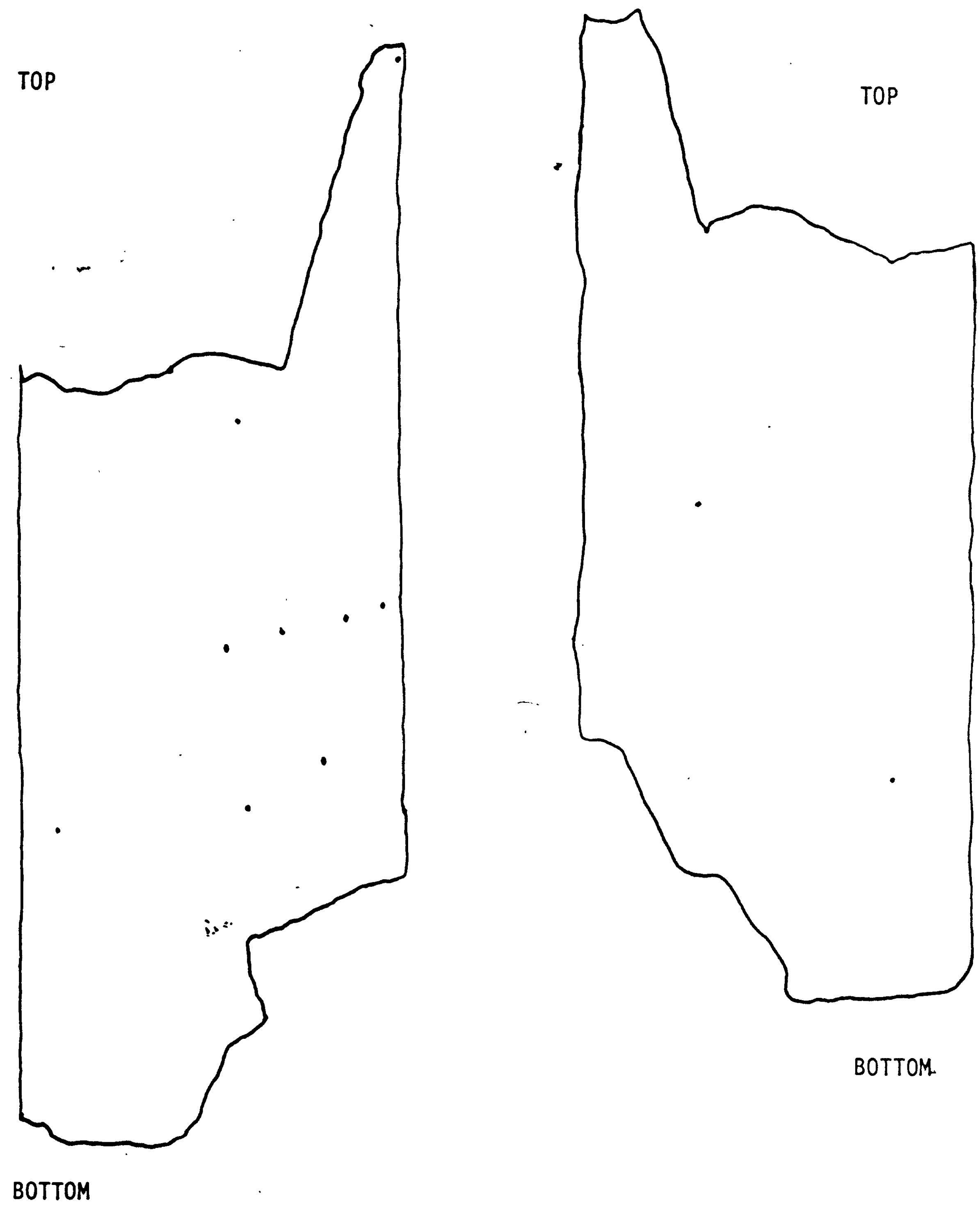
KI 79-3 #14 VESICLES
150.7'-151.1' depth interval
(45.9-46.0 meters)



KI 79-3 #15 VESICLES
161.3'-162.3' depth interval
(49.2-49.5 meters)