#195

Ecology - Marine, rocky intertidal
Arthropoda - Cirripedia
Mollusca - Gastropoda

THE DISTRIBUTION OF CIRRIPEDS AND GASTROPODS ON PLAIN VERTICAL BOCK SURFACES IN THE UPPER INTERTIDAL AND SPLASH ZONES.

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Introduction.

The problem consisted of two phases, firstly, a qualitative determination of the distribution of the species of barnacles and gastropods present from the top of Zone 1 (of Ricketts and Calvin) to about the top of the Mytilus line (or its equivalent height) on vertical rock surfaces, with special emphasis on the space relationships of any one species to the other species encountered, and secondly, the obtaining of a quantitative measure of the effects of exposure to various degrees of wave action and splash on the pattern of vertical distribution of the above species.

All counts were made on Mussel Point during the period July 3-July 14, 1947.

Methods.

Selection of sites.

Ideally, the sites chosen for such a study should have been identical in all respects save in the two variables under consideration, i. e., degree of exposure, and distribution of organisms. In practice, sites were chosen which presented one or more vertical faces of rock extending throughout the major part of the area under consideration, which had relatively homogeneous surfaces, as free as possible of projections, crevices, ledges, cavities, and other modifying factors creating local areas at variance with the general area type here considered, which showed obvious differences in degree of exposure to wave action and splash, and which were readily available for study.

Five sites on Mussel Point, Pacific Grove, Calif., were chosen, one of which (Point Despair) was later abandoned as unsuitable. The other four, although not ideal, were acceptable for study. In order, from the most exposed to the least exposed, these were: High

Rock, Hot Rock, Murphy's Rock, and Snad Rock. The locations and descriptions of these sites are included under the section on Results.

Laying out of transects.

A vertical strip, 6" wide, was laid out with red wax pencil and steel tape on each rock from top to bottom, and subdivided into 6" by 6" squares. Intervening crevices which contained an assortment of organisms quantitatively and qualitatively atypical of the surrounding vertical exposed surface were ignored, although they contained gastropods which might migrate out over the exposed surface from time to time. It is felt that this disregard for crevice fauna did not significantly alter the results.

In areas where one exposed rock did not extend to the mussel line or its equivalent (as in all except Murphy's Rock), the transect was interrupted, and continued at the next successive level on the closest similar and suitable rock face. This had a noticeable effect on the counts in at least two cases (High Rock and Snad Rock) but could not be avoided.

Making counts.

Counts were made by removing with knives all organisms from the rock within one 6" by 6" square, in the following order: littorines, limpets, and barnacles. All organisms within the square and "on the line" were counted as they were removed. Hence all identifications were made in the field except in the case of a few troublesome limpets, subsequently graciously identified by a local authority, Miss B. Schuck.

Certain sources of error were inevitable, due to the heterogeneous nature of the terrain, the enormous numbers of organisms present in the lower squares of the transects, and the methods used

for removal of individuals as they were counted. Many small littorines, particularly those living inside the shells of dead barnacles, were undoubtedly overlooked. In areas encrusted with mixed barnacle populations, it was almost impossible to remove and count the individuals of one species without disturbing adjacent individuals of the other species. In general, it is felt that the margin of error in counts of L. planaxis and of the various species of Acmaea was negligible, and did not exceed 5% for the other species counted.

Although no control transects were counted, qualitative visual observation of areas adjacent to the transects indicated a variation present on the total surface of any rock at any particular time, such variation constituting another uncontrolled variable.

Results.

Descriptions and figures of sites studied.

High Rock. (See Figs 1 and 2). This rock, located on the NNW face of Mussel Point, is exposed to a relatively high degree of wave action as compared with the other localities chosen. The rock itself extends from about 15 feet to about 3 feet above the mussel line, in the region of the transect studied. The 6 lower squares counted that were not on High Rock itself were located on the nearest flat vertical surfaces, only a few feet away. The outer surface of High Rock is marred by a transverse crevice near the top, and by another about one third of the way up. The transect was broken at these points to exclude the crevices.

The outline of the rock is not vertical. The angles of the various surfaces measured may be estimated from Fig. 2.

A sharp break in the continuity of numbers of organisms counted is shown in the counts for High Rock between squares 33 and 34, and between squares 34 and 35 (Fig. 2), indicating that conditions

in the three regions were not strictly comparable. Observations made at high tide show that squares 34 and 35-39 receive much greater splash and wave pounding than square 33 and the squares above it.

Waves strike the base of the rock at a slight angle, but not enough to prevent considerable splash at high tide.

Hot Rock. (See Figs 3 and 4). Hot Rock is situated on the west face of Mussel Point. It is subjected to a fairly high degree of wave action, since the direction of the incoming waves is on a line with the vertical surface of the rock. However, comparision of Figs 1 and 2 with Figs 3 and 4 will show that the vertical aspect of Hot Rock is protected by extensive mussel-covered reefs which mitigate the shocking power of the impinging surf. Reference to Fig. 4 will clearly show the two discontinuities in the transect. However, neither of these breaks had any marked effect on the counts, since the uppermost occurs high in the splash zone, and the lower is small.

The transect studied extends 11 feet, from the top of the outer face of the rock to the mussel line.

Murphy's Rock. (See Figs 5 and 6). Murphy's Rock is situated on the south face of Mussel Point, lying in an open cove protected to the north by a prominent rocky spit. Incoming waves pass across the face of the rock parallel to its surface, and consequently the splash zone is limited. In outline, the outer face of the rock is nearly vertical, and is unbroken by any fissures or ledges. This is in marked contrast to the other rocks studied.

Snad Rock. (See Figs 7 and 8). Snad Rock lies on the north face of Mussel Point. Although the incoming waves impinge directly on the rock, their force is abated by a perfectly overlapping series of protecting rocks. The result is that incoming water merely swells

about the base of the rock with very little force, reducing the splash zone to a minimum. The transect on Snad Rock is interrupted by one major discontinuity, as illustrated in Fig. 8; this produced a corresponding discontinuity in the number of organisms present in squares 9 and 11. Since squares 9 and 10 (see Fig. 8) were at the same level, the counts in square 10 were not included in the charts (see Appendix, Table 4, footnote).

Check-list of species found.

The following organisms were found in the transects studied:

Class Cirripedia.

Order Thoracica.

Balanus glandula Darwin

Chthamalus fissus Darwin

Tetraclita squamosa rubescens Darwin

Class Gastropoda

Order Streptoneura

Suborder Aspidobranchiata

Acmaea digitalis Eschscholtz

Acmaea pelta Eschscholtz

Acmaea digitalis x *Acmaea pelta*

Acmaea scabra (Gould)

Suborder Pectinibranchiata

Littorina planaxis Philippi

Littorina scutulata Gould

Class Pelecypoda

Order Filibranchiata

Mytilus californianus Conrad

HIGH ROCK

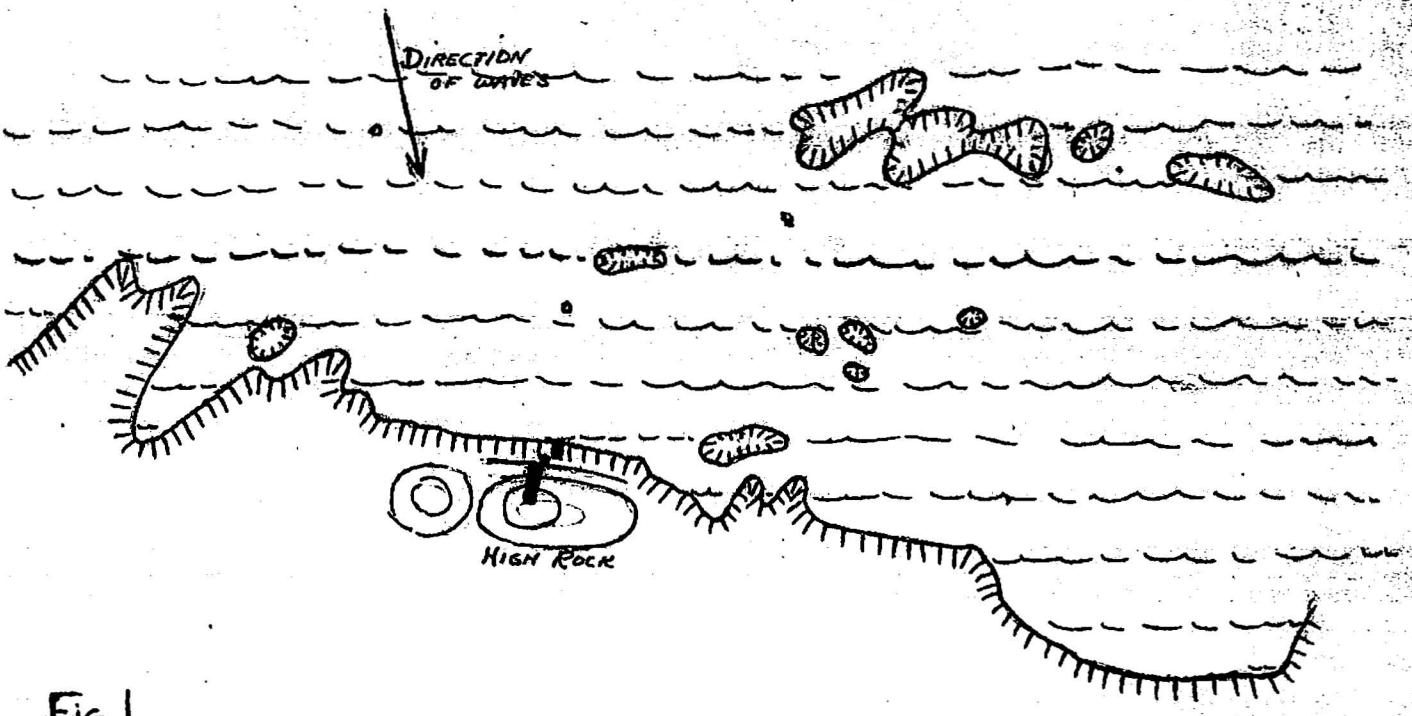


FIG. 1

HIGH ROCK AT +4.9' TIDE — TOP VIEW - DIAGRAMMATIC

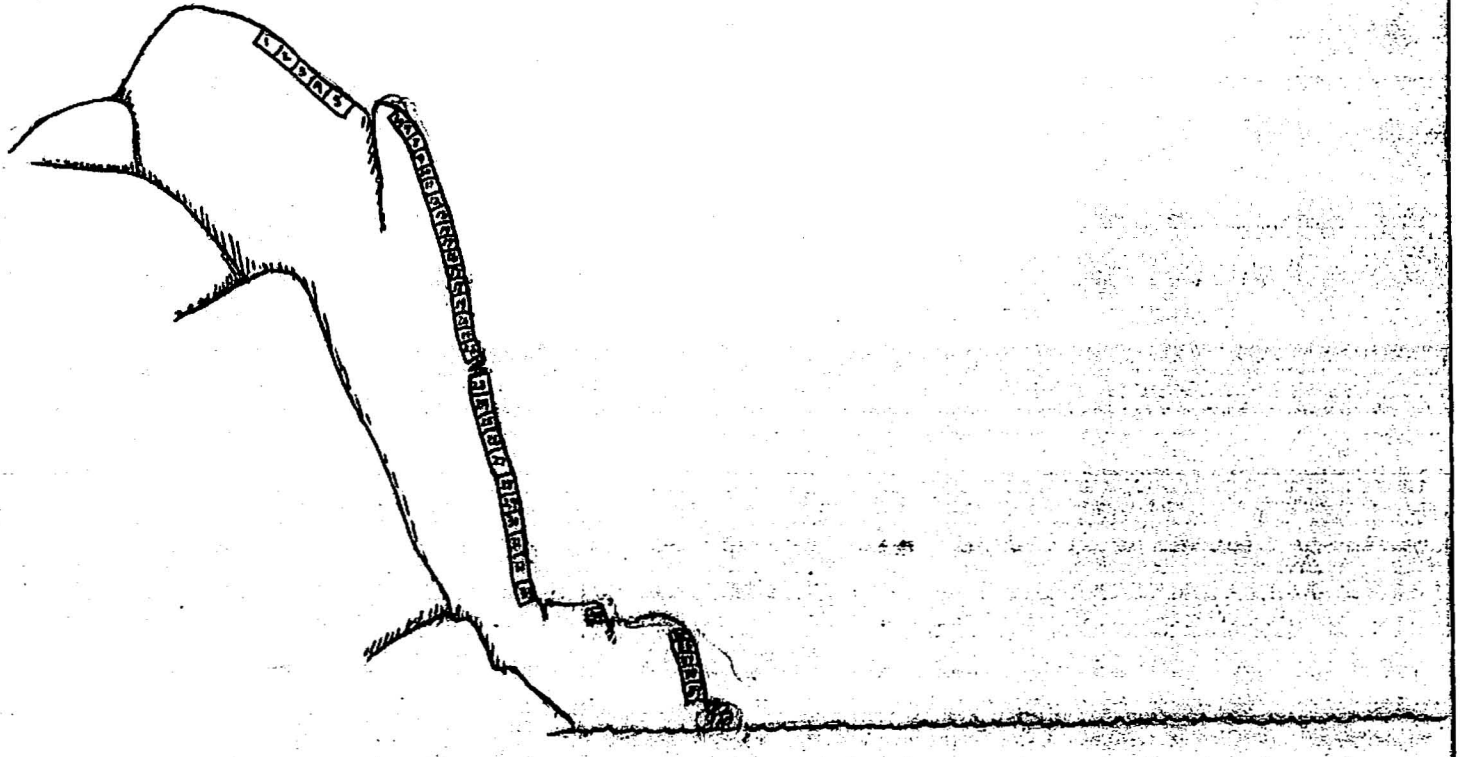


FIG. 2

HIGH ROCK AT +4.4' TIDE — PROFILE, LOOKING WEST.

HOT ROCK

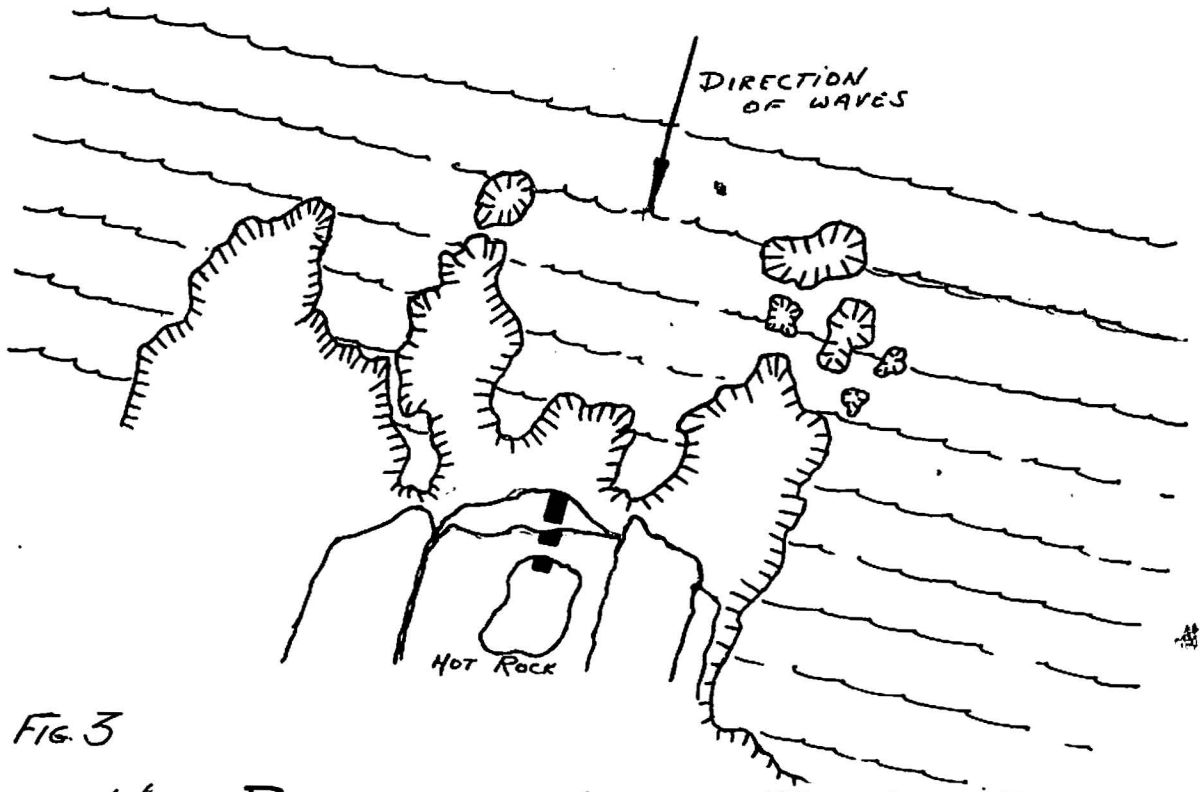


FIG. 3

HOT ROCK AT +4.4' TIDE - TOP VIEW - DIAGRAMMATIC

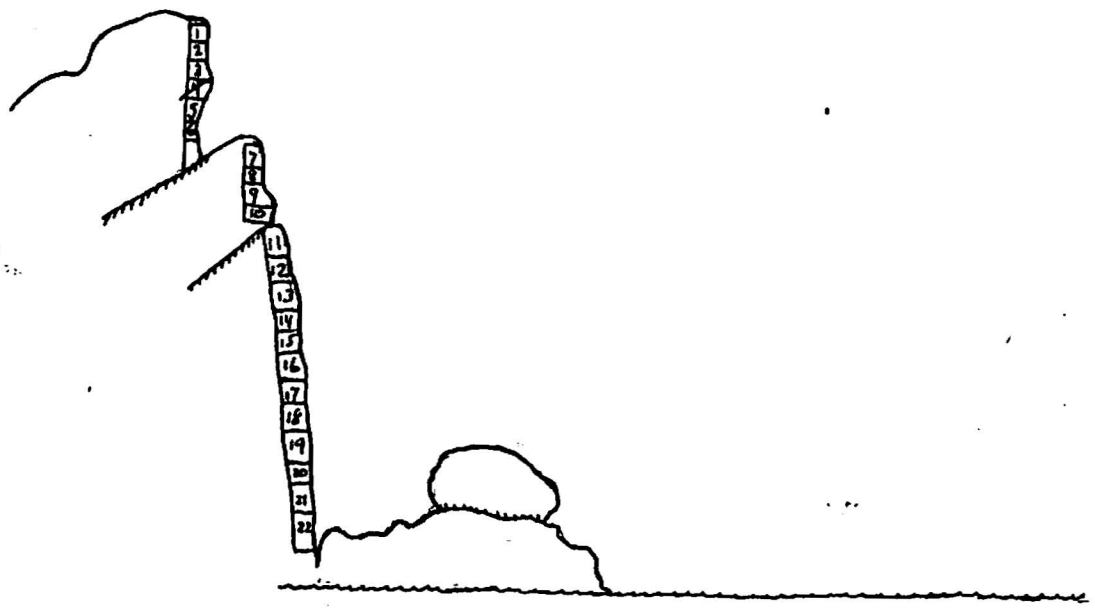


FIG 4.

HOT ROCK AT +4.4' TIDE - PROFILE - LOOKING SOUTH

MURPHY'S ROCK

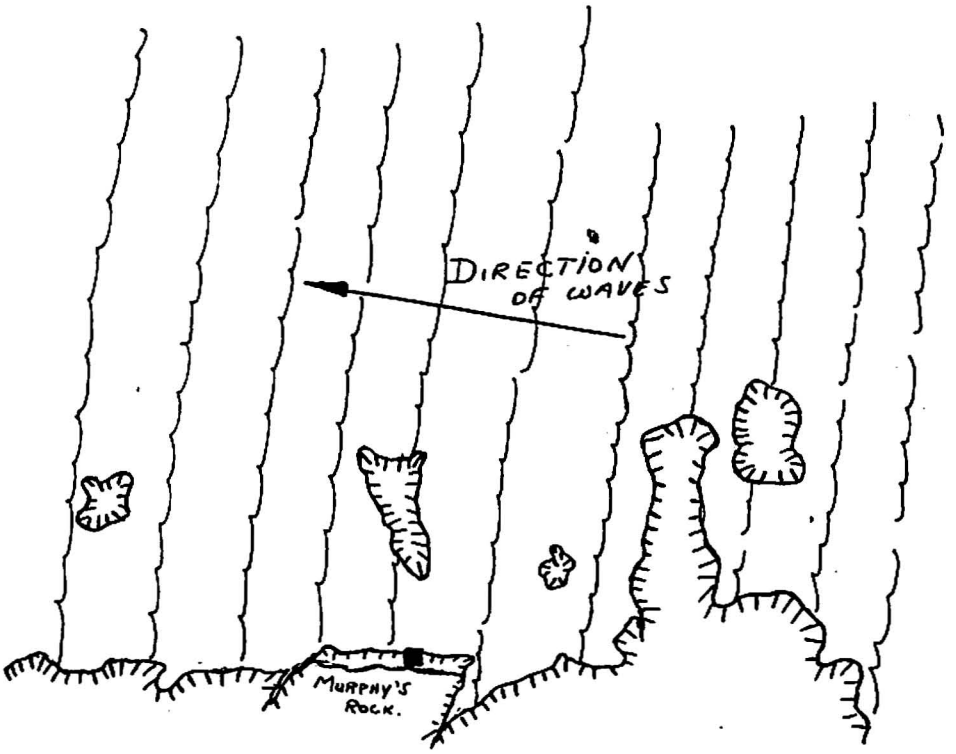


FIG. 5

MURPHY'S ROCK AT +4.4' TIDE - TOP VIEW - DIAGRAMMATIC

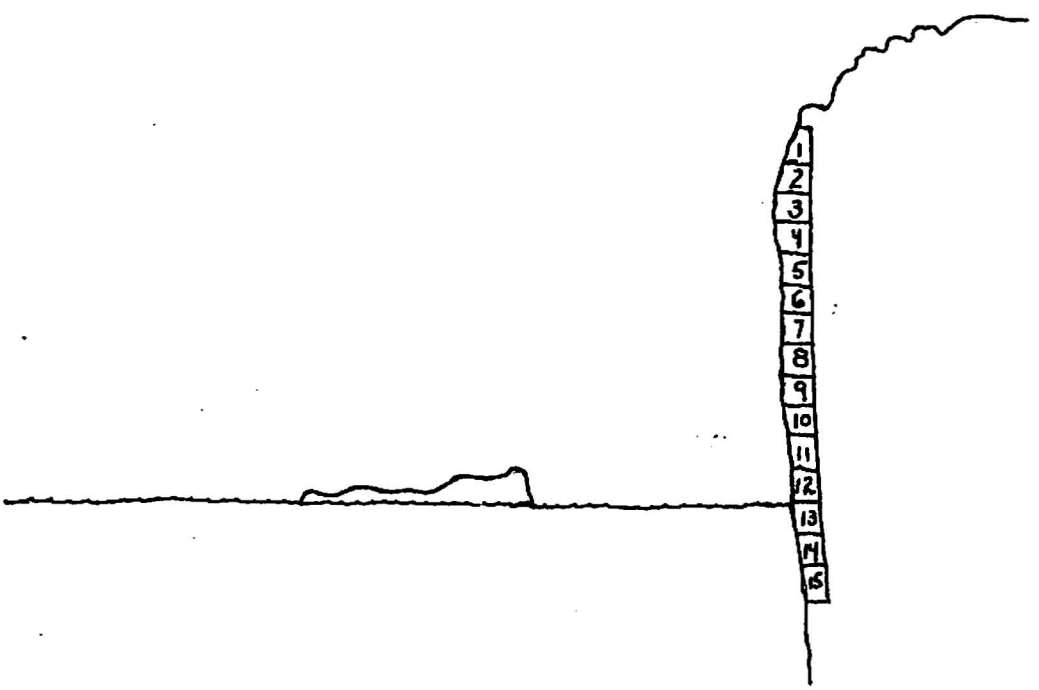


FIG. 6

MURPHY'S ROCK AT +4.4' TIDE - PROFILE - LOOKING WEST

SNAD ROCK

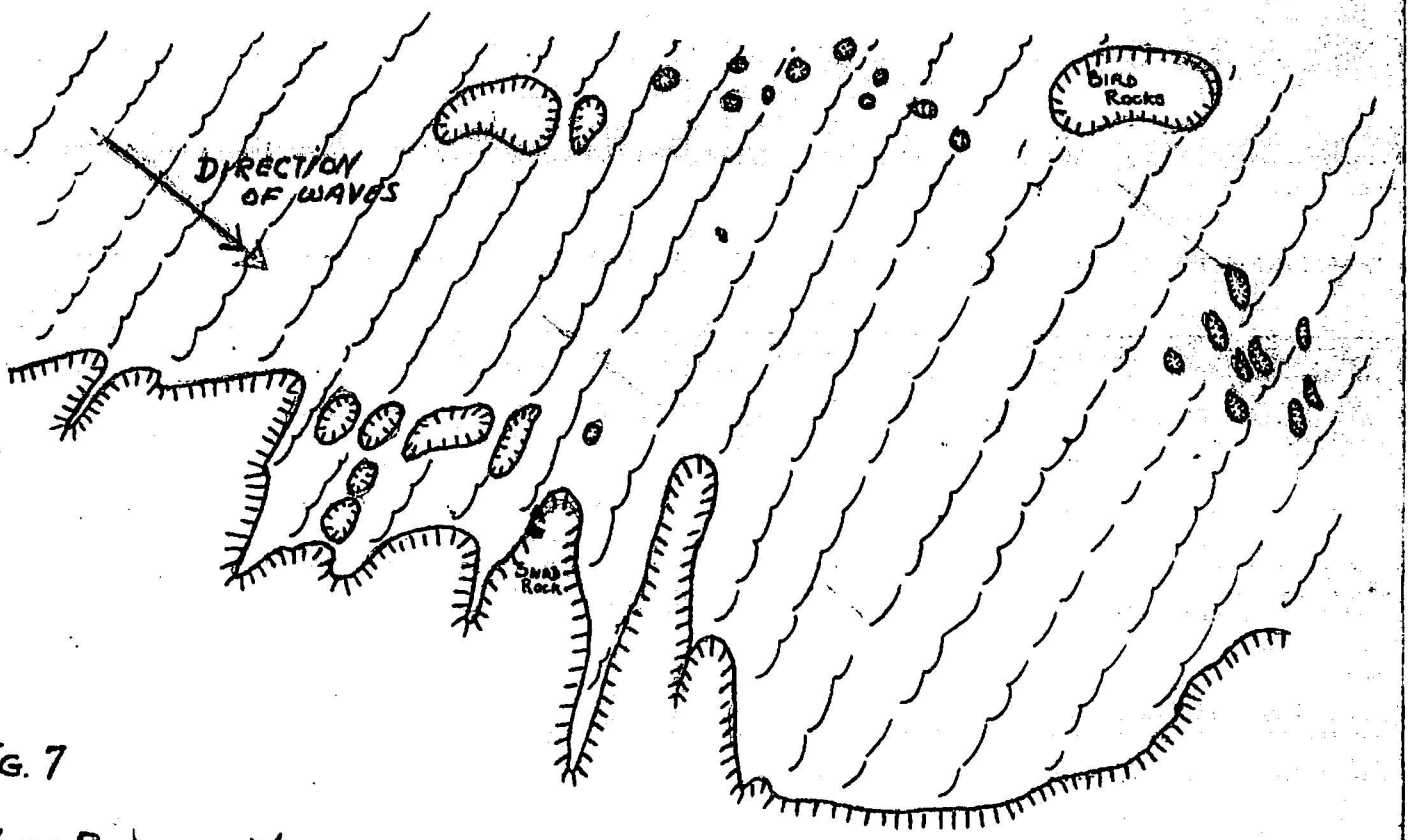


FIG. 7

SNAD ROCK AND VICINITY, TOP VIEW, AT +4.4' TIDE

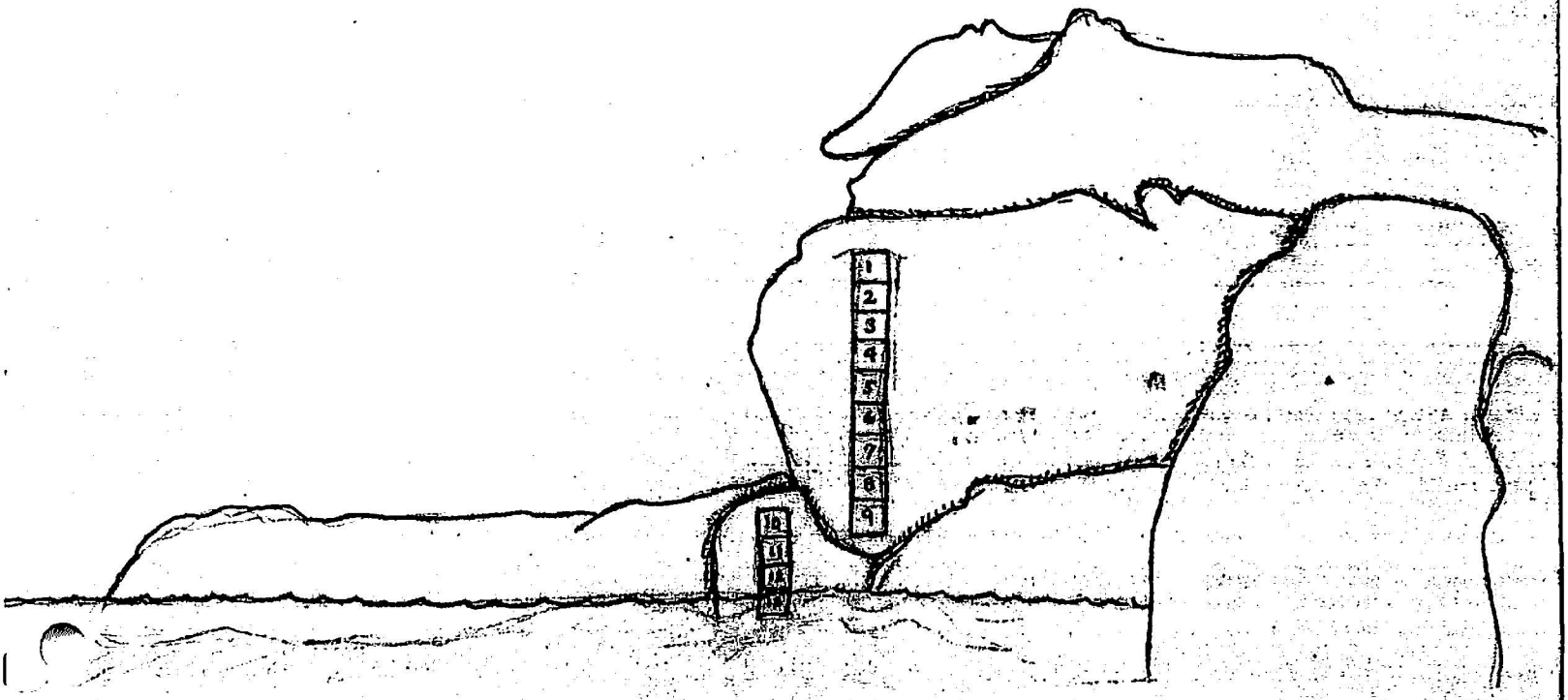
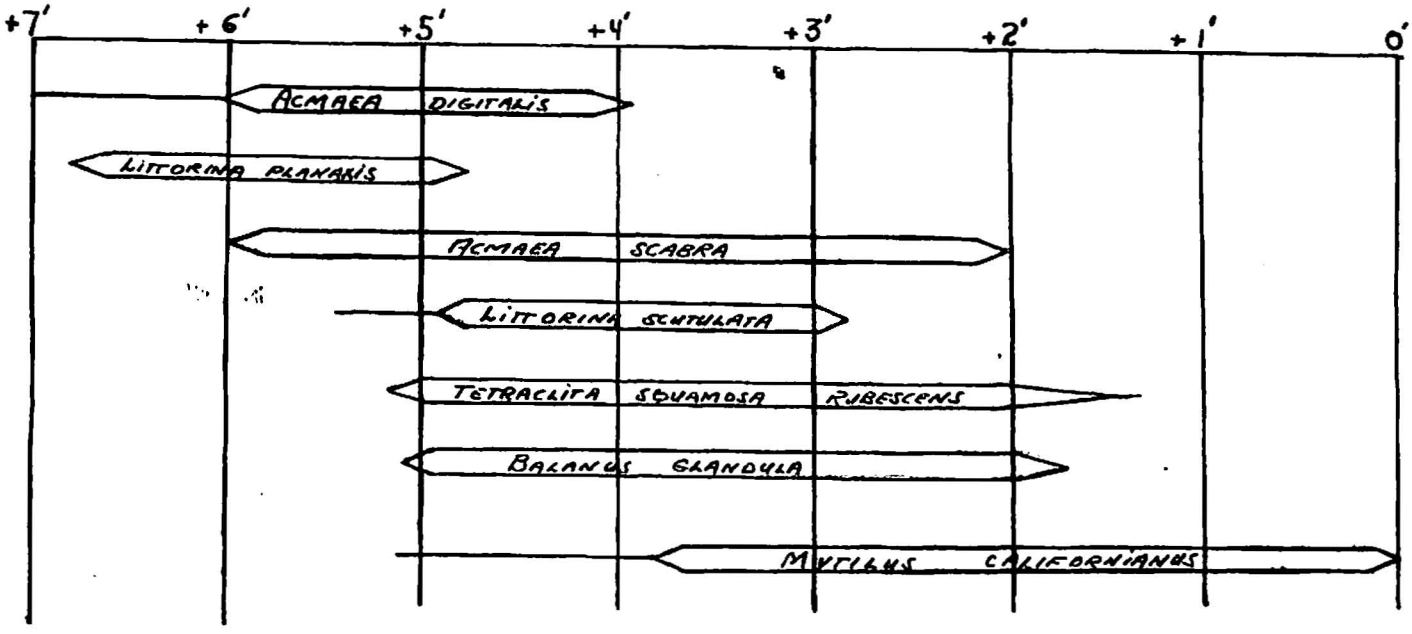


FIG. 8

SNAD ROCK, PROFILE, LOOKING EAST, AT 4.4' TIDE

Basic pattern of distribution of organisms.

According to Hewatt[1] the organisms studied occur in the intertidal zone as follows:



In the course of the present study, no such clear cut basic plan of distribution as the above was found which was applicable to all rocks. It is possible, however, to point out certain basic trends that were noted. Littorina planaxis always ranged higher than any of the other organisms. In general, the highest Acmaeas occurred slightly higher than the highest barnacles. While Acmaea digitalis is generally believed to range slightly higher than A. scabra in the rocky intertidal, our counts and qualitative observations did not consistently bear this out, and it appeared that the height reached by the highest individuals of the two species was about the same. Slightly below the highest limpets, the outposts of the barnacle frontier appear, and again, neither B. glandula or C. fissus - within the areas counted - could be said to occur consistently higher than the other as far as isolated individuals were concerned.

[1] Hewatt, W. G. 1937. Ecological studies on selected marine intertidal communities of Monterey Bay, California. Am. Midland Nat., 18: 161-206.

The most variable species in the array studied was Littorina scutulata. Even disregarding all specimens which had worked their way into noticeably protected areas, and considering only those freely exposed on bare rock faces, the highest L. scutulata might appear anywhere from above the highest limpets to below the highest barnacles.

Only in the case of L. planaxis did the areas counted include the lower limit of distribution in the intertidal, so that a complete distribution picture for the other species is lacking. A further understanding of the distribution of the species concerned must await counts extending farther downward, and studies as well of the microhabitats of exposed rocky surfaces, and of the movements made by the limpets and littorines.

Charts.

See following page.

Discussion.

The results obtained are shown in the foregoing charts and in the tabulations of actual organisms counted (see Appendix) with sufficient clarity to render extended discussion superfluous. The generally higher ranging of forms in regions of greater wave action and splash is obvious, as is the variation in degree of "compression" of the vertical distribution belts of the organisms studied, such variation being directly correlated with the degree of protection from splash. Certain features, however, require emphasis and/or explanation.

In the first place, conclusions concerning the large numbers of organisms found in the lowermost regions counted (especially in the case of Murphy's Rock) must be made with caution, as corresponding low areas were not counted on all rocks. Secondly, certain peculiar features of Snad Rock make it difficult to compare directly with the other regions. It receives almost no spray at all, the waves at low tide scarcely rising above the water level. Hence, barnacles are forced to live in a region covered by high tides. However, here they must compete for attachment sites with the algae, which grow up nearly to the high tide mark. The resulting situation has apparently crowded the barnacle belt nearly out of existence. This may not present the whole picture, as horizontal rocks adjacent to the lower squares on Snad Rock are almost completely encrusted with barnacles.

In some instances, the presence of certain organisms made possible the presence of others. This was particularly true in the case of small specimens of L. scutulata, since many tiny individuals occurred inside the shells of dead barnacles, and in the crevices between adjacent barnacles.

Finally, the degree of exposure was not measured quantitatively. However, qualitative observations at high tide afforded a fair picture of conditions with regard to wave shock and splash.

Conclusions.

Although data are incomplete, the following conclusions seem warranted:

1. Although greatly disrupted by the presence of both clear-cut and obscure modifying factors in the habitat, there seems to be a general pattern of distribution for the organisms studied.

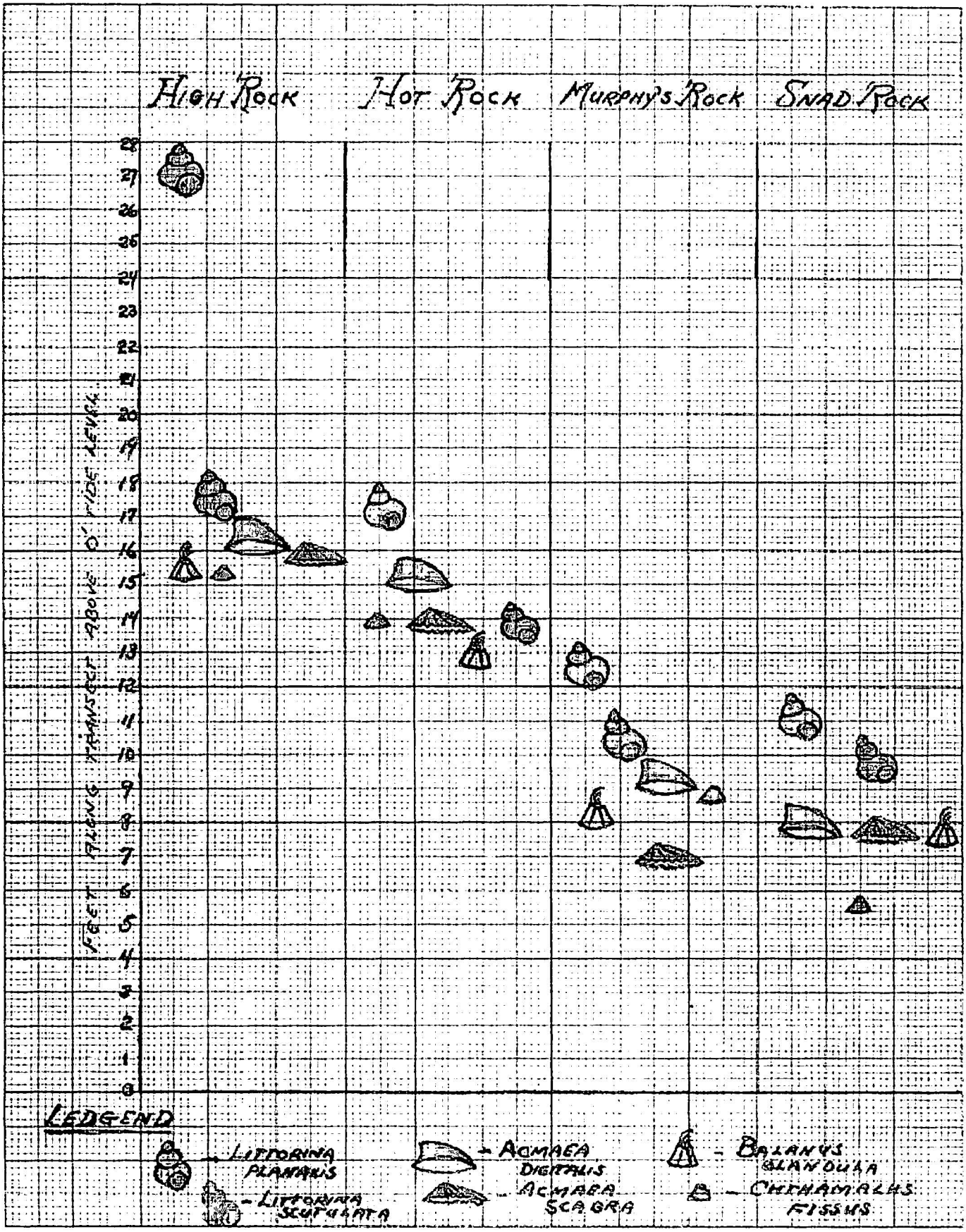
2. The degree of exposure of a plain vertical rock surface to wave action and splash has a definite effect on the distribution of gastropods and cirripeds in Zones 1 and upper 2 in the rocky intertidal area.

3. The amplitude or height of the vertical distribution belts for the species concerned varies directly with the degree of exposure to wave action and splash. Conversely, the greater the protection from waves and splash, the more these distribution belts are compressed, even to the point of disappearance.

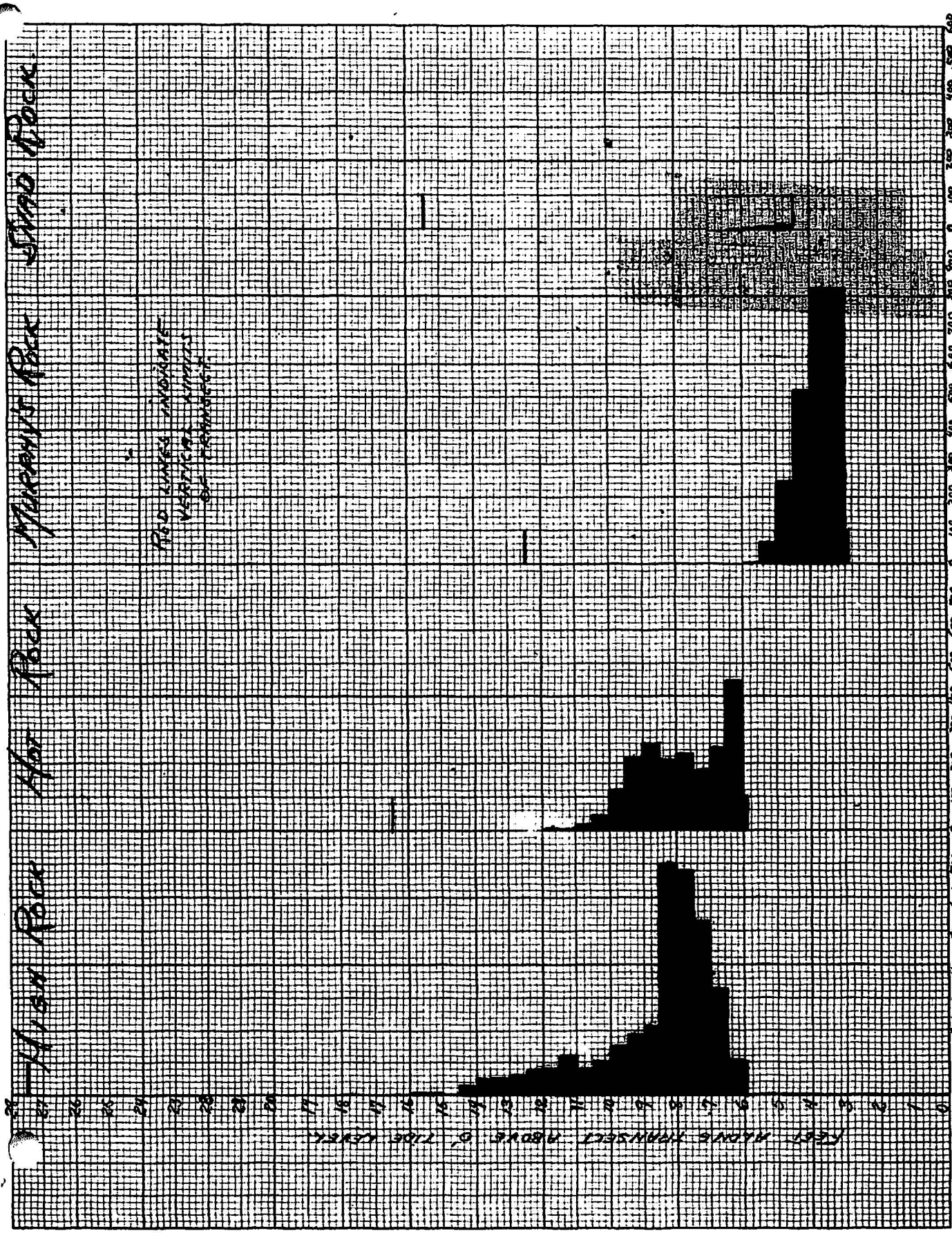
4. In the cases of Acmaea digitalis, A. scabra, and Littorina scutulata, there is a positive correlation between degree of exposure and the numbers of individuals present per unit area.

5. Although counts on High and Hot Rocks did not extend low enough to prove the point, there is a suggestion in the data that Balanus glandula flourishes equally well in both exposed and protected areas, whereas Chthamalus fissus does better in quiet waters.

Position of Highest Specimen of Each Species on the Rocks Studied

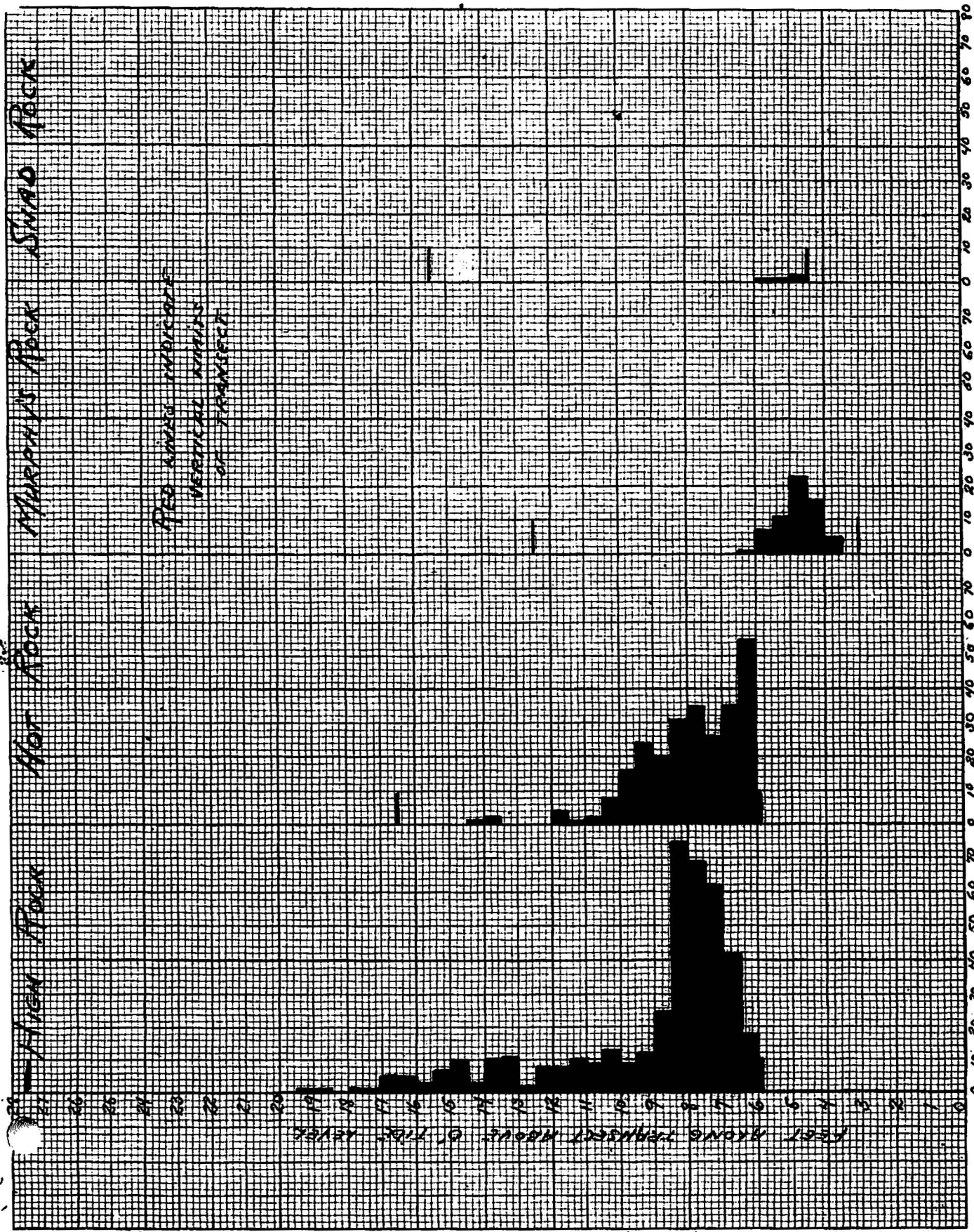


BALANUS GLANDULA



UNIVERSAL CROSS SECTION PAPER

ACMAEA DIGITALIS



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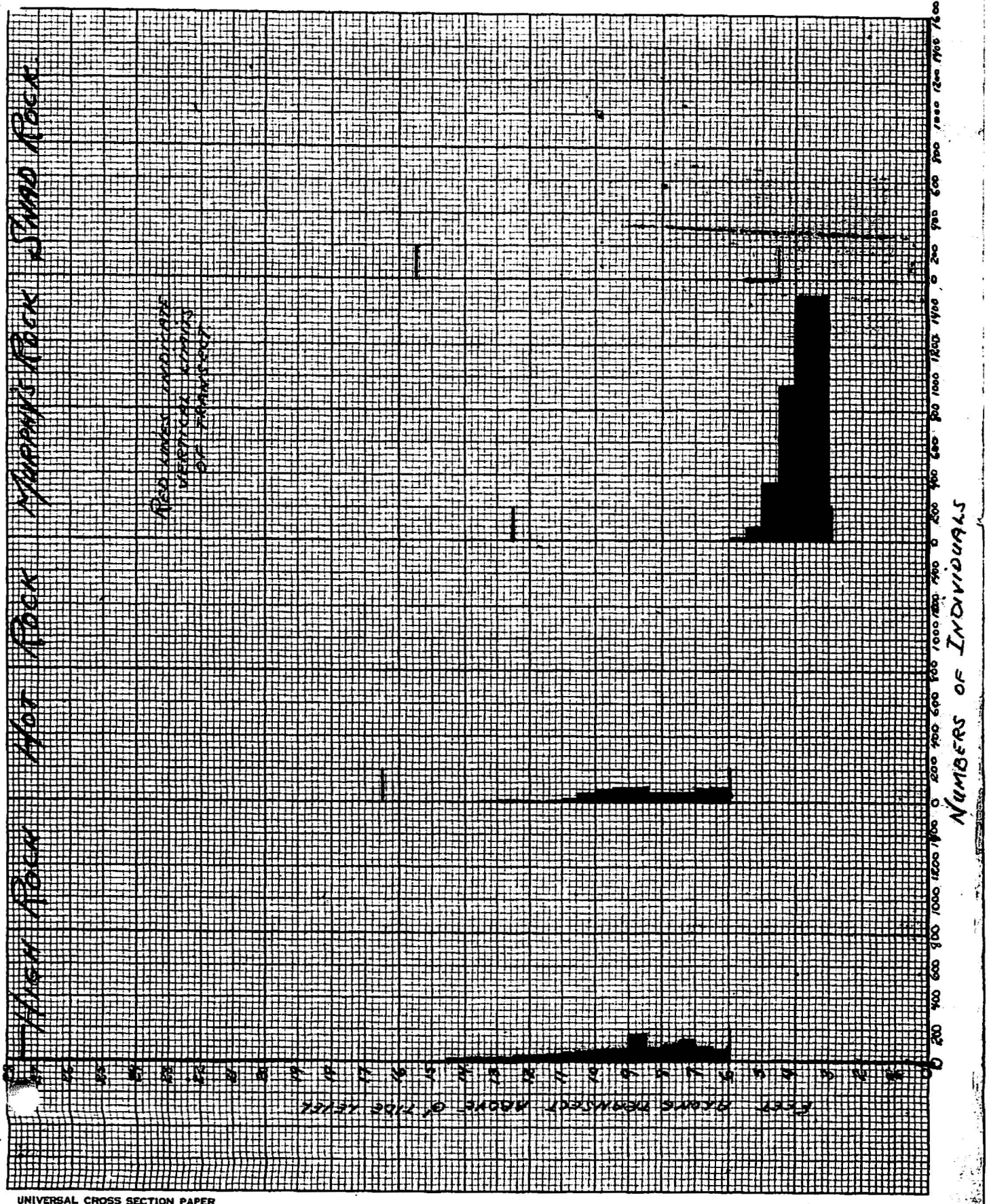
CHTHAMALUS FISSUS



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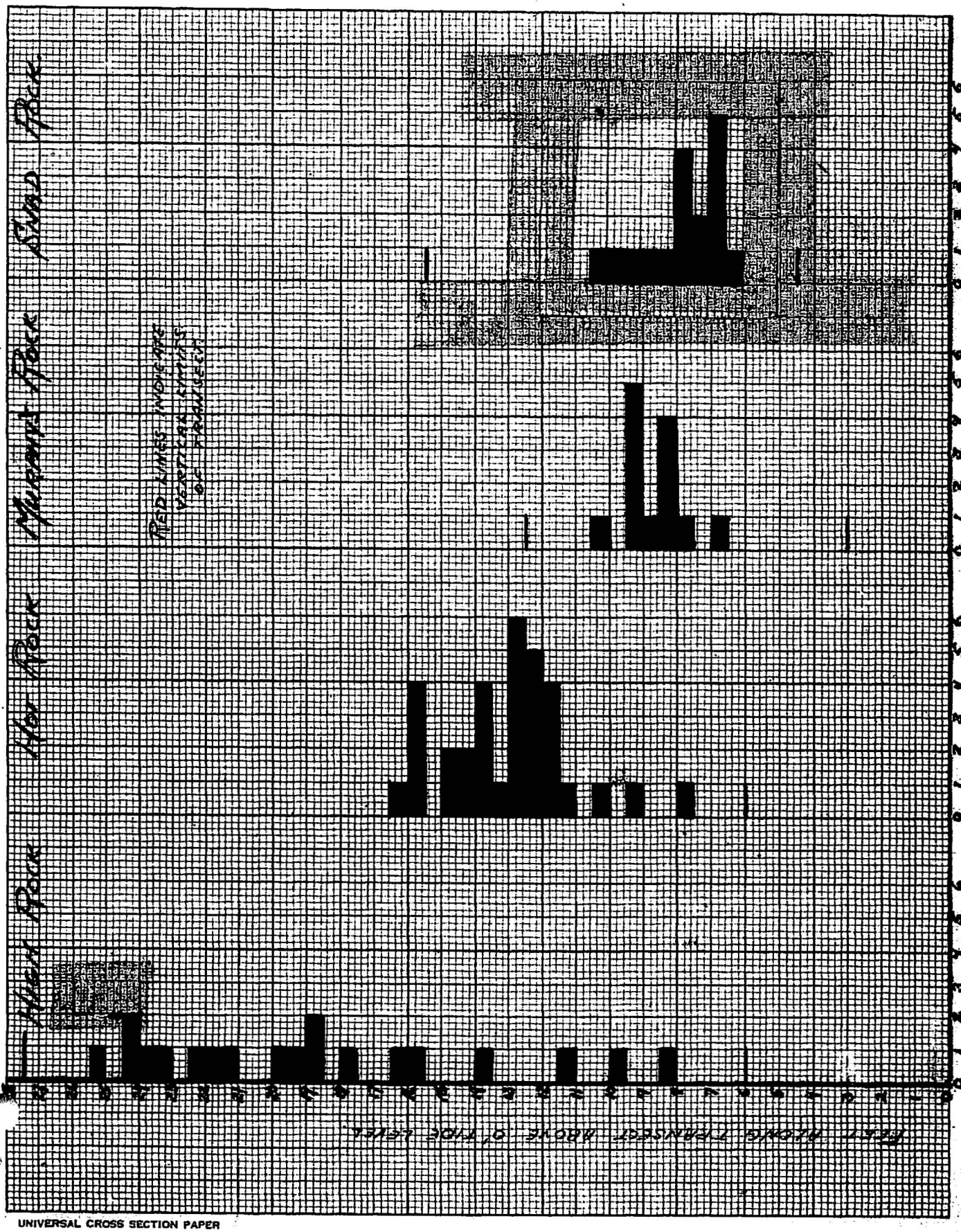
Littorina planaxis



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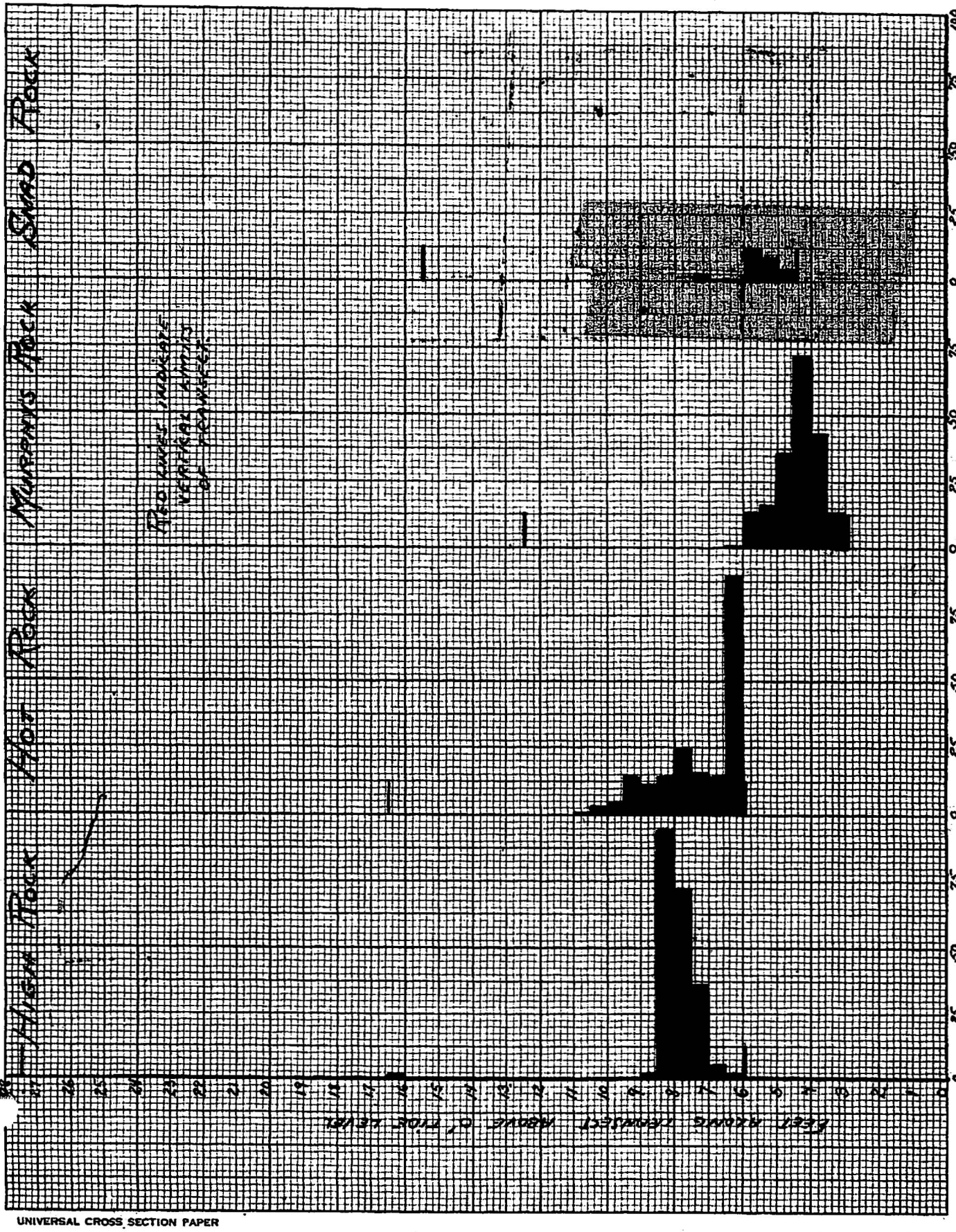
LITTORINA SCUTULATA



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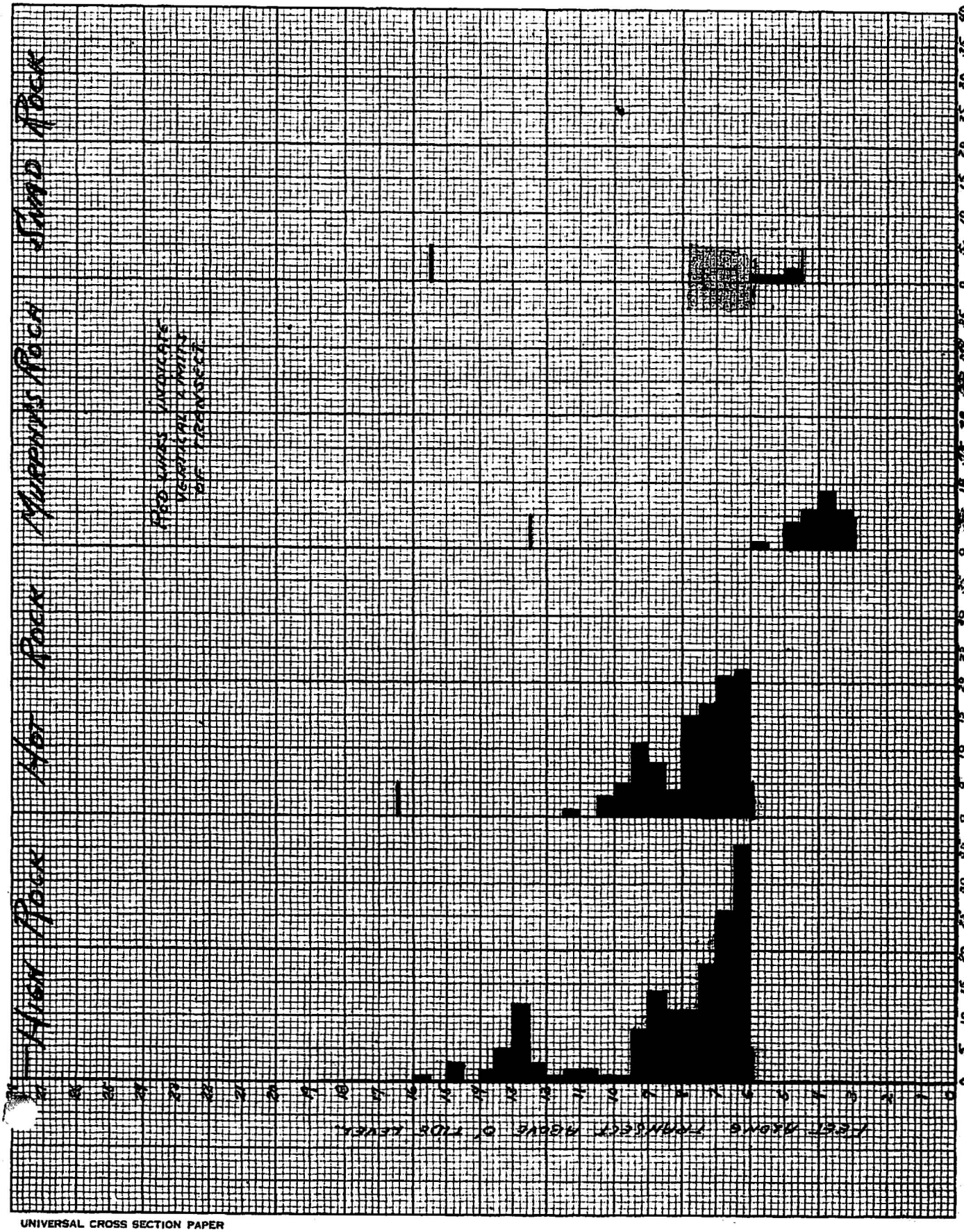
ACMAEA SCABRA



UNIVERSAL CROSS SECTION PAPER

APPENDIX

TABLES 1-4

TABLE 1

HIGH ROCK

Sq. No.	L. planaxis	L. scutulata	A. digitalis	A. scabra	C. fissus	B. glandula
1	2	0	0	0	0	0
2	0	0	0	0	0	0
3	2	0	0	0	0	0
4	1	0	0	0	0	0
5	2	0	0	0	0	0
6	0	0	0	0	0	0
7	1	0	0	0	0	0
8	1	0	0	0	0	0
9	1	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	1	0	0	0	0	0
13	1	0	1	0	0	0
14	2	0	1	0	0	0
15	0	0	0	0	0	0
16	1	0	1	0	0	0
17	0	0	1	0	0	0
18	0	0	5	0	0	0
19	1	1	5	0	0	0
20	1	0	3	1	0	1
21	0	0	7	0	0	1
22	0	0	10	3	0	0
23	0	0	3	0	11	27
24	1	0	10	2	19	44
25	0	0	11	5	13	46
26	0	0	2	12	20	61
27	0	0	8	3	28	77
28	0	0	8	1	28	81
29	1	0	10	2	43	119
30	0	0	9	2	49	81
31	0	0	12	1	57	103
32	1	0	9	1	68	148
33	0	0	12	8	76	189
34	0	2	25	14	169	214
35	0	94	75	11	83	696
36	0	72	69	11	109	679
37	0	36	62	18	136	535
38	0	6	42	26	85	331
39	0	2	18	36	72	106

The bottom of square 39 is 6 feet above 0 feet tide level.

Square 39 contained 13 *Mytilus californianus*.

TABLE 2

HOT ROCK

Sq. No.	L. planaxis	L. scutulata	A. digitalis	A. scabra	C. fissus	B. glandula
1	1	0	0	0	0	0
2	4	0	0	0	0	0
3	0	0	0	0	0	0
4	2	0	0	0	0	0
5	2	0	1	0	0	0
6	4	0	2	0	0	0
7	1	0	0	0	1	0
8	6	0	0	0	1	0
9	5	0	0	0	2	0
10	4	0	4	0	4	4
11	1	0	1	1	2	5
12	0	1	2	0	9	18
13	1	3	8	3	44	46
14	0	4	16	5	73	122
15	1	16	24	11	91	223
16	0	11	20	8	92	258
17	0	14	31	4	61	211
18	1	24	35	15	62	231
19	0	16	26	17	63	178
20	0	14	35	21	78	248
21	0	89	55	22	82	452

Bottom of square 21 is 6 feet above 0 feet tide level.

Many very small littorines not counted between squares 10-14 inclusive.

TABLE 3

MURPHY'S ROCK

Sq. No.	L. planaxis	L. scutulata	A. digitalis	A. scabra	A. pelta	C. fissus	B. glandula
1	1	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	5	0	0	0	0	0	0
4	1	0	0	0	0	0	0
5	4	0	0	0	0	0	0
6	1	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0
9	0	1	1	0	0	0	0
10	0	13	7	1	0	22	1
11	0	16	11	0	0	87	64
12	0	36	23	4	0	351	245
13	0	72	16	6	0	961	519
14	0	43	5	9	3	1500plus	818
15	0	13	0	6	0	See note	

2 feet of rock surface extending 2 feet above square 1 contained 1 L. planaxis.

Square 14 contained 2 Tetraclita squamosa rubescens.

Square 15 contained 14 T. s. rubescens.

The barnacle count for square 15 was estimated to be approximately the same as for square 14.

The bottom of square 15 is 3 feet above 0 feet tide level.

TABLE 4.

SNAD ROCK

Sq. No.	*L. planaxis*	*L. scutulata*	*A. digitalis*	*A. scabra*	*C. fissus*	*B. glandula*
1	1	0	0	0	0	0
2	1	0	0	0	0	0
3	1	0	0	0	0	0
4	1	0	0	0	0	0
5	1	0	0	0	0	0
6	4	0	0	0	0	0
7	2	2	0	0	0	0
8	5	1	0	0	0	0
9	1	1	0	1	0	0
10	See note					
11	0	12	1	1	0	9
12	0	9	1	1	7	13
13	0	4	2	2	9	17

Square 10, which was taken at the same level as square 9, contained 2 *L. planaxis*, 10 *L. scutulata*, and 1 *B. glandula*.

The 5 feet of rock surface above square 1 contained no organisms.

Square 13 contained 2 limpets identified as *A. digitalis* x *A. pelta*.

The bottom of square 13 is 4.5 feet above 0 feet tide level.