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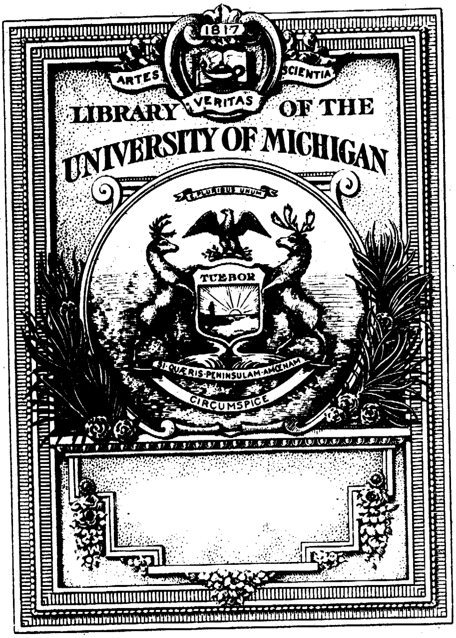
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UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

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UNIVERSITY OF IOWA
1921

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FIRST SERIES No. 35 SEPTEMBER, 1920

UNIVERSITY OF IOWA STUDIES

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VOLUME IX NUMBER 1

A LIMNOLOGICAL RECONNAISSANCE OF WEST OKOBOJI

by

E. A. BIRGE and CHANCEY JUDAY

PUBLISHED BY THE UNIVERSITY, IOWA CITY

Issued monthly throughout the year. Entered at the post office at Iowa City, Iowa, as second class matter. Acceptance for mailing at special rates of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

PROFESSOR CHARLES CLEVELAND NUTTING, M. A., Editor

Continuation of Bulletin from the Laboratories of Natural History of the State University of Iowa

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A LIMNOLOGICAL RECONNAISSANCE OF WEST OKOBOJI

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I—SITUATION, AREA, VOLUME

Lake Okoboji lies in Dickinson county close to the northern boundary of Iowa; it is situated in T. 99 N; R. 36 and 37 W. Its approximate position is lat. 43.35° N; long. 95.13° W. The region adjacent to the lake is thickly studded with other lakes and lakelets. Two lakes of considerable size—East Okoboji and Spirit lakes—are connected with it. Besides these there are ten or more bodies of water, which are large enough to bear names, and smaller ponds and pondlets by the score. None of these bodies of water, except Okoboji lake, has any considerable depth. East Okoboji lake reaches a maximum depth of about 8 m. (26 ft.), but most of its area is less than 3 m. (10 ft.) deep. Spirit lake has a maximum depth of 7.6 m. (25 ft.), but much of the area is between 6 m. and 7.5 m (20 ft., 25 ft.) deep. Okoboji lake has a maximum depth of more than 40 m. (132 ft.)[1] and therefore differs widely from its two neighbors both in physical and biological characters.

The following paper records the results of a limnological reconnaissance of the lake, July 28-August 2, 1919. The reconnaissance was made as part of the coöperative work done by the United States Bureau of Fisheries in connection with the Wisconsin Geological and Natural History Survey. The present report is issued with the permission of the Bureau. The study was carried on at the Iowa Lakeside Laboratory, to which the authors are indebted for much help and many courtesies.

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[1] Dr. Tilton ('16 p. 96) reports a depth of 135 feet. But as nothing is said regarding the calibration of his line, the maximum may still better stand at that found by the regular survey.

The region about lake Okoboji and the lake itself was surveyed by the civil engineering department of Iowa State College through its summer surveying camp. The camp was held there from 1905 to 1912, and the topography of the region and the hydrography of the larger lakes were surveyed. In 1913 a pamphlet was published by the College (Ford '13) giving the methods employed, together with maps showing the results. Among the maps are a topographical map of the region on a scale of 1 in. to 5100 ft., and a map giving the soundings in Okoboji lake on a scale of 1 in. to 2500 ft. The College also kindly furnished us with a blue print map of the lake, scale 1 in. to 1000 ft., which was used in all measurements. This map was reproduced in the Iowa report on lakes and lake beds on a scale of about 1 in. to 2030 ft. In this report about one page of description is given to the lake and its area is stated as 3788 acres (Iowa '16, p. 56, map No. 18)* The area thus given is accepted in this paper.

The small scale map of the lake gives all of the soundings, numbering 732, or about 48 per sq. km. The large scale map gives a selection of these, numbering 261. The soundings were taken from a motor boat which was kept constantly in motion. Its position at the moment of sounding was signalled to two observers on shore who kept the boat constantly in sight with transits. By this method the position of the boat could hardly have been determined with minute accuracy, especially in the deeper water, and the maps give no dot or other similar indication of the precise position of the soundings. It is known that the small area which contains the deepest soundings lies somewhat to the west of the place indicated on the map. Under these conditions no attempt was made to plat the soundings omitted on the large scale map. In drawing the contours for the hydrography a 20-foot interval was used, since there are not enough soundings along the shores to warrant the use of a 10-foot interval.

The areas included in the several contours were measured with the planimeter, with the following result:

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* Note: Appended to this article as Plate I.

TABLE 1—AREA OF OKOBOJI LAKE—ACRES
(From map, scale 1 m.=1,000 ft.)

Area at surface	3788 acres
" " 20 feet	2750 "
" " 40 "	1629 "
" " 60 "	973 "
" " 80 "	326 "
" " 100 "	114 "
" " 120 "	9 "
" " 132 "	0 "

Note: The surface area is taken from the report of the state highway commission, 1916, p. 56.

The contour map and the measurements show that the main slope of the bottom of the lake is fairly uniform to the depth of 80 ft., but that below this depth the slopes are decidedly steeper. In fact, the form of the basin is such as to lead the observer to expect a maximum depth of about 90 ft. or 100 ft. Instead of this, however, a small area extends to a depth of 132 ft., or 30 ft. to 40 ft. more than would be expected.

From the data thus secured a hypsographic curve of the lake was platted and from this were derived the areas corresponding to 5 m., 10 m., etc. From these data there were computed the area, volumes, etc., of the lake in metric units, as shown in the following table. The same data computed in cubic yards, etc., directly from the areas of the 20-ft. levels give substantially the same results.

TABLE 2—OKOBOJI LAKE—GENERAL FEATURES

Length, 8.79 km; 5.46 mi.
Greatest breadth, 4.57 km; 2.84 mi.
Direction of main axis, north and south.
Area, 1535 ha; 3788 a.
Greatest depth, 40.2 m; 132 ft.
Mean depth, 12.3 m; 40.4 ft.
Volume, 188,340,000 cu. m; 246,340,000 cu. yds.
Length of shore line, 29.3 km; 18.2 mi.
Shore development, 2.13.
Volume development, 0.92.
Mean slope of bottom, 1°34′; 2.74%.

NOTES: The mean depth is found by dividing the volume by the area of the surface. The volume of the several strata are computed from the formula $\left(A+B+\sqrt{AB}\right)\frac{H}{3}$, in which A is the area of the upper surface of the stratum, B is the area of the lower surface and H the vertical distance between the surfaces—in this case 5 meters.

By shore development is meant the ratio of the periphery of the water to the circumference of a circle of equal area.

The mean slope is computed from the formula

$$S=\left\{\frac{\tfrac{1}{2}I_0+I_1+I_2+I_3\ .\ .\ .\ .\ .\ \ +I_{n-1}\ +\tfrac{1}{2}I_n}{n}\right\}\frac{H}{A}$$

In this formula S=mean slope; I_0, I_1, etc.=length of contour lines from surface to bottom; n=number of such contours; H=maximum depth; A=area of the lake. (See Juday '14, p. 123).

TABLE 3—DETAILS OF OKOBOJI LAKE

	Area			Area between contours	Volume	
Depth meters	Ha.	Per cent of total	Stratum meters	Ha.	Cubic meters	Per cent of total
0	1535	100.0	0-5	330	68,310,000	36.3
5	1205	78.5	5-10	402	49,900,000	26.5
10	803	52.3	10-15	274	33,100,000	17.6
15	529	34.5	15-20	214	20,880,000	11.1
20	315	20.5	20-25	198	10,360,000	5.5
25	117	7.60	25-30	67	4,020,000	2.1
30	49.9	3.25	30-35	35.3	1,520,000	0.8
35	14.6	0.95	35-40.2	14.6	250,000	0.1
40	0	0			188,370,000	

The volume development is the ratio of the volume of a lake to that of a cone of equal base and height. If the lake were a tank with vertical sides the volume development would be three. Since in this case the volume development is less than 1.00, the volume of the lake is smaller than that of a cone of equal base and altitude.

This condition is rarely found in lakes, especially in lakes of considerable depth, and it constitutes the main peculiarity of the basin of lake Okoboji. In most lakes there is a steep slope on the sides below the level to which the work of the waves extends and a nearly flat bottom. In such a lake the volume exceeds that of the cone with which it may be compared. In order that this condition may be better appreciated a comparison is made between Okoboji lake and lake Geneva, Wisconsin—a lake of somewhat larger area but not much exceeding Okoboji in depth. The area of lake Geneva is 2210 ha.; its maximum depth is 43.3 meters; its mean depth is 19.7 m; and its volume development 1.41. The instructive comparisons are those of percentage of volume and area at certain depths.

TABLE 4—COMPARISON OF OKOBOJI AND GENEVA LAKES.
See Fig. 1.

Depth, meters	Area at depth; per cent		Volume below depth; per cent	
	Okoboji	Geneva	Okoboji	Geneva
0	100.0	100.0	100.0	100.0
5	78.5	80.0	64.7	77.1
10	52.3	68.5	37.9	58.3
15	34.5	61.0	20.1	41.8
20	20.5	50.7	8.9	27.6
25	7.6	39.0	3.1	16.2
30	3.25	29.3	0.9	7.6
35	0.95	14.1	0.1	2.2
40	0.00	2.7	0.0	0.2
43.3		0.0		

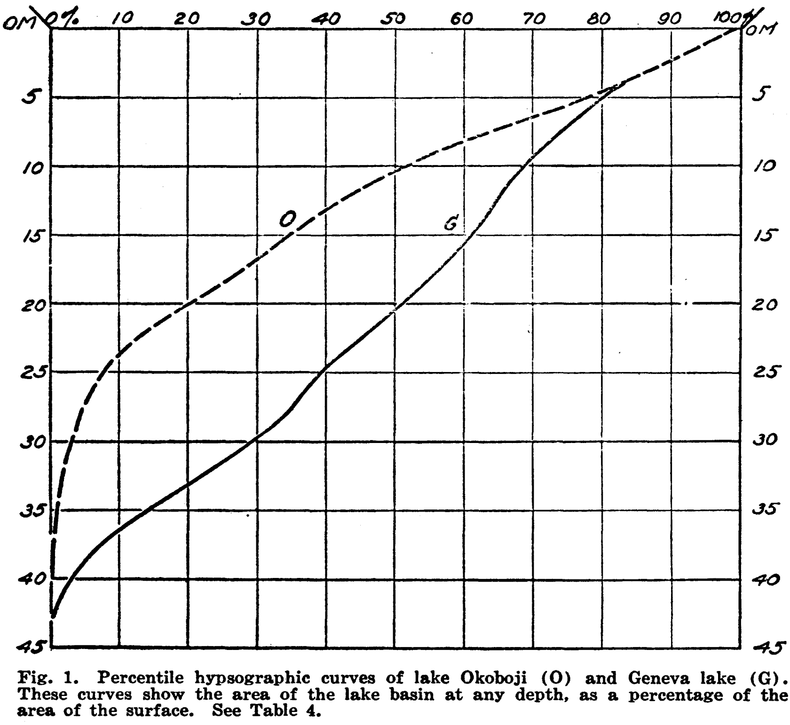

Fig. 1. Percentile hypsographic curves of lake Okoboji (O) and Geneva lake (G). These curves show the area of the lake basin at any depth, as a percentage of the area of the surface. See Table 4.

The difference between the lakes is striking. The area of the basin of Okoboji lake is reduced to one-half that of the surface just below 10 meters; in Geneva lake the same reduction is found below 20 meters, and this in spite of the fact that the areas of the two lakes at 5 meters are an almost equal per cent of the surface. Half of the volume of Okoboji lake is found above the depth of about 7.5 m., while the same volume lies at the depth of 12.5 m. in lake Geneva. Seventy-five per cent of the volume of lake Okoboji lies above the level of 13.8 m., while in lake Geneva the same level lies about 7 m. deeper, at 21 m.

The small volume of the deeper water in Okoboji lake has an important bearing on the temperature of the lower water, and so on the mean temperature and on the quantity of heat absorbed by the lake during the open season.

In computing the quantity of heat taken in by the lake, it is necessary to know one more physical constant, viz., the *reduced thickness* of the strata, or the thickness of any given stratum of water if its area is made equal to that of the surface. The mean depth is the reduced thickness of the entire lake, *i. e.*, it is equal to the depth of a vertical sided tank necessary to hold all the water of the lake, if its area is equal to that of the lake's surface. It is convenient for various purposes of computation to select strata as thin as one meter, especially near the surface and in the thermocline. The volume of such thin strata cannot be computed accurately from the soundings, nor is such accuracy needful. The percentile areas at 0 m., 5 m., etc., are platted on coördinate paper and connected by a smooth curve. Then the percentages indicated at the middle of each meter of depth will give the reduced thickness of that stratum in centimeters. From the same curve the reduced thickness of any other stratum can also be derived.

TABLE 5—REDUCED THICKNESS OF THE SEVERAL STRATA OF OKOBOJI LAKE STATED TO THE NEAREST CENTIMETER

Depth m.	RT. cm.		Depth m.	RT. cm.
0-1	98		20-25	67
1-2	94		25-30	26
2-3	89		30-35	10
3-4	84		35-40.2	1.6
4-5	80	445		
5-6	75			
6-7	70			
7-8	65			
8-9	60			
9-10	55	325		
10-11	51			
11-12	46			
12-13	43			
13-14	40			
14-15	37	217		
15-16	33			
16-17	30			
17-18	27			
18-19	24			
19-20	21	135		

In order to appreciate more fully the peculiarities of the basin of lake Okoboji, the reduced thickness of its several strata may be compared with those of lake Geneva, Wis.

TABLE 6—REDUCED THICKNESS OF THE SEVERAL 5 m. STRATA OF LAKE OKOBOJI AND LAKE GENEVA, STATED IN CENTIMETERS

Depth m.	Okoboji	Geneva
0-5	445	451
5-10	325	370
10-15	217	325
15-20	135	280
20-25	67	225
25-30	26	170
30-35	10	106
35-bottom	1.6 (40.2 m.)	43 (43.3 m.)
Total	12.266	19.70

It will be seen that the upper 5 m., of the two lakes have nearly the same reduced thickness and therefore an equal relative volume; but that the relative volume of the lower strata is much greater in lake Geneva. The 15-20 m. stratum of Geneva has a relative thickness more than twice as great as that of Okoboji; the 20-25 m. stratum is more than three times as thick; the thickness of the 25-30 m. stratum is five times, and that of the 30-35 m. stratum ten times as great as are the corresponding figures for Okoboji. The effect of this difference on temperatures is that the lower water of Okoboji lake has a higher temperature and a less quantity of heat than would be the case in the lake basin of ordinary form.

II—TEMPERATURES

TABLE 7—TEMPERATURE OBSERVATIONS ON OKOBOJI LAKE, 1919

Depth, meters	I vii 29 4.00 p	II vii 30 8.45 a	III vii 31 10.45
0	25.0	24.7	24.6
1	—	—	—
2	—	—	—
3	—	—	—
4	—	—	—
5	24.0	24.4	24.6
6	—	—	—
7	—	—	—
8	—	—	—
9	—	—	24.2
10	23.7	23.1	23.8
11	23.2	22.3	—
12	20.4	21.0	18.0
13	18.2	16.6	—
14	15.6	15.6	—
15	14.1	14.7	14.8
16	—	13.8	—
17	—	—	—
18	—	12.9	—
19	—	—	—
20	12.5	12.1	12.1
25	—	11.2*	11.2
30	—	—	11.0
34	—	—	10.8

* 23.5 m.

Series No. 1 was taken in the mouth of Miller's Bay.
Series No. II near the deepest water, which could not be placed on that day.
Series No. III in deepest water found.

In the evening of July 29 the hot weather was broken by squalls with rain and the wind shifted to the north, returning to south on July 30 and 31. The weather continued cool and the surface temperature fell, while that at 5 m. and 10 m. rose. The computations are based on the observations of

July 30, supplemented by those of July 31 for depths below 20 m.

TABLE 8—TEMPERATURE OF OKOBOJI LAKE, JULY 30, 1919

Depth, meters	Temperature
0-5	24.6°
5-10	23.9°
10-15	18.8°
15-20	13.1°
20-25	11.6°
25-30	11.1°
30-35	10.9°
35-40.2	10.8°
Mean	21.00°

From the observations in table 7, a temperature curve may be platted, as shown in Fig. 2; and from such a curve the mean temperature of each one-meter stratum may easily be derived. The figure shows a normal curve, with a strongly marked thermocline, beginning at 11 m., and ending at 15 m. There was a fall of 4.4° between 12 m., and 13 m., and only 1.9° between 13 m., and 15 m. The total fall between 11 m. and 15 m. is 7.6°. In the observation on the 29th there was a decline of 9.1° in the same distance. Such variations are of constant occurrence in a lake; and if the thermocline of lake Okoboji is defined as the zone within which the temperature falls as much as 1.0° per meter, it will be found to vary from 4 m. to 6 m. in thickness. The irregularity shown at 14 m. to 16 m., on the 30th should not influence us to limit the zone to 3 m. or extend it to 5 m. for this occasion.

The mean temperature in table 8 is computed as follows: The mean temperature of the several 5 m. strata is multiplied by the per cent of volume of that stratum, as shown in table 3. The sum of these products gives the mean temperature of the lake as 20.996°, or, as stated, about 21.0°. This is an exceptionally high mean temperature for a lake of the area and depth of Okoboji. It is due to the high temperature and small volume of the lower water; and the first of these causes is itself largely due to the second.

We may state therefore that the mid-summer temperature of Okoboji lake in 1919 was close to 21° C.

Quantity of Heat. From the data thus stated it is possible to compute the quantity of heat represented by this rise of temperature to 21°. If this gain is to be stated there must be a starting point from which the gain may be computed. This obviously is not zero, as no lake has so low a temperature. As stated in another paper (Birge '15, p. 170), there are two methods of stating the gains of heat. One is the *annual heat budget,* which takes as its starting point the mean temperature of the water immediately after the time of freezing, or, less accurately, at any time during the ice-period. The other is the *summer heat-income,* which starts from the temperature of 4°C.—that of the maximum density of water. For reasons stated in the paper referred to, the conclusions to be drawn from either of these methods are much the same. In all cases the gains between the winter temperature and 4° must be discussed apart from those above 4°. In the case of Okoboji lake we are limited to the summer heat-income, since the winter temperatures are still unknown. The gains of heat are stated in gram calories per square centimeter of the surface of the lake. A rise of 1° in a stratum 100 cm. thick represents a gain of 100 cal. per sq. cm. of surface.

The formula for computing the summer heat-income is $(T-4) \cdot RT$; in which T is the mean temperature of any stratum and RT the reduced thickness of the stratum stated in centimeters. If the lake is considered as a unit, RT is the mean depth. In this case the mean temperature is 21.0° and the mean depth 12.3 m., or more exactly 1227 cm. The summer heat-income is therefore $(21-4) \cdot 1227=20849$ cal., or approximately 21,000 cal. per square centimeter of the surface.

The value of the summer heat-income will vary slightly with the stratum used in the computation. If the computation is made by 5 m. strata the result is the same as that from the mean temperature, as the following table shows:

TABLE 9—SUMMER HEAT-INCOME, OKOBOJI LAKE

Depth, meters	T-4	RT cm.	Calories	Percent
0-5	20.6	445	9167	44.0
5-10	19.9	325	6468	31.0
10-15	14.8	217	3242	15.4
15-20	9.1	135	1228	5.9
20-25	7.6	67	509	2.4
25-30	7.1	26	185	0.9
30-35	6.9	10	69	0.3
35-40	6.8	1.6	11	0.1
			20849	100.0

This result, as well as that of the preceding table, gives the number of calories in a volume of water whose base is 1 sq. cm., and whose total height is equal to the mean depth of the lake.

If the computation is made by single meters in the upper water, the result is somewhat larger, as the following table of the upper 20 meters shows:

TABLE 10—SUMMER HEAT-INCOME BY SINGLE METERS
0 m.-20 m.

Depth meter	T-4	RT cm.	Calories	
0-1	20.7	98	2029	
1-2	20.7	94	1946	
2-3	20.6	89	1833	
3-4	20.5	84	1722	
4-5	20.4	80	1632	9162
5-6	20.3	75	1522	
6-7	20.2	70	1414	
7-8	20.0	65	1300	
8-9	19.6	60	1176	
9-10	19.2	55	1056	6468
10-11	18.7	51	954	
11-12	17.6	46	810	
12-13	14.8	43	636	
13-14	12.0	40	480	
14-15	11.0	37	407	3287
15-16	10.2	33	337	
16-17	9.4	30	282	
17-18	9.0	27	243	
18-19	8.6	24	206	
19-20	8.3	21	174	1242

In table 10 the calories in the 10 m.-15 m. stratum and in the 15 m.-20 m. stratum are greater when computed by single meters than when the mean of the five temperatures

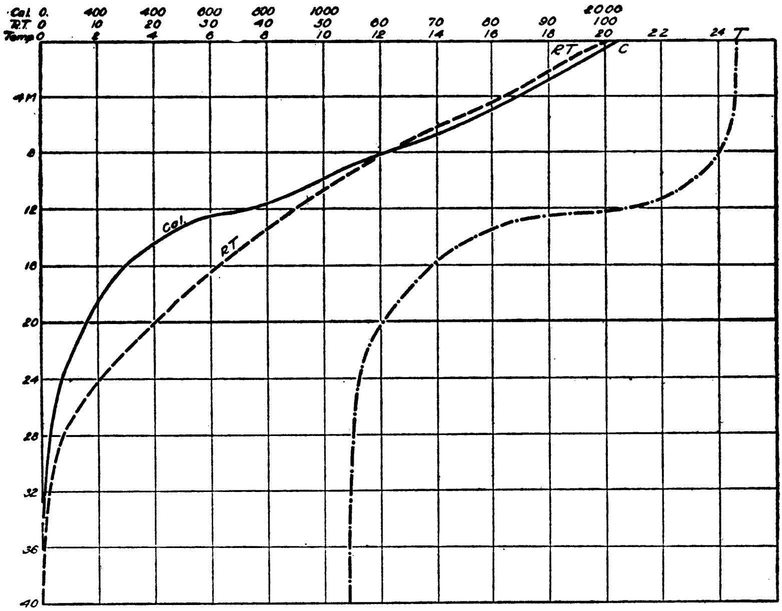

Fig. 2. Temperature, summer heat-income, and reduced thickness of Okoboji lake. The curve *RT* gives at any point the reduced thickness in centimeters (p. 8) of a stratum one meter thick whose center is at that point. The curve *cal.* gives the summer heat-income per meter of depth corresponding to the temperature curve. It is given in calories per square centimeter of the surface. It is derived from the two other curves by the formula (T-4) : RT. See p. 12.

is multiplied by the sum of the five RT's. The reason is obvious: The temperatures in the upper part of the stratum are above the mean and are multiplied by the larger numbers representing the reduced thickness. The temperatures in the lower part of the stratum, which are as much below the mean as the others are above it, are multiplied by the smaller RT. The result is to make the sum of the calories greater in the 10 m.-15 m. stratum by as much as 75; in the others the difference is small since the change of temperature is not so great. The larger amount is the more accurate, since it gives proper weight to smaller units of thickness, but in general the difference is not worth noting. In each case the summer heat-income of Okoboji lake would be stated as about 21,000 cal. in 1919. The more accurate total is convenient to use in discussing the distribution of heat. Employing single meters to 20 m. and 5 m. intervals below that depth, it is 20,933 cal.

The Distribution of Heat. Each square centimeter of the surface of lake Okoboji absorbs 20,933 cal. out of the heat delivered to it by the sun after the water has reached 4°; and this heat is distributed through the water of the lake in a manner shown by the temperature curve in Fig 2. The length of the warming period is not known from observation, but probably this lake, like lake Mendota, reaches the temperature of 4° about April 15 and continues to gain heat in the average year until August 15, although very little is gained after August 1. The sun should deliver about as much heat at Okoboji as at lake Mendota, since their latitude is practically the same and Okoboji is about 5.8° farther west. We may therefore assume that Okoboji lake, like Mendota, receives about 60,000 cal. per sq. cm. of surface during the period when the summer heat-income is gained, or about 54,000 cal. to August 1. If the lake, therefore, gains about 21,000 cal., it lays up about one-third of its total receipts of heat and about 40% of its receipts to August 1. The remainder is partly reflected; it is partly used in evaporation, and much of it is returned to the air during the night and whenever the temperature of the air falls.

It is possible to follow the distribution of the heat received by the surface through the water of the lake, as is shown by the following table:

TABLE 11—DISTRIBUTION IN DEPTH OF SUMMER HEAT-INCOME STATED IN CALORIES PER SQUARE CENTIMETER OF THE SURFACE OF THE LAKE

Depth meters	Calories
0	20933
1	18904
2	16958
3	15125
4	13403
5	11771
6	10249
7	8835
8	7535
9	6359
10	5303
11	4349
12	3539
13	2903
14	2423
15	2016
16	1679
17	1397
18	1154
19	948
20	774
25	265
30	80
35	11
40.2	0

It must be noted that this table and the account of the heat exchanges of the lake in general take no account of the heat which passes through the water and goes into the mud of the lake. It is obvious, for example, that if the bottom water at the deepest part of the lake stands at a temperature above 10° for months, no small quantity of heat must pass through it into the mud; and this heat must ultimately be supplied from the surface. At less depths the passage of heat into the bottom mud or sand must be even more rapid since the temperature of the water is higher. The number of 21,000 cal. does not represent the total heat which passes through the water of the lake, but that which remains in the water. Nothing is known about the mud temperature of Okoboji lake, or indeed of any lake, except Mendota; and information is far from complete regarding that. Perhaps 10% is a fair estimate of the addition which should be made if the heat of the mud is to be accounted for. This statement is not made with any idea of making further use of so rough an estimate, but that the table may not seem to imply that no heat whatever passes the 40.2 m. level.

For certain purposes it is necessary to state the amount of heat at each level in terms of the area at the depth in question rather than in those of the surface. The number of calories, for instance, passing through each square centimeter of the lake at the depth of 10 m. is equal to the number of calories given in table 11 divided by the per cent of the surface area which is found at 10 m., as is shown in table 3. The following table gives the result:

TABLE 12—CALORIES PER SQUARE CENTIMETER AT CERTAIN DEPTHS STATED IN TERMS
A-of the surface of the lake
B-of the area at the depth in question

Depth	Area %	Cal. A.	Cal. B.
0	100.0	20933	20933
5	78.5	11771	15000
10	52.3	5303	10140
15	34.5	2016	5840
20	20.5	774	3780
25	7.60	265	3490
30	3.25	80	2460
35	0.95	11	1160

From tables 11 and 12 it appears that nearly one-half of the heat-income remains in the upper five meters of the lake; that more than half of the remainder is left between 5 m. and 10 m.; that more than 90% is found above 15 m.; and that little more than 1% of the income is delivered into the water which lies below 25 m.

On the other hand, table 12, B shows that there is a very considerable amount of heat delivered to each square centimeter of the several 5 m. planes of the lake. At the depth of 30 m., for instance, there are found only 80 cal. per sq. cm., out of the 21,000 cal. which passed each sq. cm. of the surface. But through each sq. cm. of the 30 m. plane there passed 2460 cal.

If that part of the lake below 30 m. be considered as a lake by itself, its area (table 3) is 49.6 ha.; its volume

1,770,000 cu. m.; its maximum depth 10.2 m.; and its mean depth $\left\{\frac{V}{A}\right\}$ is 357 cm. Its mean temperature is nearly 10.9°, so that T-4 nearly equals 6.9°; and this temperature multiplied by the mean depth equals 2463 cal., or substantially the result shown in table 12 for the heat-income.

The Transportation of Heat. All of the heat accumulated by the lake comes from its surface. Even that which is brought in by ground water enters ordinarily at the surface or very close to it and in a lake so large as Okoboji the contribution of heat from the ground water—which is plus or minus, according to the time of year—is so small as to be negligible. The temperature of the water in the well at the Lakeside Laboratory was 11.3° on July 30.

There are two agents by which the heat of the summer heat-income may be conveyed from the surface to the deeper water of the lake. It may be (a) delivered directly by the sun to the deeper strata of water, since the water is not opaque; or (b) it may be conveyed by the action of the wind, causing waves and currents by which the water warmed at the surface of the lake is carried downward and mingled with the colder water. It will be seen that in a lake of the type of Okoboji the latter method is by far the more important.

It will be well to assume at first that the distribution of heat is wholly due to wind and later to estimate the contribution of the sun to this task.

So long as the temperature of the water is below 4° there is no trouble in conveying the warmed surface water downward, for it becomes heavier as it warms and it consequently sinks. The excess weight is very small and unless aided by wind the downward movement and consequent mixture would be slow. But wind is not lacking in early spring and even a light breeze is efficient in causing mixture of the water if gravity aids it.

But when the temperature of the surface water passes 4° it becomes lighter as it warms and apart from the action of the wind it would remain floating on the colder and therefore heavier water below. The wind causes both waves and currents; the former efficient in mixing the surface strata; the currents piling up the warmer water on the leeward side of the lake, mixing it with the colder water below it and in spring even setting the whole mass of water in the lake into a sort of rotation. Thus the warmer and lighter water is forced downward and mixed with the lower and colder strata and heat is thereby conveyed from the surface into the lake for a greater or less distance. Such an operation clearly involves work against gravitation.

We shall see that direct insolation is confined to the upper water and that it is quite inappreciable below the depth of ten meters. The bottom water therefore, which at thirty-five to forty meters may have the temperature of 10.8°, owes all heat above 4° to the action of the wind. How much work is involved in such warming? The process has not been done at once, but in numerous stages, and the net amount of work may be represented by the amount of energy necessary to push down through water at its maximum density a stratum of water of the smaller density possessed by water at 10.8°. If the density of water at 4° is taken as 1.000,000, that of water at 10.8° is 0.99652; one liter has lost by warming 348 mg. in weight. For each liter therefore of warmed water carried from the surface to the 35 m.-40 m. stratum a weight of 348 mg. must be moved a mean distance of 37.5 meters. If the volume of the stratum is known, the amount of work can easily be computed.

There is, however, a more convenient method of computation. Since the heat is expressed in calories per square centimeter of the surface the work needed to distribute it is best expressed in the same way. Then the volume of a stratum is represented by its reduced thickness stated in centimeters, which is equivalent to the weight in grams of a column of water whose base is a square centimeter and whose height is the reduced thickness of the stratum. The formula for computing the work is

$$RT \cdot Dm \cdot (1.000,000-D)$$

in which RT is the reduced thickness of the stratum stated in centimeters and therefore equal to the weight in grams of a column whose base is one square centimeter. Dm is the distance in centimeters from the surface to the middle of the stratum, and (1.000,000-D) is the loss of weight as a decimal fraction of unity.

In Okoboji lake the values are in the example taken

RT of 35 m.-40m.=1.6 cm. (table 5)
Dm=3750 cm.
(1-D)=0.000,348

The result is 2.088; that is, the transport of the warmed water from the surface to the 35m.-40 m. stratum calls for 2.088 gram-centimeters of work per square centimeter of the lake. In this computation no account is taken of the viscosity of the water as a hindrance to mixture.

In this way the work needed by each stratum may be computed. The value of RT·Dm would be computed once for all for each stratum of the lake likely to be needed; it is called in later tables the *factor* for that stratum. In general we compute it by single meters to 20 m. and by 5 m. intervals below that depth. The value of (1-D) is taken from a table. (See Birge '16, p. 391).

In this way is computed the value of the *direct work* as shown by the following table:

TABLE 13—OKOBOJI LAKE. DIRECT AND DISTRIBUTED WORK, JULY 30, 1919

A Stratum	B Temp.	C Factor	D 1-D	E Gcm.	F	G	H
0-1	24.7	49	2853	13.96		246.41	
1-2	24.7	141	2853	40.18		218.91	
2-3	24.6	222	2827	62.83		192.97	
3-4	24.5	294	2802	82.32		167.60	
4-5	24.4	360	2777	100.04	299.37	145.79	971.68
5-6	24.3	412	2752	113.30		124.50	
6-7	24.2	455	2727	124.22		105.67	
7-8	24.0	488	2677	130.78		86.41	
8-9	23.6	510	2579	131.58		69.91	
9-10	23.2	522	2483	129.46	629.34	53.35	441.84
10-15	18.8	2679	1581		422.90		132.22
15-20	13.1	2332	0611		143.99		38.44
20-25	11.6	1475	0431		63.57		8.41
25-30	11.1	715	0378		27.03		2.78
30-35	10.9	325	0358		11.64		0.96
35-40.2	10.8	60	0348		2.09		0.14
					1599.93		1596.47

Notes: 1. In Col. C, two ciphers 00 are omitted at the right of each number. In Col. D, 0.00 is omitted at the left of each number; the significant figures only being employed in each case.

2. Multiplication is done by Crelle's tables, using three significant figures. The difference in the total of direct and distributed work is due to omitting some of the final figures in multiplying.

3. The direct work in the 10 m.-15 m. and 15 m.-20 m. strata is the sum of the work of the single meters, as is the case in the strata above. It is therefore not exactly the product of the numbers in Cols. C and D.

4. Col. C, *Factor*, gives the product RT · Dm for each stratum. Col. D, 1-D, gives the significant figures showing the loss of density. 1.000,000—D. Col. E gives the amount of work per square centimeter of surface of the lake, necessary to raise the stratum from 4° to the temperature stated by mixture of warm water from the surface.

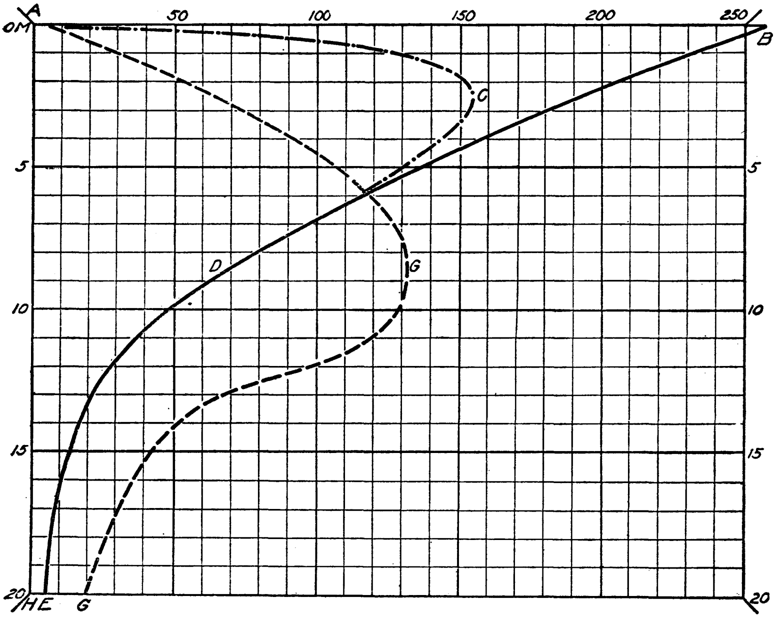

Fig. 3. Curves showing the direct work, the distributed work, and the effect of direct insolation. See pp. 19-26. The curves extend to the depth of 20 meters. The entire area enclosed by the curve of distributed work, ABDEH, is equal to that of the direct work, AGGH. The area, ACDB, gives the direct effect of the sun, and the area, ACDEH, that of the wind.

The table shows that about 1600 g. cm. of work per sq. cm. of surface of the lake were needed to distribute 21,000 cal. per sq. cm. through the water of the lake. The upper and warmer strata of the lake required most of this work. The deeper strata needed very little. The reasons for this are found partly in the small volume of the lower strata, partly in their lower temperature, and partly in the fact that the loss of density per degree is much less at lower temperatures than at higher ones. A full statement of this fact and its results may be found in Birge '10, pp. 989-1004.

Table 13, Col. E shows the work done *in behalf of* each stratum or the work needed to carry the warmed water down from the surface and put it in place. Most of the work therefore is done outside of the stratum which is to be warmed. In the case of the 5 m.-10 m. stratum two-thirds of the 629 g. cm. would be needed to bring the warmed water to the top of the stratum and one-third to distribute it through the stratum. In a similar way each upper stratum has its share of the work for all of those below it. It is possible, by a somewhat tedious computation to ascertain the amount of work done *in* each stratum. The method and details of this computation are shown in Birge '16, p. 354. The results for Okoboji lake are given in table 13, columns G and H, and show the *distributed work.*

It appears that 971 g. cm., or nearly two-thirds of the whole work are done in the upper 5 m. This amount of work is needed to carry to a depth of 5 m. the heat which goes to the strata below 5 m., and to distribute through the 0 m.-5 m. stratum the heat which remains there. Similarly, 442 g. cm. of work are done in the 5 m.-10 m. stratum.

The Rôle of the Sun. In this discussion of the distribution of heat it has been assumed that all warming below the surface is done by mixture; that the warmed water is taken from the surface and distributed by the wind. This assumption is, of course, incorrect as it implies that the water is opaque to the sun's radiation. It is necessary therefore to ascertain what aid the sun may give in the distribution of heat.

From data so small in quantity as those available for lake Okoboji this question can be answered very imperfectly. Indeed, the data can tell us only the possible maximum contribution of the sun to the work of distributing heat.

Observations were made on July 29 with the pyrlimnimeter, an instrument for measuring the penetration of solar radiation into the water of the lake and its absorption by the water. It consists essentially of 20 small thermal couples which can be alternately exposed to the sun and covered. The electric current caused by the sun during exposure is measured by a d'Arsonval galvanometer. The swing of the galvanometer is directly proportional to the heat energy in the solar radiation. If, therefore, the thermal couples are exposed first at a depth of one meter below the surface and then at a depth of two meters, the ratio of the two readings will give the rate at which the stratum of water transmits the solar radiation incident on its upper surface.

Readings were made in Okoboji lake to the depth of four meters with the result shown in the following table:

TABLE 14—OKOBOJI LAKE. READINGS OF PYRLIMNIMETER, 11.10-11.27 LOCAL TIME. SKY CLEAR. TRANSPARENCY OF WATER BY SECCHI'S DISC, 3.1 m.

Depth, cm.	Divisions	Cal.	Per cent of air	Depth	Transmission, per cent
Air	219.0	1.53	100.0	--	--
50	48.5	0.34	22.0	--	--
100	33.5	0.23	15.3	100-200	54
200	18.0	0.13	8.2	200-300	54
300	9.5	0.067	4.4	300-400	53
400	5.0	0.035	2.3		

Notes: The column marked *divisions* gives the swing of the galvanometer when the thermal couples are exposed to the sun. The column marked *Cal.* gives the value of these readings in calories per square centimeter per minute. The fourth column shows the value of the readings in the water as a percentage of the readings in the air. The last column shows the rate at which a stratum of water one meter thick transmits the solar radiation incident on its upper surface.

It appears that under the conditions of the observation about 15.3% of the solar radiation reaching the surface of the lake was present at the depth of 100 cm. Nearly 85% therefore was either lost or absorbed before reaching that depth. Such a result is a common one in lakes. The radiation at 100 cm. rarely exceeds 20% of the total radiation and often falls far below 15%. In absolutely pure water some 43% may remain at that depth. But the stains always dissolved in lake water and the particles of organic and inorganic matter suspended in it rapidly cut off the radiation.

It appears also that below the depth of one meter, about 53%-54% of the energy which reaches the surface of each one-meter stratum is transmitted to the surface of the next one-meter stratum. Stated in terms of absorption, about 46%-47% of the energy of the solar radiation present at any depth below one meter is absorbed in passing through a stratum of that water one meter thick. Thus it appears that only a small fraction of the solar radiation penetrates the lake to the depth of one meter and that this small amount is very rapidly absorbed.

If we assume that the conditions present at the time of observation are average ones, we may compute the general rôle of the sun in distributing heat. For this purpose we estimate as before that the sun delivers to the lake 60,000 cal. cm.^{2} during the warming season. We take from the pyrlimnimeter reading that 22% of this reaches a depth of 50 cm.; that 15% penetrates to the depth of 100 cm.; and that the transmission below 100 cm. is 54% per meter. The result is then as follows:

TABLE 15—HEAT DELIVERED TO THE SURFACE OF THE LAKE DURING THE WARMING SEASON AND THE AMOUNT DELIVERED TO VARIOUS DEPTHS BY DIRECT INSOLATION. STATED IN CALORIES PER SQUARE CENTIMETER OF HORIZONTAL SURFACE

Depth	Cal.
Air	60,000
50 cm.	13,200
100 "	9,000
200 "	4,860
300 "	2,620
400 "	1,440
500 "	760
600 "	410
700 "	220
800 "	120
900 "	65
1000 "	35

Table 15 shows in a very striking way how the direct influence of the sun is confined to the surface strata. At the depth of 5 m., for instance, there would be directly delivered only 760 cal. during the entire warming season of four months, or only about 6 cal. per day. The total is less than may be delivered to the surface in a day. At the same rate of transmission only 35 cal. would reach the depth of 10 m.

in four months, or about as much as may reach the surface in twenty minutes at noon.

It is obvious that this computation is not based on average conditions, since on the one hand the reading was made near noon, when the sun was at a high altitude, and on the other hand it was far from the zenith and the path of its rays through each meter of depth would be more than 100 cm. It is quite possible to determine the energy present at 100 cm. and the rate of transmission if the sun were vertical; and it is also possible from this new curve to determine the same data for the mean conditions during the warming period. The computation has been made with the following result:

	Energy at 100 cm.	*Transmission*
Observed, July 29	15.3%	53%—54%
Vertical sun	16.0%	56%—57%
Mean sun, (Apl. 15-Aug. 15)	14.2%	50%—51%

It would be possible to use the computed mean sun in the following work instead of the observed data. But the difference is not great, and the result is at best only a rough approximation. The value of the mean sun is based on five years of observation at Madison, Wis., in the same latitude as Okoboji.

Effect of Direct Insolation. We may now go on to compute the direct effect of the sun on the distribution of heat. We have as data (1) the downward movement of heat amounting to 20,933 cal. cm.^{2} at the surface (table 11); (2) the amount of work needed to distribute this heat (table 13, G); (3) the heat directly contributed by the sun to various depths (table 15). The following table gives the result:

TABLE 16—CONTRIBUTION OF THE SUN TO THE DISTRIBUTION OF HEAT

Depth cm.	Cal.	Sun	Per cent
0	20933	20933	100.0
50	20300	13200	65.0
100	19800	9000	45.5
200	19600	4860	26.1
300	17400	2620	15.1
400	16300	1410	8.6
500	15000	760	5.1
600	14100	410	2.9
700	13100	220	1.7
800	12100	120	1.0

Note: The calories which pass through each square centimeter are stated in terms of the area at that depth, in the column headed *Cal.* The direct radiation which reaches the lake bottom, say between 100 cm. and 200 cm. depth, is not available for warming the deeper water. The contribution of the sun must therefore be measured as a fraction of the energy passing through each sq. cm. of the depth in question and not in terms of the surface of the lake.

It appears, therefore, that the sun may contribute 9000 cal. of the 19,800 cal. which pass through each square centimeter of the one-meter level; that it can contribute only 760 cal. at five meters of the 15,000 cal. which pass that level; and that at eight meters only one per cent of the heat comes directly from the sun.

This is the maximum possible contribution if the observations represent average conditions, as they doubtless do approximately. The results assume that none of the heat due to direct insolation is lost; that for instance all of the 9000 cal. delivered by the sun during the warming season to the depth of one meter are part of the summer heat-income, none being lost to the lake by cooling at night or during cool periods. This assumption is manifestly far too favorable to the sun, but at present we have no data on which to correct it accurately.

The data of table 16 may be applied to Fig. 3 and a curve drawn through the points thus determined. Then the area, ABDEH, represents the total work done in distributing the heat to the depth of 25 m.; the area, ACDB, represents the contribution of the direct insolation to the work of distributing heat on the assumption that no sun-placed heat is lost; and the area, ACDEH, represents the contribution of the wind on the same assumption. The areas may be measured with a planimeter, with the following result:

TABLE 17—CONTRIBUTION OF SUN AND WIND TO DISTRIBUTING HEAT ON THE ASSUMPTION THAT NO SUN-PLACED HEAT IS LOST

Depth	Per cent of work	
	Sun	Wind
Total	20.3	79.7
0 m.-5 m.	31.6	68.4
5 m.-10 m.	3.8	96.2
0 m.-1 m.	66.3	33.7
1 m.-5 m.	20.0	80.0
Below 1 m.	12.1	87.9
Below 5 m.	2.6	97.4

It thus appears that the maximum possible contribution of the sun to the distribution of heat is about 20%. Of this about 95% is in the upper 5 m. of the lake. The sun contributed only about 2.6% to the distribution of heat below five meters, and practically nothing below ten meters.

The actual contribution of the sun is less than this. If we assume that the percentage of sun-placed heat lost is the same as the average loss, the figure of 20% will be reduced to 7%-8%, since only about one-third of the sun's radiation is absorbed by the lake. This is certainly too low an estimate of the sun as heat placed at depths of 2 m. or 3 m., or even at 1 m. would be lost far less easily than that in the upper centimeters of the water. Perhaps no better estimate can be made at present than to assume that the contributions of the sun below 1 m. is a fair amount and that direct insolation is responsible for 10%—12% of the work of distributing heat and that the wind furnishes 88%—90%.

With such estimates we must leave the subject at present. Future studies will be able to furnish greater accuracy, but no result is likely to show that the wind furnishes much below 80% or much above 90% of the work needed in the distribution of the summer heat-income through the water of lake Okoboji.

III—OTHER TEMPERATURE OBSERVATIONS ON OKOBOJI LAKE

The point has been emphasized that the small volume of the lower water of Okoboji lake gives rise to exceptionally high temperatures near the bottom. In 1919 the bottom temperature at 34 m. was 10.8° and was probably 10.7° or 10.6° at 40 m. This must be an exceptionally low temperature for the lake since lakes in the same general region had unusually low bottom temperatures in 1919. This situation was due to a period of hot calm weather in June, which heated the surface stratum of the lakes and thereby checked the distribution of heat to the lower water. The bottom temperature of lake Mendota on August 1 at 23.5 m. was 9.5°, the lowest recorded; and that of Green lake was 4.9° at 72 m., the only temperature below 5.0° found by the Wisconsin survey in this lake. That of lake Geneva was 7.0°, a low temperature, but not the lowest on record. The general temperature, however, of the water below 10 m. was the lowest recorded.

Temperature observations on lake Okoboji were made by Professor John L. Tilton, of Simpson College in 1915 and 1916 (Tilton '16, '17). The record of August 5, 1915, showed a temperature of 15.5°C. (59.8°F.) at a depth of about 35 m. (115 ft.). On the same date the surface temperature was 20.0°C. (68°F.). On July 13 the temperature at 35 m. was 15.0°C. and at about 41 m. (135 ft.) 14.7°C. These observations were made with a minimum thermometer weighted and sunk into place.

In 1916 Professor Tilton took readings in June and July. On July 18 he found a temperature of 13.1°C. at 32 m. This series was read with a Leeds and Northrop electrical resistance thermometer. This instrument became disabled and on July 26 readings were made with the minimum thermometer, showing a temperature of 15.6° at a depth of 27 m.; the reading at this depth on July 18 was 13.3°.

The attention of the authors of the present paper was called to Okoboji lake by this work of Professor Tilton. The readings at first seemed incredible. Nothing in our previous experience warranted the idea that a lake could have a midsummer temperature greater than 15° at a depth of 40 m., or even a temperature approximating 15°. Lake Geneva, the nearest parallel in depth, had shown in 18 seasons a mean bottom temperature of 8.0° with a minimum of 5.6° and a maximum of 10.0°. The temperature of Okoboji was therefore nearly twice as high as the mean of lake Geneva. The maximum gain of Geneva above 4° was 6°, or about one-half that of Okoboji.

There is no reason to doubt that Dr. Tilton's observations show the general character of the lake's temperature. He corrected his minimum thermometer for pressure, which at 135 ft. would have caused a rise of 0.24°C. This correction is not made in the figures given above. The temperature of the lower water of all lakes in this region was exceptionally high in 1915, in most cases at a maximum. This was due to the low temperature of the air during May, June, and July, which favored the distribution of heat.

The air temperatures at Madison were as follows:

	Mean	*1915*	*1916*
May	14.2°	11.1°	14.0°
June	19.6°	16.5°	16.5°
July	22.4°	20.0°	26.5°

There is only one year on record in which the temperature of May was lower than in 1915. June was the coldest on record in both 1915 and 1916, and July, 1915, was the coldest since 1891. May, 1916, was practically at the mean, while July was much above the mean. Under these conditions we should expect to find unusually high bottom temperatures in lakes during both years. This condition was present in the Wisconsin lakes. Lake Geneva had a bottom temperature of 9.8° in August, 1915. This is the highest on record except in 1917 when it rose to 10.0°. In that year the temperature of May and June was the same as in 1915, and the first half of July was also cold.

There is therefore no reason why the records from Okoboji lake in 1915 and 1916 should not be accepted as showing the general situation.

On the other hand it does not seem probable that they are exactly accurate. The readings of 1915 near the bottom are as follows:

100 ft.	60.0°F.
110 "	56.5°F.
115 "	59.8°F.

Here is apparently a drop of nearly 2.0°C. in about three meters followed by a rise of about 1.8°C. in 1.5 m. Such changes at this depth are highly improbable and lead one to query whether the thermometer functioned accurately. If the 110-ft. reading is to be taken as correct, the bottom temperature is 13.6°; if we take the 115-ft. reading it is 15.5°. It may be added that the amount of the oxygen found by us in the lower water forbids the idea of a possible rise of the bottom temperature due to fermentation. (See p. 42).

The observations of July 26, 1916, are open to the same criticism. The readings on that date show the following:

18 m.	17.6°
19 m.	16.8°
20 m.	18.6°
21 m.	17.1°
22 m.	16.5°

Such irregularities are unprecedented. It is not easy to see how a temperature of 18.6° could be reached at 20 m. with much lower temperatures at 19 m. and 21 m.

Another though somewhat similar query arises regarding the 1916 series. There is no objection to accepting 13.1° as a correct reading at 32 m. on July 18 and 13.3° at 27 m. on the same day. These readings were made with the Leeds-Northrop instrument. But if these are correct it is hard to see how we can accept the readings by the minimum thermometer on July 26. This gives a temperature of 15.6° at 27 m. or a rise at that depth of 2.3° in eight days. These days were bright hot days with little wind, according to weather records at Madison.

In this case the criticism is not based on the idea that the temperature reported is impossibly high; on the contrary it seems quite within the possible limits. The difficulty is to see how so great gains of heat could have been made in the week available for them.

The thermocline was well established on July 18 and therefore conditions would be as unfavorable as possible for the distribution of heat to the lower water. Still further the record of the minimum thermometer on July 26 shows large gains at all depths as compared with July 18. The total gains to the depth of 25 m. amount to nearly 2600 cal. per sq. cm. of surface, or more than 300 cal. per day. This sum must be considerably more than half the heat delivered by the sun, which at Madison averaged 460 cal. for the days in question. A gain of this magnitude in July seems impossible. Such gains are not infrequently made in April when the temperature of the water is low, so that distribution of heat is easy and when it is also above that of the air so that losses from the surface are at a minimum. In July the mean daily gain of lake Mendota is 69 cal. and in July, 1915, it was 97 cal. It seems clear therefore that the apparent rise of temperature between July 18 and July 26 can not be a real one. It is possible, since the volume of the bottom water is so small, that it may be displaced by wind in such a way as to cause this apparent rise, or the apparent fall between June 28 and July 18. (Tilton '17, p. 39). If so, these oscillations of temperature are exceptionally great and are themselves worth study.

The alternative conclusions can not be avoided, either that Okoboji lake is exceptional to a wholly unprecedented degree, or that the readings of the minimum thermometer need further correction. It is best therefore to defer detailed discussion of them until a careful study has been made of the heat exchanges of the lake. In reaching this conclusion we ought not to fail to recognize the great service done to limnology by Dr. Tilton's observations. He recorded for the first time the bottom temperatures in a deep lake whose basin is of such form as to give rise to very high temperatures at the bottom. He thus showed where exceptional opportunity lay for the study of the effect of the form of the basin on the temperature of lakes and perhaps in other respects.

We may be pardoned an illustration of the influence of Dr. Tilton's records. There is in Wisconsin a small body of water, Rock lake, whose dimensions are: Area, 496 ha.; maximum depth, 20.4 m.; mean depth, 6.1 m.; volume development, 0.90. (Juday '14, p. 34, map VII). It is therefore almost a morphometric copy of Okoboji lake on a small scale. This lake had been sounded by this Survey but no temperature readings had ever been made in it. It was visited in August, 1918 in consequence of the work of Dr. Tilton and its bottom temperature was found to be 20.0°, while that of Mendota (a much larger lake) at the same time and depth was 13.0°. No reading approaching 20° had ever been made before at such a depth in any Wisconsin lake. It is plain that in this case also the form of the lake basin profoundly influences temperature. It may be added that in 1919 the bottom temperature, like that of Okoboji, was exceptionally low—13.1°.

IV. COMPARISONS OF TEMPERATURES IN LAKES OKOBOJI AND GENEVA

While the bottom temperature of lake Geneva in 1919 was not as low as it has been on other years, the mean temperature is the lowest recorded—14.2°, as compared with a 16-year mean of 16.5°. The next lowest temperature was 15.4° in 1897, so that in 1919 the water was 1.2° colder than in any other August on record. The low record of 1919 was due to the temperature of the water below 10 m. since the epilimnion was by no means exceptionally cold on August 30, and earlier in the month it must have been quite up to the average. The most conspicuous difference was in the 10 m.-15 m. stratum which was 5.2° below the mean of 18 years. The thermocline showed a drop of 10.0° in three meters, from 21.0° at 9 m. to 11.0° at 12 m. This is a remarkable decline considering the direction and force of the wind which was from the northwest on August 30. This would tend to spread rather than to condense the isotherms at the place of observation. The thin epilimnion is no doubt an inheritance from the hot weather in June and to this is due the low temperature of the 10 m.-15 m. stratum.

The summer heat-income of Geneva as measured by the observations on August 30 is as follows:

TABLE 18—TEMPERATURE AND SUMMER HEAT-INCOME OF LAKE GENEVA, WIS., AUGUST 30, 1919

Depth	Temp.	Cal. RT
0-5	21.3	7802
5-10	20.1	5957
10-15	11.9	2568
15-20	9.4	1512
20-25	8.7	1058
25-30	8.0	680
30-35	7.4	360
35-40	7.1	121
40-43	7.0	12
	14.18	20070

If the heat budgets of lakes are to be fairly compared there must be some common adjustment of the temperature of the epilimnion. This is rapidly affected by the temperature of the air and the relative volume of the epilimnion is so great that its temperature has a large influence in determining the heat budget. In Okoboji lake in 1919 more than 75% of the summer heat-income was in the epilimnion and in lake Geneva nearly 70% was in the same stratum. If therefore a lake is visited at the close of a hot period the temperature of its epilimnion will be found to be high, and both the mean temperature and the summer heat-income will be correspondingly large; while a week later after several days of cool weather the epilimnion may have lost considerable heat. This is the case in the two lakes under consideration. The surface of lake Okoboji was at 24.7°, while that of Geneva was only 21.4°, and the difference in the 0 m.-5 m. stratum amounted to nearly 1400 cal. in favor of Okoboji, due wholly to a difference in temperature which was itself largely due to the different dates on which the lakes were visited. On the other hand, the temperature of thermocline and hypolimnion in such lakes as these ordinarily changes very little between the last week of July and the first of September.

Our observations on Wisconsin lakes show that under similar conditions there is but little difference in the midsummer temperature of the epilimnia of lakes in the same general region, whatever the size of the lake or the thickness of the stratum. Differences are especially small when lakes of the same order of size or depth are compared. In order therefore to eliminate so far as possible differences in temperature due to weather condition of short period and to employ temperatures which show the effects of the season as a whole, we have been accustomed to assume a midsummer temperature of the epilimnion at the average maximum ordinarily reached. This for our lakes is 23°, so that T-4=19°. This temperature may ordinarily be assumed without any necessity of modifying the lower part of the temperature curve to fit the change in the upper part.

The effect of this assumption in Okoboji and Geneva lakes may be seen from the following table, in which temperatures and calories below 10 m. remain as observed, but the epilimnion is given a temperature of 23°. This reduces the budget of Okoboji and raises that of Geneva.

TABLE 19—SUMMER HEAT-INCOME OF OKOBOJI AND GENEVA LAKES COMPARED WITH EPILIMNION AT 23°

	Okoboji			Geneva		
Depth, meters	T-4	RT	Cal.	T-4	RT	Cal.
0-5	19.0	445	8455	19.0	451	8569
5-10	19.0	325	6175	17.5	370	6475
10-15	14.8	217	3212	7.9	325	2568
15-20	9.1	135	1228	5.4	280	1512
20-25	7.6	67	509	4.7	225	1058
25-30	7.1	26	185	4.0	170	680
30-35	6.9	10	69	3.4	106	360
35-40	6.8	1.6	11	3.1	39	121
40-				3.0	4	12
Total			19844		1970	21355

Under these conditions the heat budget of Geneva is about 1500 cal. larger than that of Okoboji, and most of the excess is in the lower water. The budget of Geneva below 15 m. is about 3740 cal. and that of Okoboji is 2000 cal. The larger volume of the lower water more than makes up for the lower temperatures of lake Geneva. In the 10 m.-15 m. stratum the reverse is true; here Okoboji has nearly 550 cal. more than Geneva. T-4 is nearly twice as great, and this more than compensates for the smaller value of RT.

The table therefore shows very clearly the effect of the volume of the lower water on heat gains. The temperature of the water in the lake of greater volume is lower but the total quantity of heat is greater.

The same point may be further illustrated by considering the temperatures reported by Dr. Tilton for Okoboji in 1916 and comparing these with maximum temperatures for Geneva.

TABLE 20—COMPARISON OF LAKE OKOBOJI AND GENEVA AT HIGH TEMPERATURES OF THE WATER.

	Okoboji July 26, 1916				Geneva Sept. 8, 1899			
	Observed		Epi. at 23°		Observed		Epi. at 23°	
Depth, meters	Temp.	Cal.	Temp.	Cal.	Temp.	Cal.	Temp.	Cal.
0-5	26.5	10012	23.0	8455	23.7	8885	23.0	8569
5-10	24.7	6728	23.0	6175	23.7	7289	23.0	7030
10-15	18.6	3163	18.6	3163	22.5	6012	22.2	5915
15-20	17.2	1782	17.2	1782	15.4	3192	15.4	3192
20-25	16.2	817	16.2	817	12.0	1800	12.0	1800
25-30	15.4	296	15.4	296	10.2	1054	10.2	1054
30-35	15.2	112	15.2	112	9.2	551	9.2	551
35-40	15.0	17	15.0	17	8.6	179	8.6	179
40-43					8.3	17	8.3	17
		22927		20817		28979		28307

Compare first the budgets of Okoboji lake in 1919 (Table 19) and 1916. They are approximately 21,000 and 23,000 respectively—a difference of 2000 cal. If the temperature of the epilimnion is reduced to 23° they are 19,800 cal. and 20,800 cal., respectively—a difference of 1000 cal. in favor of 1916. Yet in that year the temperature of the water below 15 m. averaged more than four degrees higher than in 1919; but as the total reduced thickness of the lake below 15 m. is only 240 cm. this rise in temperature represents an income of only about 1,000 cal. cm.^{2} of the surface.

In lake Geneva we find a summer heat-income of about 29,000 cal., in 1899, or, placing the temperature of the epilimnion at 23°, an income of 28,300 cal. Thus Geneva may gain from 6,000 cal. to 7,000 cal. more than has been found in Okoboji, assuming the correctness of Dr. Tilton's record of 1916.

Lake Geneva has been visited for so many seasons that we can hardly expect to find in its temperature a much larger range of variations than has already been shown. We may therefore infer that the summer heat-income may range from about 20,000 cal. to 29,000 cal., or that with the epilimnion at the standard temperature of 23° the range will be from 21,000 cal. to 28,000 cal. Another 1000 cal. may be added to the maximum if we impose the warmest observed epilimnion on the warmest observed temperature for the lower water.

In the case of Okoboji the limits are not thus known. Temperatures of 1919 are probably close to the minimum for the lower water, and therefore no heat-income is likely to be lower than 19,000 cal. to 20,000 cal, with the epilimnion at 23°. But the volume of the lower water is so small that its temperature has very little influence on the heat-income; and the same fact also brings it about that but little work is needed to raise the temperature of the lower water much above the minimum. In 1916 weather conditions were such as to favor a very high temperature. Yet the total heat-income (Table 20) was only 2000 cal. above that of 1919 at observed temperatures. A temperature much above that of 26.5° for the upper five meters is hardly to be expected; a mean gain of one degree at all depths of the water below 10 m. means only 460 cal. total gains, and one degree in the hypolimnion below 15 m. means only about 240 cal. Under such conditions we can hardly expect the maximum heat-income to rise much above 24,000 cal.-25,000 cal. The latter figures would involve a mean temperature of the hypolimnion close to 20°, or more than 4° above that of 1916.

Even such extreme temperatures do not seem excluded from possibility—at least not by the amount of work involved in the distribution of heat at such high temperatures. The distribution of heat in Okoboji in 1916 when the bottom water reached 15° required 1981 g. cm.; the distribution of heat in Geneva in 1899 demanded 2752 g. cm. or nearly 800 g. cm. more than that of Okoboji. It would thus seem possible for the wind to do more work on Okoboji and under favorable circumstances raise the temperature of the lower water above 15°. If we assume that the supply of heat and of wind were such as to add 4° to the temperature of each stratum below 10 m. (the temperature 0 m.-10 m. remaining as in the 1916 series), the work would rise only to 2561 g. cm.—an amount which would seem within the limits of the capacity of Okoboji. Under these conditions the summer heat-income would be only 24,690 cal., a small gain over 1916 or 1550 cal. for 581 g. cm. of work. Apparently, therefore a summer heat-income of about 24,500 cal. is a maximum for lake Okoboji. This income would involve a mean temperature of 24° for the water of the lake, and this would imply a mean temperature of about 20° for water in the 15 m.-40 m. region of the lake. The distributing agencies seem theoretically able to effect this. But it would require a rare conjunction of delivery of heat and efficiency of distribution to secure results much greater than those recorded in 1916.

Systematic study of the lake, therefore, is required to show whether temperatures even higher than those of 1916 are attainable in lake Okoboji. Such speculations as that just given have very little value, but they may be permissible in the case of a lake so exceptional as Okoboji. The possibilities of life in the lower water of such a lake are profoundly influenced by these exceptional possibilities of temperature, and the lake therefore offers chances for unusual problems in the ecology of the plankton as well as similar problems in the physics and chemistry of lakes.

V. DISSOLVED GASES

West Okoboji lake belongs to the temperate type in which there are two circulation periods and two stratification periods each year; these periods correspond in general to the four seasons of the year. The water is in complete circulation for a time in the spring and again in the autumn, but it is in a state of stratification in summer and in winter. During the periods of complete circulation the temperature of the water is substantially uniform from surface to bottom and the dissolved substances are practically the same at all depths; but during stratification the water of the upper and lower strata show important thermal and chemical differences which become more marked as the period of stratification advances. The differences which were found about the middle of the summer period of stratification in West Okoboji lake are shown in tables 7 and 21 (pp. 10 and 44).

Samples of water from the different depths of the lake were obtained by means of a water bottle and the carbon dioxide and dissolved oxygen were determined for the different strata. The former was determined by the Seyler method, using phenolphthalein and methyl orange as indicators for the titrations with standard acid and alkali. The Winkler method was used for the determination of the dissolved oxygen. (For descriptions of these methods see Birge and Juday, '11, pp. 13-23).

CARBON DIOXIDE

Carbon dioxide is usually present in lake waters in three different states; that is, as fixed, half-bound, and free carbon dioxide. The quantity of fixed and half-bound is dependent upon the amount of the substances present with which this gas is usually combined, chiefly calcium and magnesium. The fixed carbon dioxide is that portion which is held in a close chemical union, most generally with calcium and magnesium, and forms the carbonates of these substances. The half-bound is held in a rather loose combination by the carbonates, converting them into bicarbonates.

In addition to these a lake water may hold in solution a certain amount of carbon dioxide in an uncombined state and this constitutes the free carbon dioxide. From the biological standpoint the half-bound and free carbon dioxide are the most important since they constitute the sources from which the aquatic chlorophyllaceous organisms obtain their carbon dioxide for photosynthesis. No portion of the fixed carbon dioxide is directly available for photosynthesis, but indirectly the quantity of it is a very important factor because the amount of half-bound carbon dioxide is dependent upon the quantity of carbonates present in the water. In a water that gives a neutral or acid reaction with phenolphthalein it is assumed that the quantity of half-bound carbon dioxide is equal to that of the fixed.

Fixed carbon dioxide. Table 21 shows that the quantity of fixed carbon dioxide in West Okoboji lake amounted to 38.58 cc. per liter of water from the surface to a depth of 14 m. Below this depth the amount was somewhat larger, ranging from 39.59 cc. at 15 m. to 41.20 cc. at 33 m, the bottom.

At the close of the vernal period of circulation the quantity of fixed carbon dioxide is substantially the same at all depths; but soon after the water becomes stratified in early summer there is an appreciable difference between the epilimnion and the hypolimnion. There is a decrease of the fixed carbon dioxide in the upper water, due in part to the rise in the temperature of the water which tends to make the carbonates less soluble, and in part to the fact that the chlorophyllaceous organisms of this stratum draw upon the half-bound carbon dioxide. This process gives the water an alkaline reaction and thus tends to precipitate the carbonates, more especially the calcium carbonate. The submerged aquatic plants growing in the shallow water, such as *Chara,* also remove a considerable amount of calcareous material from the upper water.

The water of the hypolimnion soon comes to have a distinctly acid reaction, which is due to the free carbon dioxide that is liberated in the decomposition of organic matter in this region and in the respiration of the various organisms that inhabit this stratum. Thus any carbonates that are precipitated in the upper water and sink into this region will be redissolved; at the bottom where the water contains the largest amount of free carbon dioxide the fixed carbon dioxide is largest in amount because this acid water dissolves some of the calcareous material in the bottom mud. As the summer period of stratification advances the difference in the fixed carbon dioxide content of the upper and lower water becomes more marked, the maximum difference being found a short time before the autumnal overturn takes place.

Half-bound carbon dioxide. When the water of a lake is neutral or acid in reaction to phenolphthalein the half-bound carbon dioxide is regarded as equal in amount to the fixed carbon dioxide; but in waters which give an alkaline reaction the quantity of the latter is greater than that of the former. The excess of the latter is equivalent to the amount of free carbon dioxide that would be required to give the water a neutral reaction; in table 21 the deficiency is indicated by a minus sign in the column showing the free carbon dioxide.

Free carbon dioxide. The epilimnion is preëminently the zone of photosynthesis and where the chlophyl-bearing organisms are abundant a rather large supply of carbon dioxide is required for this process. The demand thus becomes larger than the supply of free carbon dioxide and the organisms draw upon the supply of half-bound carbon dioxide. Since this leaves an excess of normal carbonates the water has an alkaline reaction and the degree of alkalinity depends upon the amount of half-bound carbon dioxide that has been used. It has been found that more than 80% of the half-bound carbon dioxide may be thus utilized.

As a result of the activities of the chlorophyl-bearing organisms the epilimnion of Okoboji lake was distinctly alkaline at the time of these observations. (See table 21, p. 44). This alkalinity was equivalent to 4.28 cc. of free carbon dioxide; that is, it would have required 4.28 cc. of this gas per liter to make this water neutral. The water at a depth of 5 m. showed the same degree of alkalinity as that at the surface; but at 10 m. it was distinctly less alkaline and became neutral at 13 m.

The water of the hypolimnion gave a distinctly acid reaction; a maximum of 1.72 cc. of free carbon dioxide per liter was noted at 33 m. This is the usual condition in lakes of this type. Much decomposition takes place in this stratum which furnishes a constant supply of free carbon dioxide and an additional amount is derived from the respiration of the organisms that inhabit this region. Since the water of the hypolimnion is cut off from the air during the stratification period and since this gas diffuses very slowly through water, there is very little loss of free carbon dioxide during such periods. As a result the lower water soon gives an acid reaction, even when it is distinctly alkaline at the time of stratification, and the free carbon dioxide shows an appreciable increase in quantity as the season advances; the largest amount is found at the bottom just before the overturn takes place.

DISSOLVED OXYGEN

During the vernal and autumnal periods of circulation this gas is also substantially uniform in its distribution from surface to bottom; the largest amount is found at the close of the latter period because oxygen is more soluble in cold than in warm water. With the rise in the temperature of the water in the spring there is a corresponding decrease in the amount of oxygen but the water remains nearly or quite saturated with this gas as long as the vernal cirulation continues. When stratification becomes established in early summer, however, it is soon followed by appreciable differences in the quantity of oxygen in the different strata.

The temperature of the epilimnion continues to rise until the summer maximum is reached which means a decreased capacity for dissolved oxygen. Decomposition and respiration also tend to decrease the supply of this gas but the water of this stratum is kept in circulation by the wind and thus freely exposed to the air which tends to keep the supply near the saturation point. Another source of supply is the oxygen liberated in this stratum during the process of photosynthesis. In general, then, the quantity of oxygen in the epilimnion does not fall very far below the saturation point during the summer period of stratification and, under favorable conditions, the stratum may even become supersaturated.

On July 31, 1919, the dissolved oxygen in the epilimnion of West Okoboji lake amounted to 5.80 cc. per liter at the surface and 5.40 cc. at a depth of 10 m. While these quantities represent an abundant supply of this gas, nevertheless they are both well below the point of saturation, the former being 95.5% and the latter only 86.6% of the amount required for saturation. This indicates that the water of the epilimnion was being depleted of its supply of oxygen through decomposition and respiration faster than it was receiving this gas from the air and from the photosynthetic activities of the chlorophyl-bearing organisms.

The hypolimnion remains practically uniform in temperature after the formation of this stratum so that its capacity for oxygen is scarcely affected during the summer. On the other hand, however, it is cut off from contact with the air by the epilimnion and conditions are not favorable for photosynthesis at that depth; it is thus deprived of the two main sources from which a supply of oxygen can be obtained and any decrease during the summer remains as a deficiency until the autumnal overturn takes place. Decomposition and the respiration of the organisms which occupy this stratum contribute to the decrease of the oxygen supply and the extent of this decrease depends upon the volume of the hypolimnion and upon the abundance of decomposable material and living organisms; if the volume is relatively small and these two processes are fairly vigorous there will be a marked decrease in the supply of oxygen as the summer advances and a portion, or even practically all, of this stratum may be deprived of its dissolved oxygen.

It will be noted in table 21 that the hypolimnion of Okoboji lake possessed a relatively small amount of dissolved oxygen at the time of these observations; the amount varied from 2.23 cc. per liter at 15 m. to 0.86 cc. at a depth of 33 m. At 18 m., however, the amount was a little more than half a cubic centimeter larger than at 15 m. Such differences have been noted in other lakes but the cause of the phenomenon has not yet been definitely ascertained. Stated in percentages the quantity of oxygen varied from 36.5 % of saturation at 18 m. to only 10.9% at 33 m. With such a marked decline in the dissolved oxygen at this stage of the summer stratification period it is safe to predict that this gas all disappeared from the lower portion of the hypolimnion, at least, before the time of the autumnal overturn.

In the mesolimnion, or thermocline, the quantity of oxygen declined from that of the epilimnion above to that of the hypolimnion below; that is, from 5.40 cc. per liter of water at 10 m. to 2.40 cc. at 13 m., while there was a further decline to 2.23 cc. at 15 m. Thus the greater part of the decrease took place in the upper half of the mesolimnion.

The last item in table 21 shows the results obtained on water from the well of the Lakeside Laboratory. This water had a temperature of 11.3°. It will be noted that there was an abundance of free carbon dioxide, about seven times as much as was noted in the lake water at a depth of 33 m. It also contained almost two and a half times as much fixed carbon dioxide as the surface water of the lake. There was a fairly large supply of dissolved oxygen in this well water; the result shown in the table is undoubtedly too high since, in obtaining the samples, the water was exposed to the air as it was being pumped into the bottles.

A set of observations on the dissolved gases of lake Mendota was made on August 6, 1919, and the results are shown in table 22. The epilimnion of lake Mendota showed the same degree of alkalinity as that of West Okoboji lake, but the lower water of the former had a distinctly larger amount of free carbon dioxide. The epilimnion of lake Mendota possessed a smaller amount of fixed carbon dioxide than West Okoboji lake, averaging about 5 cc. per liter less, but the difference in the hypolimnion was not so marked. The amount found at the bottom, 22 m., in the former lake was the same as that at 15 m. and 20 m. in the latter, while that at 15 m. and 18 m. in lake Mendota was the same as that in the upper water of West Okoboji lake. Both lakes belong to the "hard water" group, with the water of West Okoboji lake carrying a somewhat larger quantity of carbonates in solution.

A slightly larger amount of oxygen was found in the upper water of lake Mendota but there was a distinctly smaller amount in the hypolimnion than in West Okoboji lake.

TABLE 21—Observations on the dissolved gases of Okoboji lake, July 31, 1919. In the column for free carbon dioxide the minus sign indicates that the water gave an alkaline reaction and the plus sign that it gave an acid reaction with phenolphthalein.

Depth, meters	Carbon dioxide, cc. per liter.		Oxygen	
	Free	Fixed	Cc. per liter.	Per cent of saturation
0	— 4.28	38.52	5.80	95.5
5	— 4.28	38.52	5.42	88.8
10	— 3.21	38.52	5.40	86.6
12	— 1.07	38.52	3.46	53.5
13	Neut.	38.52	2.40	36.0
14	+ 0.86	38.52	2.32	32.3
15	+ 0.86	39.59	2.23	30.7
18	------	----	2.75	36.5
20	+ 1.29	39.59	1.75	22.8
25	------	----	0.90	11.5
30	------	----	0.90	11.5
33	+ 1.72	41.20	0.86	10.9
Well	+11.18	94.16	2.55	32.7

TABLE 22—Observations on the dissolved gases of lake Mendota on August 6, 1919. In the column for free carbon dioxide the minus sign indicates that the water was alkaline and the plus sign that it was acid to phenolphthalein.

Depth, meters	Carbon dioxide, cc. per liter.		Oxygen	
	Free	Fixed	Cc. per liter.	Per cent of saturation
0	— 4.28	33.70	6.16	100.7
8	— 4.28	33.70	5.21	83.5
10	+ 0.86	38.00	1.40	19.5
13	+ 0.86	38.00	0.64	8.2
15	+ 1.92	38.52	0.52	6.5
18	+ 2.58	38.52	0.20	2.4
22	+ 2.58	39.59	0.10	1.2

VI. THE PLANKTON

The small floating and free swimming organisms that constitute what is known as the plankton may be divided into two groups, namely, (a) those which are large enough to be easily obtained with the regular plankton net and (b) those which are so small that they readily pass through the meshes of the finest bolting cloth. The former constitutes what is known as the net plankton and the latter the nannoplankton. Strictly speaking the latter term has been applied only to organisms whose maximum diameter does not exceed 25 μ., but it is such a convenient term that it is proposed to extend its meaning to include all of the forms that escape through the meshes of the net.

Methods. The net plankton was obtained by means of a closing net whose coefficient has been determined as 1.2; that is, about 83% of the column of water through which it is drawn passes through the net and is strained. The material was transferred from the plankton bucket to vials and preserved in alcohol. In the subsequent enumeration the volume of the catch and preservative was reduced to 10 cc.; after shaking thoroughly 2 cc. were removed with a piston pipette and the crustacea and rotifers contained therein were counted. The number thus obtained multiplied by 5 gives the total number of the various organisms in the catch. When only a few individuals of the larger crustacea were present the total was ascertained by direct count.

The Protozoa and algae were enumerated by placing a cubic centimeter of the material in a Sedgwick-Rafter cell and then counting the various forms in the usual manner with a compound microscope.

The dry weight and organic matter of the net plankton were also obtained. For these determinations a net haul was made from surface to bottom (0-32 m.). This catch was concentrated on a small piece of bolting cloth; the material was then carefully removed from the cloth with a knife blade and transferred to a small platinum crucible. Considerable care is necessary at this stage to prevent loss of material. A drop or two of chloroform kills the organisms and prevents putrefaction while the material is drying. The air dried material is then placed in a drying oven at 60° for 24 hours and then in a desiccator for 24 hours. The dry weight of the catch is obtained by means of a sensitive assayer's balance. The material is then ignited in an electric furnace until the ash appears white, after which the weight of the ash is ascertained.

Samples of water for a study of the nannoplankton were obtained from the various depths by means of a water bottle. These minute organisms were removed from the water with an electric centrifuge which has a speed of 3,600 revolutions per minute. The sedimentation was continued for about six minutes and the material from the bottom of the tube with one cubic centimeter of water was transferred to a Sedgwick-Rafter counting cell and the various organisms were enumerated. These organisms should be counted in the living state since experiments have shown that some of them are destroyed by the various preserving agents. It is necessary, therefore, to count this material as soon as possible after securing the samples.

It has been found practical to obtain the dry weight and organic matter in the nannoplankton also. A sufficient amount for this purpose is usually obtained from 90 cc. to 120 cc. of water. With the standard centrifuge 30 cc. of water are centrifuged at each run and the material from three or four runs is concentrated in one tube from which it can be removed after a final centrifuging with one cubic centimeter of water and transferred to a small platinum crucible. A drop of chloroform is added and the water is allowed to evaporate. Beyond this point the procedure is the same as that described above for the net plankton. A certain amount of organic matter is dissolved in the water and this is not removed with the centrifuge; it is necessary, therefore, to run a blank for this by determining the amount of loss on ignition for one cubic centimeter of centrifuged water.

THE NET PLANKTON

In order to ascertain the vertical distribution of the various planktonts, catches were made with the closing net from each 5 m. stratum of the lake. The organisms in the different strata have been enumerated and the results of these enumerations are shown in table 23. The figures given in this table indicate the number of individuals or colonies per cubic meter of water.

Phytoplankton. As might be expected the phytoplankton was confined chiefly to the upper 10 m., or the epilimnion, since the supply of light upon which it is dependent for carrying on photosynthesis is most favorable in this region.

Only four forms of green and blue-green algae were found in the material, namely, *Anabaena, Gloiotrichia, Microcystis,* and *Staurastrum.* They were present in relatively small numbers so that these forms constituted a relatively small portion of the total net plankton.

Four genera of diatoms were present with *Stephanodiscus* as the most abundant; the maximum number of this form was found in the 5 m.-10 m. stratum.

Ceratium was the most abundant protozoan and it appeared only in relatively small numbers. A few specimens of *Dinobryon* and a heliozoan were found in the 0 m.-5 m. stratum while *Vorticella* was noted in the 5 m.-10 m. stratum.

The catches contained only a small number of rotifers and they were confined principally to the epilimnion. They were uniformly distributed in this stratum.

The copepods were relatively the most abundant forms and, with the exception of *Canthocamptus,* they were fairly uniform in their distribution from surface to bottom. As a whole they furnished the greater part of the material obtained in each catch. *Diaptomus* was more abundant than *Cyclops* and furnished the major portion of the copepod material. Two species of *Diaptomus* were present, namely, *D. clavipes* and *D. siciloides.*

Adults of *D. clavipes* constituted about 4% of the total number of Diaptomi, but the immature individuals of this species composed about two-thirds of the total. These immature specimens contained a rather large supply of reserve food in the form of oil globules and these gave a yellowish tint to the whole plankton catch.

Cyclops was most abundant in the upper 10 m. and below 25 m., with very few individuals between these two depths. The copepod nauplii also showed a similar vertical distribution; they were much more numerous above 10 m. and below 25 m. than in the intermediate strata.

The Cladocera were represented by specimens of *Bosmina, Diaphanosoma* and three species of *Daphnia.* A few individuals of *Bosmina* were found in the 5 m.-10 m. stratum while a somewhat larger number of *Diaphanosoma* was noted in the upper 10 m. Of the three species of *Daphnia* the most abundant was *D. retrocurva* which reached 17,000 individuals per cubic meter in the upper 5 m. Only about a quarter of these were adults. About a third as many were found in the 5 m.-10 m. stratum and the number was relatively small in the deeper strata. This corresponds to the usual distribution of this form, which is confined chiefly to the epilimnion. *Daphnia pulex* prefers the cool water of the hypolimnion and it was most abundant in that stratum of West Okoboji lake. The maximum number was found in the 25 m.-30 m. catch. A few specimens of *Daphnia longispina* var. *hyalina* were noted in two catches, namely, those from the 10 m.-15 m. and the 30 m.-32 m. strata. This form is usually distributed throughout the entire depth of a lake, but in this instance it appeared only in the mesolimnion and in the lower part of the hypolimnion.

The catch which covered the entire depth of the lake (0-32 m.) yielded 211.7 mg. of dry net plankton per cubic meter of water, of which 91.3% (193.2 mg.) was organic matter.

The average weight of the individuals belonging to the more abundant forms of crustacea was ascertained. For this purpose specimens were sorted out under a dissecting microscope and these were transferred to small platinum dishes. They were then dried, weighed, and ignited as described above. The results are given in table 24.

Six different forms of crustacea were weighed. Immature individuals of *Diaptomus clavipes* were substantially the same in size as the adults of *Diaptomus siciloides* so that it was impossible to separate the two and obtain weights of each. The adults of *D. clavipes* gave a larger dry weight and also a larger amount of organic matter for each individual than any of the other crustacea. The average was almost three times as large as that for immature *D. clavipes* and adult *D. siciloides* and about 40% larger than *Daphnia pulex* and *Daphnia longispina* var. *hyalina*. *Cyclops* averaged somewhat larger than the immature *D. clavipes* and adult *D. siciloides* and had a much higher percentage of ash.

Immediately following the catch which was used to determine the weight of the total net plankton a second haul from surface to bottom was made and the material was preserved for purposes of enumeration. A computation based on the results of this enumeration and on the average weights of the different crustacea indicates that these six forms of crustacea furnished about 69% of the dry organic matter in the total net plankton, of which about 56% was derived from the two species of *Diaptomus*.

TABLE 23—Results of the enumerations of the net plankton catches from West Okoboji lake, August 1, 1919. The figures indicate the number of individuals per cubic meter of water for the different strata.

The following abbreviations have been used: Cladocera—B=*Bosmina*, D.h.=*Daphnia longispina* var. *hyalina*, D.p.=*Daphnia pulex*, D.r.=*Daphnia retrocurva*, Di=*Diaphanosoma;* Copepoda—Ca=*Canthocamptus*, C=*Cyclops*, D=*Diaptomus*, N—*nauplii;* Rotifera—A. c.=*Anuraea cochlearis*, C=*Conochilus*, P=*Polyarthra;* Protozoa—C=*Ceratium*, D=*Dinobryon*, H=*Heliozoan*, V=*Vorticella;* green and blue-green algae—An=*Anabaena*, G=*Gloiotrachia*, M=*Microcystis*, S=*Staurastrum;* diatoms—A=*Asterionella*, F=*Fragilaria*, M=*Melosira*, S=*Stephanodiscus*.

Depth, meters	Cladocera	Copepoda	Rotifera	Protozoa	Green and blue-green algae	Diatoms
0-5	D.r. 17,000	C 6,300	A.c. 390	C 31,200	An124,800	A 23,400
			C 130	D 7,800	G 11,000	F 15,600
	Di 650	D 11,600	P 390	H 7,800	M 46,800	M 15,600
		N 10,700				S 140,400
5-10	B 130	Ca 390	A.c. 260	C 15,600	An 31,200	F 23,400
	D.p. 130	C 4,600	C 130	V 260	G 2,000	S 156,000
	D.r. 6,000	D 4,700	P 650		M 70,200	
	Di 780	N 16,500			S 7,800	
10-15	D.h. 130	C 650			An 7,800	F 7,800
	D.p. 650	D 10,000	C 130		M 7,800	S 31,200
	D.r. 520	N 4,300				
15-20	D.r. 130	C 260				
		D 9,000	P 130		M 23,400	S 23,400
		N 1,170				
20-25	D.p. 910	C 260				
	D.r. 130	D 8,500			An 7,800	S 7,800
		N 1,170				
25-30	D.p. 1,700	C 1,600				
	D.r. 390	D 6,500		C 7,800	M 7,800	S 7,800
		N 13,700				
30-32	D.h. 300	C 4,000				
	D.p. 600	D 10,000				
		N 10,000	A.c. 300		An 3,100	S 3,100

TABLE 24—The dry weight, organic matter, and ash of the worms and various crustacea are shown in this table.

	Number weighed	Dry weight in mg.	Ash		One individual		Remarks
			Mg.	Per cent.	Dry weight in mg.	Organic matter in mg.	
Diaptomus clavipes	70	1.61	0.115	7.14	0.023	0.0213	Adult
Diaptomus siciloides and immature D. clavipes	400	3.22	0.09	3.00	0.00805	0.00782	
Cyclops	95	0.905	0.09	10.00	0.00953	0.00858	Mainly adult
Daphnia pulex	100	1.97	0.39	20.00	0.0197	0.0158	Mainly adult
Daphnia longispina var.hyalina	75	1.395	0.265	19.00	0.0186	0.01506	Adult
Daphnia retrocurva	250	1.43	0.26	18.18	0.00572	0.00468	Mainly young
Oligochaeta	180	34.79	1.67	4.80	0.19328	0.184	Mixed sizes

THE NANNOPLANKTON

A relatively small number of forms was present in the nannoplankton material, but two were found in considerable numbers. (See Table 25). The ciliated Protozoa were represented by *Halteria* and *Vorticella;* a comparatively small number of each was found in the epilimnion while the former was also found in the material from a depth of 33 m. Some specimens of *Cryptomonas* were noted in the samples from 10 m. and 30 m. as well as *Pandorina* at 10 m. Minute flagellated monads were distributed throughout the depth of the lake, but they were much more abundant in the epilimnion than in the other strata.

Only two forms of algae were noted, namely, *Aphanocapsa* and *Oocystis.* A small number of the latter was found in the surface sample. The *Aphanocapsa* consisted of small colonies of minute cells, 25 to 100 in number, embedded in a gelatinous matrix. It seems to have a wide distribution since it appears in the nannoplankton of all of the lakes of this country on which observations have been made. It was found at all depths, but was most abundant in the upper strata. Attention may be called to the fact here that this form has also been found in the lower water of much deeper lakes, such, for example, as Seneca lake, New York, which has a maximum depth of 188.4 m. (618 ft.).

TABLE 25—Analysis of the nannoplankton. The figures given in this table indicate the number of individuals per liter of water.

The following abbreviations have been used:
Protozoa, C=*Cryptomonas*, H=*Halteria*, M=*Monas*, P=*Pandorina*, V=*Vorticella;* Algae, A=*Aphanocapsa*, O=*Oocystis*.

Depth, meters	Protozoa		Algae	
0	H	5,200	A	859,100
	M	156,200	O	5,200
	V	5,200		
10	C	10,400		
	H	5,200	A	781,000
	M	234,300		
	P	5,200		
20	M	10,400	A	781,000
30	C	5,200	A	390,500
	M	5,200		
33	H	5,200	A	390,500
	M	15,600		

For obtaining the weight of the nannoplankton a composite sample was prepared by mixing equal volumes of water from each 5 m. level of the lake. The dry organic matter in the material obtained from this sample amounted to 333.0 mg. per cubic meter of water. This amount plus that in the net plankton (193.2 mg.) gives 526.2 mg. per cubic meter of water for the total plankton; approximately 63% of this total is derived from the nannoplankton and 37% from the net plankton. This sum multiplied by the maximum depth of the lake, that is, 40.2, gives 21,153 mg., or 21.1 grams, per square meter of surface in the deepest water.

Assuming that this plankton material was uniformly distributed over the whole lake, then the average per square meter of surface for the entire lake may be obtained by multiplying the sum of the net plankton and nannoplankton by the mean depth, namely, 12.3 (See table 2). This gives 6,472 mg., or about 6.5 grams per square meter of surface. Again assuming a uniform distribution, the dry organic matter in the total plankton of the entire lake may be calculated from the volume given in table 2; this amounts to 98,520 kg. which is equivalent to about 108 tons. Expressed in terms of a unit area this is 64.5 kg. per hectare, or 57.5 pounds per acre. In the living state this material would weigh about ten times as much, since various experiments have shown that about 90% of the live weight of these organisms consists of water.

This represents a small amount of organic matter per unit of area but these figures indicate only the standing crop at this particular time of the year. Both production and destruction of this material are taking place at all seasons of the year and the quantity of organic matter found at a particular time is the resultant of these two processes. Some of the forms reproduce much more rapidly than others and also reproduction is much more vigorous at certain seasons so that there is considerable variation in the quantity of this material at different seasons. The more minute organisms serve as food for the larger ones, such as the crustacea, and these in turn are eaten by the fish and other aquatic organisms; some forms of the crustacea, in fact, prey upon others. Thus the whole problem is a very complex one so that it would be extremely difficult to ascertain, even roughly, the total annual production of plankton.

A comparison with results that have been obtained on lake Mendota will serve to show the relative plankton productiveness of the two lakes. Table 26 gives the amount of net and nannoplankton found in this lake during the last week in July and the first week in August both in 1915 and 1916. The figures represent the average amount of organic matter for these two weeks in both years and they indicate the quantity in milligrams per cubic meter of water. It will be noted that the organic matter in the net plankton of lake Mendota in 1915 was substantially the same as that of West Okoboji in 1919, but that it was very much smaller in the former in 1916. On the other hand the nannoplankton of lake Mendota was about five times as great in both years as that of West Okoboji lake. The last column of the table shows that the total plankton was more than three times as great in the former lake as in the latter. On the assumption that the amounts in this table represent a fair average per cubic meter of water for the whole lake, a computation based on these figures gives an average of 222.2 kg. per hectare of surface for lake Mendota in 1915, or 198 pounds per acre. The quantity in 1916 was about 6% less than this amount. This is nearly four times as much as was found in West Okoboji lake in 1919. The quantity of total plankton has been determined for only a few of the Wisconsin lakes, but, of those on which determinations have been made so far, only one falls as low as West Okoboji lake. The total plankton of Devil's lake, Wisconsin, on August 27, 1919, amounted to 500 mg. of dry organic matter per cubic meter of water, or about 2% less than that of West Okoboji lake. This result for Devil's lake means a much smaller amount per unit of area since it is a much shallower lake; that is, it represents only 44.5 kg. per hectare, or approximately 40 pounds per acre. On the basis of these results both of these lakes must be classed as plankton poor.

TABLE 26—This table gives the number of milligrams of organic matter per cubic meter of water in the net plankton and in the nannoplankton of lake Mendota and of Okoboji lake in the years indicated. The quantities given for the former lake are the averages of the last week in July and the first week in August each year, while those for the latter lake were obtained in observations made on July 31, 1919.

Lake	Year	Net	Nannoplankton	Total
Mendota	1915	195.7	1,634.3	1,830.0
Mendota	1916	96.5	1,630.6	1,727.1
West Okoboji	1919	193.2	333.0	526.2

BOTTOM FAUNA

Some samples of mud were obtained from the bottom in the deeper water by means of an Ekman dredge. This material was sifted through a fine meshed net for the purpose of ascertaining the number and variety of the macroscopic fauna of the bottom. The time that could be devoted to this work was very brief so that hauls were made at only two different depths, namely, 21 m. and 33 m. The results obtained from the samples are shown in table 27; they give only a very fragmentary idea of the bottom fauna since they are limited to two depths and since they were made at a time when the insect larvae are at their minimum in variety and number. A proper study of the bottom population would require hundreds of observations; these should cover all depths, from the shoreline to the deepest water in various parts of the lake, as well as all seasons of the year. Such a study would involve the expenditure of much time and labor but the results would undoubtedly amply justify the undertaking.

Only three groups of bottom dwellers were found in any abundance. The *Chironomus* larva apparently belongs to the *tentans* group and all of the specimens were either full grown or nearly so, varying in length from 21 mm. to 25 mm. *Protenthes* was not noted at 21 m. but a few were found at 33 m.; these specimens were substantially full grown larvae also. The Oligochaeta included representatives of *Limnodrilus* and *Tubifex*. In addition to these some ostracods and nematodes were noted at both depths.

The chironomids were more abundant at 21 m. than at 33 m. while the reverse was true of the Oligochaeta.

The weight of the forms shown in table 27 were determined and the amount of organic matter per square meter of bottom is indicated in the table in grams. The Oligochaeta varied greatly in size so that it was necessary to pick out and weigh all of the specimens in a single haul of the dredge in order to get an average. While the total number of individuals was much larger at 33 m. than at 21 m., the reverse was true on the basis of the amount of dry organic material; the larger number of Oligochaeta at the former depth did not compensate for the larger bulk of the chironomids at the latter depth.

Stated in larger units this bottom fauna yielded 109.6 kg. of dry organic matter per hectare, or 97.6 pounds per acre, at 21 m., and 65.1 kg. per hectare, or 58.0 pounds per acre, at 33 m. The latter figure is substantially the same as the average yield of the total plankton. (See p. 51). These figures, like those for the total plankton, do not represent the annual production, but they indicate the number of bottom dwellers present at a particular time and the amount of organic matter in them. The annual production involves the yearly turn-over in the bottom population, and this question includes such problems as the number of broods of insect larvae annually, the rate of reproduction of the Oligochaeta, and the extent of the depletion of this entire population each year by being consumed as food and by other causes.

TABLE 27—Observations on the bottom fauna of Okoboji lake, July 30 and 31, 1919. The first column for each depth shows the number of individuals per square meter of bottom and the second column gives the number of grams of dry organic matter per square meter.

	Twenty-one Meters		Thirty-three Meters	
	Number	Organic Matter	Number	Organic Matter
Chironomus	1,110	9.49	355	3.03
Protenthes			266	0.88
Oligochaeta	7,992	1.47	14,120	2.60
Total		10.96		6.51

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FIRST SERIES No. 38 DECEMBER 1, 1920

UNIVERSITY OF IOWA STUDIES

STUDIES IN NATURAL HISTORY

VOLUME IX NUMBER 2

NESTING HABITS OF THE HERMIT THRUSH IN NORTHERN MICHIGAN

by

DAYTON STONER

PUBLISHED BY THE UNIVERSITY, IOWA CITY

Issued semi-monthly throughout the year. Entered at the post office at Iowa City, Iowa, as second class matter. Acceptance for mailing at special rates of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

Professor CHARLES CLEVELAND NUTTING, M. A., Editor

Continuation of Bulletin from the Laboratories of Natural History
of the State University of Iowa

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THE NESTING HABITS OF THE HERMIT THRUSH *Hylocichla gŭttata pallasi* (Cab.) IN NORTHERN MICHIGAN

By Dayton Stoner

INTRODUCTION

The data which serve as a basis for this paper were obtained at the University of Michigan Biological Station on Douglas Lake while the writer was a member of the station staff. Observations were made during the latter part of July and the first few days of August, 1919. In addition to the writer's own observations and notes, the assistance of the members of the class in ornithology was requisitioned. Several other members of the camp also very kindly rendered service in various ways. To all of these obligation is gratefully acknowledged.

The Douglas Lake region lies in the extreme northern part of the southern peninsula of Michigan about seventeen miles from Lake Huron on the east, the Straits of Mackinac on the north and Lake Michigan on the west. The soil is exceedingly sandy. The topography is strongly rolling and was formerly covered by hardwoods and conifers but large areas have been cut over and burned over so that little of the original forest now remains. There are numerous lakes in the region of Douglas Lake which is about two hundred feet above sea level and some two and one-half miles wide by four miles long; its greatest depth is about ninety feet. Its shores are variable as to height and slope but are everywhere wooded.

Near the Biological Station camp on the east side of the lake where the following observations were made, the shores are low and gradually receding with a long, clean, sandy beach. Conifers, maples, birches and aspens, mostly second growth, are found though not in abundance. Blueberry bushes and brake fern make up the characteristic smaller vegetation.

Naturally such situations afford unusual inducements for nesting birds of various species. Here song sparrows, ovenbirds, slate-colored juncos, towhees, red-eyed vireos, cedar waxwings and many others find suitable sites for homes and the rearing of their young. The hermit thrush is one of the commoner summer birds of the region and several nests were discovered during the course of the eight weeks' summer session beginning June 30.

Although numerous papers have been written concerning the nesting behavior of the hermit thush, the observations made by Norman McClintock[1] in the Huron Mountains forty miles northwest of Marquette, Michigan, are the most complete and detailed of any that the writer has seen. However, the observations herein recorded are, in some respects, somwhat at variance with those of McClintock and additional data are also included in this paper.

The particular nest here discussed was accidentally discovered on July 5 by one of the members of the ornithology class but it was not under more than casual observation until July 25 when a blind was first put into position for the observers. The nest itself was built on the ground in a partly shaded area about twenty yards from the lake shore and the same distance from the mess tent which was visited three times a day by thirty-nine people. It was partially hidden among the blueberry bushes and brake fern and was composed almost entirely of pine needles with a few dead twigs at the top and on the outside for support.

The observation blind of faded, olive-green canvas was erected on two T-poles. It was about forty inches in height by twenty inches in width by thirty-eight inches in length and was placed thirty inches from the nest. Observation of the birds and nest was made possible through a slit about six inches long in the canvas and through a round hole two inches in diameter. Entrance to the blind was gained on the side away from the nest and it was left in position continuously from the time it was erected until August 8, when the birds left their home. During the process of setting up the blind the female hermit thrush flew away thus exposing the five eggs; as soon as the canvas was in place the observer left. The next morning the writer visited the blind but remained only long enough to make sure that the female was incubating. During the following night a heavy

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[1] McClintock, Norman, *A Hermit Thrush Study*, *Auk*, XXVII, 1910, 409-418.

wind disarranged the blind and while it was being repaired and readjusted on the morning of the 27th the female remained on the nest apparently little excited by the procedure.

The female remained constantly on duty until 6:00 P. M. on July 30 when she was flushed, and four nestlings, not more than twenty-four hours old, were disclosed. The fifth egg proved to be addled but remained in the nest during the entire subsequent brooding period.

BROODING

So far as our observations are concerned all the brooding was done by the female. When the young were first hatched the female seldom left them for long intervals, but toward the close of our period of observation the time spent by the adult on or at the nest was much reduced. However, it seemed that both parents were near and ready to swoop down to recover a voided excreta sac.

During the first part of the brooding the female would often rise slightly in the nest and look down at the youngsters solicitously. This occurred oftener on warm days and was probably for the purpose of giving the nestlings air. Sometimes when in this attitude the female would peck none too gently the heads and eyelids of the nestlings.

At times, while brooding, the female reached down into the bottom of the nest with her bill and shaking her head rapidly up and down or from side to side appeared to be loosening the packed-down materials. As the young grew larger the female did not sit on them but hovered over them, clinging with her feet to the sides of the nest. During the last two days of our observations she remained on its edge seldom attempting to brood the nestlings. In brooding the female always rested with her head toward the blind.

The male was much more nervous and noisy in his actions than the female. Although he took no part in the brooding he was particularly active in securing food for the young birds. Usually he left almost immediately after delivering the food, often touching the blind with the tips of his wings in his hasty departure.

FOOD AND FEEDING HABITS

Perhaps the most interesting part of the entire study was concerned with the food and feeding habits. Probably the larger share of all the food fed to the young was gleaned within a few yards of the nest.

On the writer's appearance near the blind at 7:30 A. M. of July 31 the male from a near by tree gave a sharp call, and three minutes later a rustling in the leaves on the side of the nest away from the blind betrayed his approach. The brooding female turned her head upward and backward and accepted a bit of food from him. It was impossible to identify this food for the male inserted his bill well down into the wide open mouth of the female. This was the first and, with two exceptions, the only time that one adult bird was observed to feed the other.

The following tables, chronologically arranged, will serve to show the principal details regarding the feeding of the young by the parents as well as to give data on nest sanitation. A word of explanation concerning the characters and abbreviations employed in the tables may be opportune at this point.

Lepid. larva indicates a lepidopterous larva of some kind.

Acridiid refers to any of the several species of short-horned grasshoppers which formed a substantial part of the diet of the young.

Gryllid refers to whatever species of cricket may have been served as food.

Ad. refers to one of the adults, sex undetermined.

Juv. refers to one of the nestlings.

? inserted in the "Kind of food" column indicates that the food which was brought could not be determined either from lack of ability to see it sufficiently or to properly identify it.

A blank space in any colmn indicates that such part of the observation was not made.

The usual signs ♂ (male) and ♀ (female) are used freely.

Table I—*July 31*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
7:49 A. M.	?	♂ feeds 2 juvs.		
8:04 A. M.	Lepid. larva	♀ feeds 1 juv.	None	
8:09 A. M.	?	♂ gives food to brooding ♀ who feeds 1 juv.	Deposited in nest	Picked up and swallowed by ♀
4:10 P. M.	Lepid. larva 1½" long	♀ divides larva between 2 juvs.	None	
4:12 P. M.	Acridiid	♀ feeds 1 juv.	By 2 juvs.	Received directly; swallowed by ♀
4:35 P. M.	?	♂ feeds 1 juv.	By 1 juv.	Received directly; swallowed by ♂
4:50 P. M.	Larva partly crushed	♀ feeds 2 juvs.	By 1 juv.	Received directly; swallowed by ♀
4:52 P. M.	?	♂ feeds 1 juv.	None	
4:58 P. M.	Cutworm	♀ feeds 3 juvs.	None	
5:08 P. M.	3 Acridiids	♂ feeds 3 juvs.	None	
5:17 P. M.	?	♂ feeds 1 juv.	By 1 juv.	
5:18 P. M.	?	♀ feeds 1 juv.	By 1 juv.	

General Remarks on Table I

Observations were made between the hours of 7:00 and 9:30 A. M. and 4:00 and 5:22 P. M., a total period of four hours and fifty-two minutes, during which the young were fed twelve times.

At 8:39 A. M. the brooding female partly arose from the nest and picked up an excreta sac which had been deposited by one of the young. While in most cases the parent was on the lookout at the time the excreta sac was voided, this was not invariably true. After feeding a nestling the parent bird sometimes waited for from several seconds to a minute at the edge of the nest to see if the excreta sac would be voided. Whenever it was expelled the adult ordinarily immediately swallowed it before it fell. As near as could be ascertained this excreta sac was swallowed by the parent at the nest until about noon on August 3, when the adult was first seen to carry the sac away.

The excreta sac was not always voided by a nestling immediately after it had been fed as is indicated in numerous instances in the tables. Usually when the young voided the excrement both the head and the vent were raised, although on some occasions the head was lowered in this act. The excrement appeared to be contained within this gelatinous sac during the entire time that the young were in the nest.

TABLE II—*August 1*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
9:06 A. M.	2 Lepid. larvae	♀ feeds both to 1 juv.	By same juv.	Act occurred immediately after being fed. Swallowed by ♀
9:26 A. M.	?	♂ feeds 2 juvs.	By 1 juv.	Swallowed by ♂
9:35 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
9:46 A. M.	Acridiids	♂ feeds 4 juvs.	By 1 juv.	Swallowed by ♂; leaves at once
9:52 A. M.	?	♀ feeds 2 juvs.	By 1 juv.	
9:58 A. M.	3 Acridiid nymphs	♀ feeds 2 juvs.	By 1 juv.	
10:14 A. M.	Lepid. larva 2″ long	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂; leaves at once
11:14 A. M.	Acridiid	♀ feeds 1 juv.	By 1 juv.	
11:15 A. M.	Acridiid	♂ feeds 1 juv.	By 2 juvs.	Received and swallowed by ♂
11:16 A. M.	Hairy Lepid. larva	♀ feeds 1 juv.		

General Remarks on Table II

Observations were made on this date only between the hours of 9:00 and 11:18 A. M. during which period the young were fed ten times.

From what the writer saw on this and subsequent occasions he is led to the belief that the parent birds, both of whom fed the young and removed the excreta, exercised very little choice or discrimination in selecting a certain nestling to receive whatever food was brought. One nestling might receive food two or three times in succession, while another might have to go hungry for as many visits.

During the first days of feeding the nestlings both parents announced their arrival in the vicinity by a low trill or chirp. Invariably upon hearing this note the mouths of all the youngsters were opened widely. The female ordinarily alighted about five feet from the nest, surveyed the situation for an instant, then ran toward the waiting young. The male usually arrived at or very near the nest with a considerable flutter of wings.

The hairy lepidopterous larva fed at 11:36 was an unusual morsel for the nestlings; during the entire time that the birds were under observation a hairy caterpillar was not again offered.

The larva which was brought to the young by the male at 10:14 was offered to one nestling who made a vigorous but unsuccessful attempt to swallow it. The parent seeing the dilemma of the youngster took it from his throat and ran the larva slowly and carefully through his own mandibles, in this way crushing it; he then fed it to a different nestling who also attempted the impossible. After removing the larva from his throat and crushing it still further and in the same manner as before the parent offered the now sadly bedraggled larva to the original recipient who succeeded in his efforts at swallowing it. The entire performance lasted about three minutes.

As again illustrating the fact that the young void the excrement at other times than immediately after being fed the following excerpt from the writer's notes of this date may be quoted: "At 9:19, after the female had been brooding for several minutes, she arose in the nest and took a bit of excrement from one of the nestlings."

The hour between 10:14 and 11:14 when the young were not fed was occupied partly by the female in brooding although she did not return to the nest until 10:28 at which time she brought no food.

TABLE III—*August 2*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
7:06 A. M.	?	♀ feeds 1 juv.		
7:18 A. M.	Larva	♂ feeds both ♀ and juv.		
7:25 A. M.	?	♂ feeds both ♀ and juv.		
8:08 A. M.	Insect	♀ feeds 1 juv.		
8:09 A. M.	Larva	♂ feeds 1 juv.		
8:21 A. M.	Larva	♀ feeds 1 juv.		
8:24 A. M.	Larva	♂ feeds 1 juv.		
8:26 A. M.	Larva	♀ feeds 1 juv.		
8:42 A. M.	Larva	♀ feeds 1 juv.		
8:50 A. M.	Larva	♂ feeds 1 juv.		
9:02 A. M.	Larva	♂ feeds 2 juvs.		
9:30 A M..	?	♀ feeds 2 juvs.		
10:01 A. M.	Insect	♂ feeds 3 juvs.	By 1 juv.	
10:31 A. M.	Insect	♂ feeds 2 juvs.	By 1 juv.	
10:40 A. M.	Gryllid & Acridiid	♂ feeds 1 juv.	By 1 juv.	
10:41 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
11:12 A. M.	Larva	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂
11:27 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
11:34 A. M.	Acridiid	♂ feeds 3 juvs. ♀ feeds 2 juvs.	By 1 juv.	Swallowed by ♀
11:57 A. M.	?	♂ feeds 1 juv.		
12:01 P. M.	Lepid larva	♀ feeds 1 juv.		
2:03 P. M.	?	♂ feeds 2 juvs.	By 2 juvs.	Swallowed by ♂
2:12 P. M.	?	♂ feeds 2 juvs.	By 2 juvs.	Swallowed by ♂
2:23 P. M.	Lepid. larva	♂ feeds 1 juv.	None	
2:28 P. M.	?	♂ feeds 1 juv.	None	
2:29 P. M.	?	♂ feeds 3 juvs.	None	
3:15 P. M.	Leg of Acridiid	♀ feeds 1 juv.	None	
3:23 P. M.	Fragment of Acridiid	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
3:25 P. M.	?	♂ feeds 1 juv.	None	
3:35 P. M.	?	♀ feeds 1 juv.	None	
3:46 P. M.	?	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂
4:21 P. M.	Lepid. larva	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
4:39 P. M.	?	♂ feeds 2 juvs.	By 1 juv.	Swallowed by ♂
4:45 P. M.	Moth	♀ feeds 2 juvs.	None	
4:52 P. M.	Gryllid	♀ feeds 1 juv.	None	
5:06 P. M.	Insect	♀ feeds 1 juv.	None	
5:16 P. M.	Green Lepid. larva	♀ feeds 1 juv.	None	

General Remarks on Table III

On this date observations were made between 9:00 A. M. and 12:01 P. M. and between 2:00 and 5:18 P. M. during which period thirty-eight feedings were administered.

The insect fed to the nestling at 8:08 was secured by the female not more than a foot from the nest. She left her brooding only long enough to capture the insect and to feed it to the nestling then resumed her place on the nest.

At 11:34 both parents appeared at the nest with food at about the same time, an unusual occurrence.

At 11:52 A. M. and again at 3:02 P. M. one of the nestlings defecated without having been fed. The excreta sac was taken from the vent of the nestling and swallowed by the brooding female on both occasions.

At 4:50 the female picked and ate blueberries near the nest but offered none to the nestlings. At no time during our observations were the young offered berries or fruit.

TABLE IV—*August 3*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
9:12 A. M.	?	♂ feeds 2 juvs.		
9:17 A. M.	?	♀ feeds 2 juvs.	By 1 juv.	Swallowed by ♀
9:35 A. M.	Lepid. larva & 2 Acridiids	♂ feeds 2 juvs.	By 1 juv.	Swallowed by ♂
9:43 A. M.	2 Gryllids	♂ feeds 2 juvs.	None	
9:54 A. M.	1 Gryllid	♂ feeds 1 juv.	None	
9:56 A. M.	1 Gryllid	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
9:57 A. M.	Spider	♂ feeds 1 juv.	None	
10:14 A. M.	2 Gryllids	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂
10:15 A. M.	2 Gryllids	♀ feeds 1 juv.	By 2 juvs.	Swallowed by ♀
10:27 A. M.	1 Gryllid & 1 Acridiid	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂ as he flew away
10:42 A. M.	Lepid. larva & Gryllid	♂ feeds 1 juv.	By 1 juv. (not the one fed)	Swallowed by ♂
10:43 A. M.	?	♀ feeds 1 juv.	None	
10:50 A. M.	Gryllid	♂ feeds 1 juv.	None	
10:54 A. M.	1 Acridiid & 1 Gryllid	♀ feeds 1 juv. both insects at same time	By 1 juv. (not the one fed)	♀ flies away with excrement in bill
3:10 P. M.	Insect	♀ feeds 1 juv.	None	
3:28 P. M.	Insect	♀ feeds 1 juv.		
3:42 P. M.	3 insects	♀ feeds 4 juvs.		
3:45 P. M.	Insect	♀ feeds 1 juv.		
3:58 P. M.	?	♂ feeds 1 juv.	None	
4:08 P. M.	Several insects	♂ feeds 2 juvs.		
4:11 P. M.	Larva	♀ feeds 3 juvs.		Excreta swallowed by ♀
4:22 P. M.	?	♂ feeds 2 juvs.		
4:30 P. M.	?	♀ feeds 2 juvs. (not the ones just fed)		
4:35 P. M.	?	♂ feeds 1 juv.		
4:52 P. M.	Insect	♀ feeds 3 juvs.		
4:59 P. M.	?	♂ feeds 1 juv.		

General Remarks on Table IV

The observations on this date covered the time between 8:55 and 11:00 A. M. and 3:05 and 5:06 P. M. during which twenty-six feedings were administered.

The male usually announced his arrival by a low trill and as soon as the brooding female heard it she left the nest. Almost immediately after feeding the young he flew away again. This behavior was fairly constant throughout our observations.

The foregoing table shows a greater variety of food brought to the nestlings than heretofore.

At 9:57 both parents were at the nest with food. At 4:58 the female after having been absent for four minutes returned without food.

Apparently the young defecate only when one of the parent birds is at the nest.

TABLE V—*August 4*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
7:25 A. M.	?	♀ feeds 4 juvs.	By 1 juv.	
7:31 A. M.	Lepid. larva	♀ feeds 4 juvs.		
7:34 A. M.	?	♂ feeds 1 juv.		
7:50 A. M.	Lepid. larva	♂ feeds 2 juvs.	By 2 juvs.	Swallowed by ♂
8:02 A. M.	?	♀ feeds 1 juv.	♀ picks bit of excrement from bottom of nest and swallows it	
8:16 A. M.	Lepid. larva	♂ feeds 1 juv. (leaves at once).		
8:26 A. M.	Green lepid. larva	♀ feeds 2 juvs.	By 1 juv.	♀ flies away with it
8:32 A. M.	?	♂ feeds 3 juvs. (leaves at once)		
8:40 A. M.	?	♂ feeds 2 juvs. (leaves at once)		
8:43 A. M.	?	♀ feeds 3 juvs.		
8:46 A. M.	Larva	♂ feeds 1 juv. (leaves at once)		
8:50 A. M.	?	♂ feeds 1 juv.	By 1 juv	Removed by ♂
8:51 A. .M	?	♀ feeds 2 juvs.		
8:52 A. M.	?	♂ feeds 1 juv.		
9:07 A. M.	Larva	♂ feeds 3 juvs.		
9:09 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
9:16 A. M.	?	♂ feeds 2 juvs.	None	
9:32 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
9:42 A. M.	?	♀ feeds 3 juvs.		
9:45 A. M.	Green lepid. larva	♂ feeds 1 juv. (leaves at once)		
10:03 A. M.	Insect	♀ feeds 2 juvs.	By 1 juv.	Swallowed by ♀
10:06 A. M.	Gryllid	♂ feeds 2 juvs.	By 1 juv.	♂ flies away with excrement in bill
10:18 A. M.	Green lepid. larva	♂ feeds 2 juvs.		
10:25 A. M.	Green lepid. larva	♀ feeds 1 juv.	By 1 juv.	♀ flies away with excrement in bill
10:48 A. M.	Green lepid. larva	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
10:55 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
3:12 P. M.	?	♂ feeds 1 juv.		

3:20 P. M.	Insect	Ad. feeds 3 juvs. (leaves at once)		
3:31 P. M.	Insect	♂ feeds 1 juv.	By same juv. as fed	Swallowed by ♂
3:34 P. M.	?	♀ feeds 1 juv. (leaves at once)		
3:48 P. M.	?	Ad. feeds 1 juv.	By 1 juv.	Ad. leaves with excrement in bill
4:02 P. M.	?	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂
4:03 P. M.	?	♀ feeds 1 juv.		
4:08 P. M.	?	♂ feeds 1 juv.	By 1 juv.	♂ flies away with excrement in bill
4:35 P. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
4:41 P. M.	?	♂ feeds 2 juvs.		
5:52 P. M.	?	Ad. feeds 1 juv.		
5:53 P. M.	?	♀ feeds 1 juv.		
5:55 P. M.	?	♂ feeds 1 juv.	By 1 juv.	♂ flies away with excrement in bill

General Remarks on Table V

The observations on this date were made between 7:05 and 11:05 A. M. and between 3:00 and 6:02 P. M. during which period the young were fed thirty-nine times. As before, the male usually announced his arrival at or near the nest by a low trill.

Under the caption "excreta sac removed by ♂" the observer was not sure whether the excreta was swallowed or simply removed. In some cases the adults flew away with the excreta sac in the bill. Whether it was subsequently swallowed was not ascertained.

The nestling fed at 9:09 was one of the three that had been fed by the male at 9:07. It still seemed that the parents used little selection or discrimination in feeding the young. At 9:16 the nestling first fed was the one that had been neglected at the two preceding feedings.

At 3:25 both parents were away from the nest and the nestlings were apparently suffering from the heat. Neither adult was at the nest between 4:43 and 5:52, an unusually long absence.

TABLE VI—*August 5*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
9:40 A. M.	?	♀ feeds 1 juv.	By 1 juv.	Swallowed by ♀
9:45 A. M.	?	♂ feeds 1 juv.	By 1 juv.	Swallowed by ♂ (leaves at once)
9:50 A. M.	?	♀ feeds 1 juv.		
9:55 A. M.	?	♀ feeds 1 juv.		
10:02 A. M.	Larva	♂ feeds 1 juv. (leaves at once)		
10:10 A. M.	?	♀ feeds 1 juv. (leaves at once)		
10:14 A. M.	Insect	♂ feeds 1 juv.	By 1 juv.	♂ leaves with excrement in bill
10:16 A. M.	Gryllids	♂ feeds 2 juvs.	♂ picks up excrement from bottom of nest and flies away	
10:27 A. M.	?	♀ feeds 1 juv.		♀ flies away with excrement in bill
11:14 A. M.	Gryllids	♂ feeds 1 juv. (leaves at once)		
11:16 A. M.	Insect	♀ feeds 1 juv.		
11:18 A. M.	Green larva	♀ feeds 1 juv. (flies away at 11:19)		
11:22 A. M.	Gryllid	♂ feeds 1 juv.		
11:24 A. M.	?	♂ feeds 1 juv.		
11:25 A. M.	?	♀ feeds 1 juv.		
2:02 P. M.	Gray Lepid. larva	♂ feeds 1 juv. (leaves at once)		
2:07 P. M.	?	♂ feeds 1 juv. (leaves at once)		
2:17 P. M.	3 Gryllids	♀ feeds 3 juvs.	1 juv. deposits pellet of excrement in nest; seized by ♀ who flies away at once	
2:22 P. M.	1 Gryllid	♀ feeds 1 juv.	By one juv.—not the one fed—swallowed by ♀	
2:41 P. M.	1 Gryllid	♂ feeds 1 juv. (leaves at once)		
2:51 P. M.	1 Gryllid & 1 Acridiid	♂ feeds 2 juvs.	♂ received pellet of excrement and flew away	
2:57 P. M.	Gryllid	♀ feeds 1 juv.	♀ waits a few seconds for pellet of excrement and flies away	
3:05 P. M.	Gryllid	♀ feeds 1 juv.		
3:17 P. M.	1 Gryllid & 2 Acridiids	♀ feeds 3 juvs.	♀ receives pellet of excrement from 1 juv. and flies away	
3:30 P. M.	?	♀ feeds 1 juv.	♀ swallows pellet of excrement and flies away	
3:31 P. M.	?	♂ feeds 1 juv.	♂ swallows pellet of excrement and flies away	
4:00 P. M.	Green lepid. larva	♂ feeds 1 juv.	♂ swallows pellet of excrement and flies away	

General Remarks on Table VI

Observations were made on this date between 9:30 and 11:30 A. M. and between 2:00 and 4:02 P. M. during which time the young received twenty-seven feedings.

The nestlings appeared more active than at any previous date, moving about in the nest, scratching their heads and eyes with their feet and pecking at their own plumage as if dressing and preening it.

At 10:35 the female, after an absence of eight minutes, arrived at the nest without food but remained for only three minutes; this time she occupied in pulling and pushing the nest materials about as if to make the home more tidy.

At 11:27 the observer noted the female chasing a grasshopper near the nest; she was unsuccessful in her attempts to catch the insect.

Again at 3:57 P. M. the female arrived without food; upon her arrival all the mouths opened as usual and the adult pecked the inside of the mouth of one nestling as if to make him believe he were being fed. The ruse seemed to have the effect of quieting the youngster.

TABLE VII—*August 6*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
3:11 P. M.	?	♀ feeds 1 juv.		
3:23 P.M.	Insect	♂ feeds 1 juv.	♂ receives pellet of excrement and flies away	
3:48 P. M.	Larva	♀ feeds 2 juvs.	None	
3:51 P. M.	Insect	♂ feeds 1 juv.		
4:10 P. M.	Insects	♀ feeds 3 juvs		
4:55 P. M.	Insect	♀ feeds 1 juv.		

General Remarks on Table VII

Observations were conducted only between the hours of 3:05 and 5:06 P. M. during which time the young received six feedings.

The adults remained away from their brood a great deal of the time, and the number of feedings was somewhat reduced, averaging but three per hour.

The nestlings were now so large as to occupy almost the entire space within the nest, leaving little room for the parent who often sat at the edge looking at her brood. The young birds were well feathered and appeared more alert to outside disturbances than before. They flapped their wings from time to time in an apparent attempt to leave the nest and pulled and tugged at their plumage as if to clean it.

At 3:47 the female returned without food, remained but a moment, then flew away. Again at 4:32 the female returned without food and remained sitting on the edge of the nest looking at the nestlings.

TABLE VIII—*August 7*

Time of feeding	Kind of food	Remarks	Disposition of excreta	Remarks
7:25 A. M.	?	Ad. feeds 1 juv.	Ad. leaves after picking up excrement	
8:00 A. M.	?	Ad. feeds 3 juvs.	Ad. flies away at once with excrement in bill	
8:07 A. M.	?	Ad. feeds 2 juvs.	Ad. waits in vain 2 minutes for juv. to defecate—flies away	
8:17 A. M.	?	Ad. feeds 1 juv.	Ad. flies away with excrement	
8:22 A. M.	?	Ad. feeds 1 juv.	Ad. flies away with excrement	
8:24 A. M.	?	Ad. feeds 1 juv.	Ad. flies away with excrement	
8:26 A. M.	Acridiid	Ad. feeds same juv. as at 8:17	Ad. flies away with excrement	
8:31 A. M.	?	Ad. feeds 1 juv.		
8:40 A. M.	?	Ad. feeds 1 juv.		
8:57 A. M.	?	Ad. feeds same juv, as at 8:40		
10:24 A. M.	?	Ad. feeds 1 juv.	None	
10:30 A. M.	Larva	♀ feeds 3 juvs.	By 1 juv.	♀ flies away with it
10:37 A. M.	Black insect & Acridiid	♀ feeds 1 juv.	By 1 juv.	♀ flies away with it
10:40 A. M.	Acridiid	Ad. feeds 1 juv.		
3:50 P. M.	?	♂ feeds 1 juv.	By 1 juv.	♂ flies away with it
3:55 P. M.	?	♂ feeds 1 juv.	By 1 juv.	♂ flies away with it
3:57 P. M.	Larvae	♀ feeds 3 juvs.	Not until 4:01	♀ swallows it
4:30 P. M.	?	♂ feeds 1 juv.		

General Remarks on Table VIII

Observations were conducted between the hours of 7:20 and 11:00 .A M. and between 3:00 and 5:00 P. M. during which period eighteen feedings were administered and excreta sacs were voided twenty-one times.

The nestlings appeared even more restless than on the preceding day. They were continually shifting their positions, preening their feathers, trying their wings and pecking the side of the nest or one another.

The adults absented themselves for considerable periods of time. Neither parent visited the young between 3:00 and 3:30 P. M. at which time the male returned without food and remained at the edge of the nest for twelve minutes.

At 9:16 one of the adult birds suddenly swooped down from a nearby perch, picked up a voided excreta sac and carried it away; again at 9:24 and 9:38 this performance was repeated. At 9:46 the female returned cautiously, obtained a voided excreta sac and flew away. Excreta sacs were removed by the adults also at the following hours: 10:07, at which time two sacs were voided by different birds, 10:15, 3:45, 4:04 and 4:44. At none of these times were the adults on the nest but apparently they were on watch near by. Food was not brought on any of these visits which were apparently solely for the removal of the excreta sacs.

At 8:43 a chipmunk appeared near the blind and immediately upon discovering it the female dashed at the rodent from a near by log. She followed the intruder with much pecking and flapping of wings until he sought the friendly refuge of the mess tent a few yards away.

OBSERVATIONS ON AUGUST 8

On August 8 observations were begun at 7:00 A. M. when both parents were absent from the nest. While the writer was attempting to lift up one of the young birds in his hands it escaped, and, at the same time, two of the other nestlings with much squawking, fluttered off through the ferns and bushes amid the excited cries of the parents in the low branches of trees a few feet away. In its effort to repel the intruder one of the adult birds flapped him on the head with its wings. During all this excitement one nestling remained on the nest, but at 7:03 it too left, half flying, half running through the blueberry bushes. The young were by this time well scattered and the adult birds called every few seconds for over an hour, the nestlings answering at intervals.

At 7:07 the female returned to the nest which now contained only the addled egg and three excreta sacs with one of which she immediately flew away. At 7:10 she returned for another sac and a minute later she flew back for a third sac which she carried away. She did not seem excited at the absence of the nestlings and apparently was preparing the nest for further use.

The female visited the nest again for a moment at 7:13 and at 7:48 she returned, pecked two or three times in the bottom, walked across it and flew away, returning once more at 7:53 when the same performance was noted.

At 8:10 one of the adults with food in its bill alighted on a low limb of a birch tree near by; every few seconds it called to the young. Fifteen minutes later an adult bird carrying food was again observed in the vicinity. It uttered an unbroken series of low clucks and after a moment flew to the ground where one of the young was calling and probably fed it, for not a sound was heard from this spot for more than a minute.

Although the family was now dispersed the adults seemed to be as active as ever in feeding the nestlings and not much time was lost in idleness once the disturbance of the morning had abated.

The nest and vicinity were again inspected in the evening but no trace of the adults or young was discovered; only the addled egg remained. Our observations were thus brought to a rather sudden and untimely end. However, it seems certain that in another twenty-four hours the young would have left the nest of their own accord instead of in the rather unsummary and irregular manner herein described.

Although nothing was seen of the young thrushes subsequent to this episode it is likely that they remained in the vicinity for a time or at least until they could fly well. Concerning the habits of this species after deserting the nest Audubon remarks.[2] "The young run after the parents, on the ground, for several days after they leave the nest." Similar and corroborative observations have since been made on this point although the writer was unable to follow up this phase of the study to his own satisfaction.

TABLE IX—TABULAR SUMMARY

Date	No. hrs. observation	No. times food was brought to young
July 31	4 hrs. 52 min.	12, ♂ 6, ♀ 6
August 1	2 hrs 18 min.	10, ♂ 4, ♀ 6
August 2	8 hrs. 18 min.	38, ♂ 20, ♀ 18
August 3	4 hrs. 6 min.	26, ♂ 15, ♀ 11
August 4	7 hrs. 2 min.	39, ♂ 21, ♀ 15 sex undetermined on 3 occasions
August 5	4 hrs. 2 min.	27, ♂ 11, ♀ 16
August 6	2 hrs. 1 min.	6, ♂ 2, ♀ 4
August 7	5 hrs. 40 min.	18, ♂ 3, ♀ 3 sex undetermined on 12 occasions
Total	38 hrs. 29 min.	176

GENERAL SUMMARY

1. Observations on the young in the nest were conducted over a period of thirty-eight hours and twenty-nine minutes between July 31 and August 8. During this time 176 feedings were administered.

2. Brooding was carried on only by the female.

3. At no time during our observations were the young indulged with a vegetarian diet, although the adults were seen to eat blueberries on at least two occasions. The food of the nestlings was entirely of insects either in the larval or adult stage.

4. On many occasions the parent bird fed more than one nestling. At no time was feeding by regurgitation observed.

5. At no time during our observation was the male hermit thrush heard to sing, although the familiar high-pitched call very like that of the cedar waxwing was given often.

6. The nestlings did not always void the excreta sac immediately after being fed, sometimes not for several minutes or even longer after the act of feeding occurred.

7. During approximately the first half of the nestling period the adults swallowed the excreta sac. During the latter half of

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[2] Audubon, John James, *American Ornithological Biography*, I, 1831, 303.

the period the sac was usually, although not invariably, carried away. The female was seen to swallow an excreta sac at the nest on August 7.

8. Toward the close of the nestling period the adults remained away from the nest for considerable intervals. Sometimes the adults returned to the nest without food and only for the purpose of carrying away the voided excreta sacs.

9. The male and female each had their own particular mode of approach to the nest, the female usually alighting a few feet from it and running quietly up to the young while the male usually alighted almost immediately at the nest with food. He was more nervous and noisy in his actions than the female.

FIRST SERIES No. 40 JANUARY 1, 1921

UNIVERSITY OF IOWA STUDIES

STUDIES IN NATURAL HISTORY

VOLUME IX NUMBER 3

THE EROSIONAL HISTORY OF THE DRIFTLESS AREA

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PUBLISHED BY THE UNIVERSITY, IOWA CITY

Issued semi-monthly throughout the year. Entered at the post office at Iowa City, Iowa, as second class matter. Acceptance for mailing at special rates of postage provided for in section 1103, Act of October 2, 1917, authorized on July 3, 1918.

UNIVERSITY OF IOWA STUDIES
IN NATURAL HISTORY

PROFESSOR CHARLES CLEVELAND NUTTING, M. A., Editor

Continuation of Bulletin from the Laboratories of Natural History of
the State University of Iowa

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PART I

MULTIPLE EROSION CYCLES IN PRINCIPLE

CONTENTS

PART I

MULTIPLE EROSION CYCLES IN PRINCIPLE

INTRODUCTORY SKETCH

First steps in the interpretation of the erosional histories of regions were taken when (1) the processes of land degradation by streams were worked out, (2) the limits of change were recognized, and (3) the stages of reduction, expressed in the terms *youth, maturity,* and *old age* were described.

Second steps were taken by Dutton[1] who conceived that the Arizona plateau had been degraded to low levels and then had been uplifted in such a way as to start new cycles of erosion. Following the lead of Dutton but bringing to bear upon their studies critical and analytical methods Willis[2], Hayes and Campbell[3], Davis[4] and others wrote histories of parts of the Appalachian mountains, not only presenting and explaining evidences of more than one cycle of erosion, but working out evidences of more than two cycles, describing the degree of completeness of reduction reached in each cycle, giving the geologic dates of each event in the erosional history of the region, interpreting the number, character and dates of uplift, etc. But, by its very thoroughness and accuracy, this work has led unfortunately to confusion. Later the principles so well used in the Appalachian region were applied, with little consideration, to regions where their application was doubtful. Complex series of events were thus assigned to regions whose histories were simple, and there came to be more raised peneplains in literature than in the field. The care-

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[1] Dutton, C. E., "Tertiary History of the Grand Canyon District," *U. S. Geol. Surv.*, Monograph No. 2, 1882.

[2] Willis, Bailey, *The Northern Appalachians, Physiography of United States,* 1895, pp. 169-202.

[3] Hayes, Willard C., and Campbell, M. R., "Geomorphology of the Southern Appalachians," *Nat'l Geog. Mag.*, Vol. VI (1894), pp. 63-126.

[4] Davis, W. M., "Rivers and Valleys of Pennsylvania," *Nat'l Geog. Mag.*, Vol. I (1889), pp. 183-253.

lessness of physiographic interpretation during this time was followed by a period of reaction ushered in by the criticism of Tarr[1] who seems to have been the first to sound a note of warning and present the idea that not all flattish surfaces above streams are old peneplains.

But now Tarr's argument in turn seems to have been carried beyond the point intended by its author, for many geologists having convinced themselves and others that some physiographic features which have been described as raised peneplains are not old erosion surfaces, have proceeded to the extreme conclusion that there are no such things as raised peneplains and consider no evidence either in favor of or against the peneplain theory in working out the histories of regions in the field. The conclusion that because some upland flats are not old peneplains there is no such thing as raised peneplains is as unwarranted and as great a detriment in the search for truth as was the conclusion of the older physiographers that because some upland surfaces were old peneplains, all such surfaces could be identically interpreted.

The extreme reaction against the peneplain theory seems to be giving way at present to a revival of interest in the subject, as shown in the spirited discussion among Umpleby[2], Atwood[3], Blackwelder[4], and Rich[5], all of whom assume the existence of a raised peneplain and differ among themselves only in regard to the age of the plain. R. T. Chamberlin[6] also clearly believes in the peneplain theory, as evidenced in one of his latest productions. Physiographers seem still to be about evenly divided into two groups, the members of one of which disregard the peneplain theory en-

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[1] Tarr, Ralph S., "The Peneplain," *Am. Geol.* Vol. XXI (1898), pp. 351-371.

[2] Umpleby, Joseph B., "An Old Erosion Surface in Idaho—Its Age and Value as a Datum Plane," *Jour. Geol.*, Vol. XX, No. 2, pp. 139-147; "An Old Erosion Surface in Eastern Utah—Its Age and Value in Time Determination," Abstract, *Wash. Acad. Sci. Jour.*, Vol. 2, pp. 109-110, 1912; "The Old Erosion Surface in Idaho," *Jour. Geol.*, Vol. XXI. pp. 224 et seq, 1913.

[3] Atwood, Wallace W., "The Physiographic Conditions at Butte, Montana and Bingham Canyon, Utah When the Copper Ores in These Districts were Enriched," *Econ. Geol.*, Vol. XI, pp. 687-740, 1916; "Physiographic Conditions and Copper Enrichment," *Econ. Geol.*, Vol. XII, pp. 545-547, 1917.

[4] Blackwelder, E.. "Physiographic Conditions and Copper Enrichment," *Econ. Geol.*, Vol. XII, pp. 541-545, 1917.

[5] Rich, John L., "An Old Erosion Surface in Idaho: Is it Eocene," *Econ. Geol.*, Vol. XIII, No. 2, March, 1918.

[6] Chamberlin, R. T., "The Building of the Colorado Rockies," *Jour. Geol.*, Vol. XXVII, pp. 145-251.

tirely in field work, while those of the other group believe that raised peneplains exist, but are doing little constructive thinking or writing in substantiation of the theory itself.

It now seems appropriate to bring together all the methods which have been used in the interpretation of erosional histories, to analyze each method, to discuss its uses and abuses, and to attempt to assign to each its proper value. These are the purposes of this paper.

Both in the analysis of the principles and in the construction of the paper, the writer has been greatly assisted by Professors R. D. Salisbury, M. M. Leighton, and Leroy Patton, of whom all were so kind as to read the first draft and to make helpful suggestions for incorporation in the final paper.

MORE THAN ONE CYCLE OF EROSION

Theoretic Considerations

The rate of land degradation by streams has been estimated at 1 foot in 9000 years, under conditions which exist in the United States[1]. If the average altitude of the land today be taken as 2300 feet it would take more than 20,000,000 years for streams to reduce the land to sea level. But the process of degradation becomes slower as the lands are reduced. This progressively decreasing rate of reduction carried through from youth to the ideal baselevelled condition would involve an amount of time approaching infinity. Indeed, it seems doubtful if geologic time has been as long as a *complete* cycle of erosion would be. But, though it be uncertain that lands were ever reduced to base level, they have been reduced to low levels; that is, *perfect baselevel plains* are probably not formed, but *peneplains* may be. There is no theoretic reason for believing that extensive areas have not been peneplained again and again.

If the history of land surfaces were merely a matter of formation and subsequent degradation, most lands should to-day be in the condition of peneplains. The fact that

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[1] Water Supply Paper No. 234, U. S. Geological Survey, pp. 78-83.

high lands exist demonstrates that there are forces which give lands high altitudes and that these forces, on the average, at least balance the processes of degradation. These renewing forces are diastrophic.

There is not perfect agreement among geologists concerning some of the phases of diastrophism, but the principles involved in land formation are fairly well agreed upon. Lands are due to lithospheric contraction. As the lithosphere shrinks, the ocean basins settle more than the continental platforms, the capacity of the ocean basins increases, the water withdraws from the continental platforms, and lands are increased in area or height or both. If lands have been reduced to low levels and the lithosphere shrinks, these lands are left higher by the withdrawal of the sea and a new cycle of erosion is inaugurated.

If diastrophism were a continuous process, land would be reduced slowly if general degradation exceeded uplift, it would remain at a generally constant level if degradation and uplift were equal, and it would become slowly higher if uplift took place more rapidly than degradation. The height of land would depend upon a balance between diastrophic uplift and degradation by all agents of which running water is chief.

Pronounced diastrophism manifests itself periodically rather than continuously. Degradation goes on uninterruptedly between periods of diastrophism, but sooner or later the uplift comes, degradation is renewed and new cycles of erosion are inaugurated.

The relative duration of erosion cycles and diastrophic periods now becomes important. If the diastrophic period is longer than the erosional cycle, land is totally destroyed and then formed again. If the periodic uplifts come so frequently and the land is uplifted each time so high that the land added by each uplift is not entirely destroyed before the next uplift, the history is one of land increase, partial degradation, further increase, partial degradation, and so on. Neither the cycle of erosion nor the diastrophic period is of determinate duration, and therefore there can be no invariable rule in their relative values, but a study of geologic history leads to the conclusion that the *complete* erosion cycle is in most cases at least longer than the diastrophic period. This being the case most cycles of erosion are interrupted by uplift and few if any cycles of erosion have been complete. Doubtless there have been cases in which lands have been so reduced by all the agencies at work on their surfaces and by deposition in the sea that the sea spread over them, but probably there has never been a time when whole continents have been so destroyed. In any case the present paper deals only with those surfaces which have not been reduced to the condition of submergence.

The question now arises as to what stage of degradation is reached by the average surface before the cycle is interrupted. Tarr[1] has argued that because there are few if any low level plains to-day which have been developed by streams, there never have been any and that pleneplains have never existed. This conclusion is hardly warranted, for the present day may be one closely following an uplift.

The writer would agree that probably no continent-wide and perfectly flat erosional plains have been developed in the past, but he cannot agree that smaller areas have not been brought to an earlier stage of reduction which might be defined by the term peneplain.

It seems unavoidable to suppose that erosion cycles might be interrupted either in youth, maturity, or old age. But interruption in old age should theoretically be most common, for degradation takes place most rapidly in youth and maturity, and is much slower in old age. Land is reduced rather quickly to the peneplain stage but further reduction to complete base level is almost infinitely slow. That is, in a complete cycle the stage of old age would be longer than youth and maturity.

If a region reached old age in the first cycle and has gone only to maturity of the second, some of the characteristics of the first cycle will have held over into the second, and the history should be ascertainable. If on the other hand, a region is in youth of the first cycle when the interruption

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[1] Tarr, R. S., "The Peneplain," *Am. Geol.*, Vol. 21, pp. 351-370.

occurs, and it is in youth of the second cycle at the time of observation, it would be almost impossible to determine that it had entered upon a second cycle. It would be still more difficult to interpret the history of a region in which a cycle of erosion had gone so nearly to completeness that all evidences of a former cycle had been obliterated. Indeed, satisfactory determination seems to be almost limited to cases where each cycle of erosion is less nearly complete than those which preceded.

Evidences of More Than One Cycle of Erosion

Several different physiographic features have been used as criteria for more than one cycle of erosion in the history of land surfaces. If their relative values are to be fixed, it is necessary that each of these features be analyzed.

Interrupted Profile

Streams which have reached grade, normally have concave profiles with progressively decreasing gradients from source to debouchure. (abc Fig. 1). If such a profile be developed in old age of a first cycle of erosion and if the region then be uplifted so that a steep bordering slope is formed, rejuvenating the stream, degradation will be renewed first near the mouth of the stream, where a new valley and a new profile will be developed. As this new valley, with its profile, is extended headward, there will come a time when there is a double or interrupted profile (abe Fig. 1) in which the upper portion was made in the

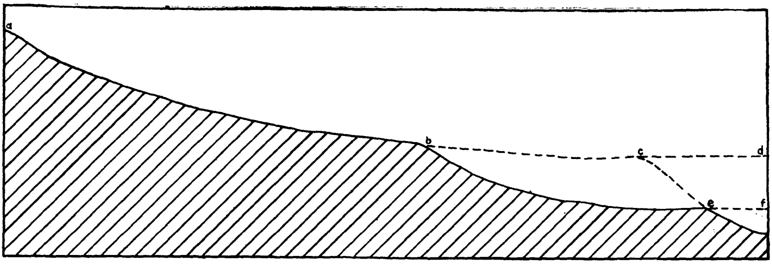

Fig. 1. A diagram in explanation of interrupted profile due to rejuvenation of a stream. abc is the profile of the stream in old age of the first cycle when sea level was cd. abe is the profile after sea level has taken the position ef and the rejuvenated stream has worked headward to be.

first cycle and the lower portion in the second cycle of erosion.

There are, however, distinct limitations to the use of interrupted profiles as criteria of rejuvenated streams. Any stream which flows across resistant to non-resistant rock, and which has not yet brought the resistant rock to grade, may develop an interrupted profile in a single cycle of erosion. (Fig. 2). If a relatively flat surface emerged from the sea and came to stand distinctly above its surroundings, as in the case of a plateau, water would run down the gently sloping summit surface and down the steep bordering slope and would acquire an interrupted profile which would last until the lower portion of the stream had worked headward to the very source of drainage. Any region therefore having unequally resistant rock or any flattish surface bordered by a distinct descent, may have streams with interrupted profiles.

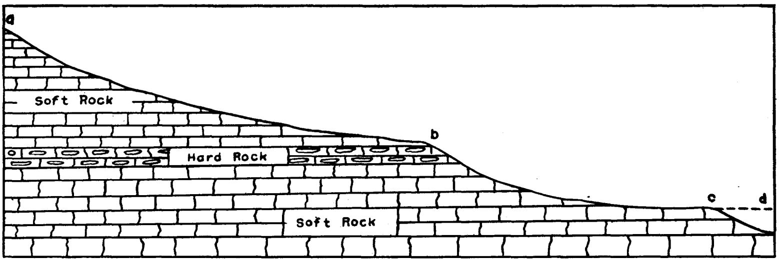

Fig. 2. Diagram showing how interrupted profile abc may be developed in a single cycle of erosion with reference to sea level cd, due to inequalities in the hardness of the rock formations.

In the abstract, interrupted profiles in the streams of a region merely suggest that the region may be in the second cycle; they do not furnish strong evidence, much less proof, of a second cycle. They amount to strong evidence, only after all other possible interpretations have been eliminated by careful study in the field.

Stream Terraces

The uplift of a surface in which a stream has previously reduced its bed to grade and developed a valley flat causes the stream to intrench itself in the flood plain and form terraces. (Fig. 3). Terraces so formed involve more than one cycle of erosion.

However, stream terraces are formed in a single cycle of erosion (1) by unequal widening at the levels of unequally resistant horizontal strata, (2) by the partial removal of glacial or fluvio-glacial fills in valleys, (3) by the recession of falls through temporarily graded valley bottoms, (4) by the removal of dams, such as landslides, lava flows, sand dunes, etc., (5) by renewed erosion of a valley flat, due to increased volume in a pirate stream, (6) by the intrenchment of graded valley bottoms as a stream acquires greater length and more and longer tributaries and comes to drain a larger area, and increases in volume, (7) by a graded stream receiving less load from its head as gradients are lowered, and intrenching itself, (8) by a stream picking up much fine material from its flood plain and dropping less coarse material in its place, (9) by the shifting of meander belts down stream, etc. These are common processes and all the events in the history of many stream terraces take place in a single erosion cycle.

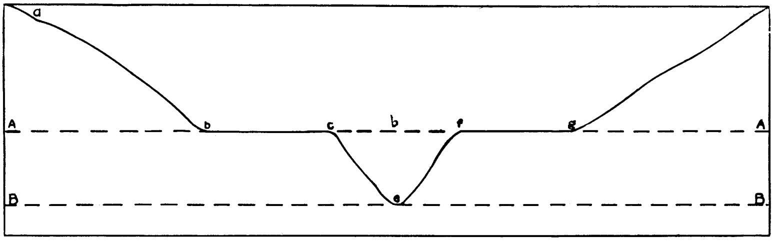

Fig. 3. Diagram showing how stream terraces may be formed by uplift of the surface after a stream has developed a valley flat. The profile abcdfgh is the cross section of the valley after grade level AA has been reached. By uplift a new level was established at BB, the rejuvenated stream cut the new valley cef, and terraces bc and fg were formed.

From the above, it is clear that terraces along the streams of a region can seldom be used as adequate evidence of more than one cycle of erosion. On the other hand, if stream terraces can be analyzed and all possibilities can be eliminated except the one involving more than one cycle of erosion, they might be considered to be more than merely suggestive of a second cycle, especially if there are other evidences which corroborate the conclusion.

Intrenched Meanders

Meandering streams in young valleys have long been used as evidence of second cycles of erosion in regions. By some they have been used as proof, even in regions which afford practically no other evidence of more than one cycle of erosion[1]. As commonly interpreted, the history of intrenched meanders is somewhat as follows: (1) in a first cycle of erosion a stream reaches grade, becomes sluggish, and develops a broad valley flat and broad meanders; (2) the surface is uplifted relative to sea, the stream is rejuvenated, and intrenches itself without changing its meandering course.

The value of intrenched meanders as evidences of more than one cycle depends upon the definition of meanders, and the accuracy with which they may be distinguished from other crooks in streams. During all stages of their history all streams are more or less crooked. The first water which flows over a newly formed land surface concentrates in crooked courses, (1) where there are original depressions irregularly distributed, (2) where unequally resistant materials are not arranged in orderly fashion, or (3) where there are differences in the amount of water supply. If in this stage the streams are flowing over a low, almost flat surface, they are easily deflected and curves are developed which are identical in principle with meanders developed on valley flats by streams at grade. In this first stage of its history such a stream is said to be consequent and its curves might be called *consequent crooks*. Continuing their histories, such streams lengthen by headward erosion, their heads being extended up the steepest slopes, through the least resistant material, and toward the greatest water supply. Inasmuch as these determining conditions are irregularly distributed on most surfaces, this stage of stream adjustment involves the development of a second set of crooks which are also consequent. As the cycle of valley development and the cycle of land reduction continue, a third stage is reached in which stream piracy takes place,

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[1] Gannett, Henry, "Physiographic Types," Folio No. 1, *U. S. Geol. Surv.* Fourth map and page 2.

streams are diverted and beheaded, drainage is reversed in direction, and still other crooks are developed. During any one of these first stages in stream adjustment, streams may reach *temporary grade,* on the upstream sides of resistant rock or upstream from glacial dams, blocking lava flows, landslides, or artificial dams, and develop meanders. Finally, when the stream has developed its valley to old age, has large tributaries and large volume, and has reached a still later stage of adjustment, the stream is sluggish, is likely to be depositing, is easily turned from side to side, and stream meanders, as the term is commonly applied, are formed. The crooks developed in the first three stages as outlined above, may be formed and intrenched in a single cycle of erosion. It would require an uplift and a second cycle of erosion for the intrenchment of the meanders developed in the fourth stage. If meanders be defined as the curves acquired by a stream in the late stages of valley development, intrenched meanders would be proof of a second cycle of erosion. But a difficulty lies in distinguishing such meanders from crooks developed during earlier stages.

The writer does not see any means of distinguishing crooks developed in youth on a flat surface (Fig. 4, AA and BB) nor meanders formed on temporary flood plains upstream from obstructions, from meanders developed in old age (Fig. 4 DD and EE). It seems even difficult, and in many cases impossible to distinguish the meanders of old age from ordinary crooks due to topography, irregularities of resistance, or stream piracy (Fig. 4 CC).

It has been said that meanders differ from other crooks, (1) in being more symmetrical, (2) in being so arranged that every portion of the stream course is a part of two meanders, and (3) in having a ratio of distance across the necks of meanders to distance around the meanders of about 1 to 7. A study of the courses of the Missouri and Sioux rivers on the Elk Point, S. D. topographic sheet, the Missouri and Platte rivers on the Leavenworth, Kas. sheet, Mississippi river on the Baton Rouge, La. sheet, Missouri river on the Marshall, Mo. sheet, the Wabash, White and Patoka rivers on the Princeton, Ind. sheet, the Wabash and Little

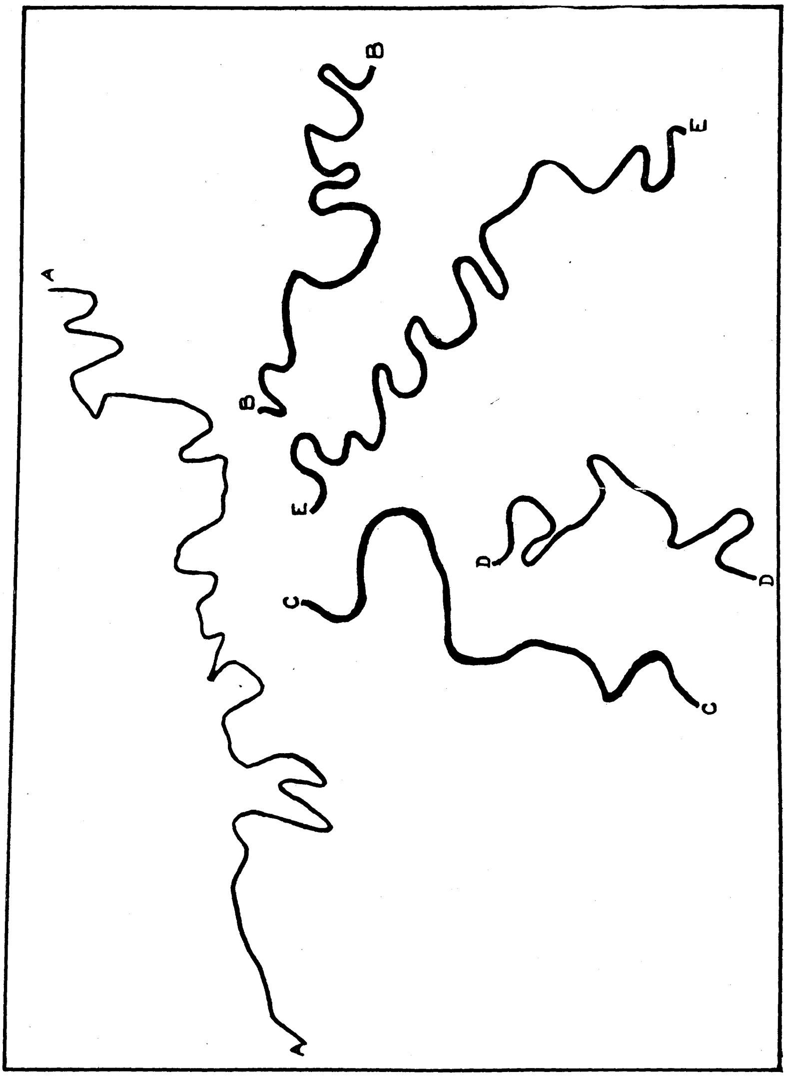

Fig. 4. A series of plats of stream courses of different histories.
AA is a part of the course of Maple river taken from the Casselton, No. Dak. topographic sheet. It has a consequent course in youth of its first cycle. Curves developed on low, flat land.
BB Rock river, Waterloo, Wis. sheet. A consequent stream on the surface of glacial drift.
CC Deerfield river, Wilmington, Vt. sheet. A stream in harmony with rock hardness and topography.
DD Platte river, Leavenworth, Kas. sheet. Meanders developed in old age.
EE Big Sioux river, Elkpoint, So. Dak. sheet. Meanders developed in old age.

Wabash rivers on the New Haven, Ills. sheet, and Nemaha river on the Falls City, Nebr. sheet, all of which are streams with meanders formed in old age, shows that these three characteristics of meanders are more imaginary than real. Few if any distinguishable differences between the meanders of old age and crooks made in other ways are brought out by the comparison of the meandering streams referred to with typical crooked streams not in old age, such as Red and Buffalo rivers on the Fargo, N. D. sheet, Otter creek on the Brandon, Vt. sheet, Deerfield river on the Wilmington, Vt. sheet, Des Moines river on the Boone, Iowa sheet, San Joaquin river on the Westley, Cal. sheet, Tuolumne river on the Westport, Cal. sheet, Canadian river on the Brilliant, N. M. sheet, Stanislaus river on the Ripon, Cal. sheet. There being no distinguishable differences between the meandering streams referred to above and ordinary streams which have never reached old age, it follows that it is impossible to tell from the maps, after a study of the curves themselves, whether intrenched meanders of the second cycle of erosion or ordinary crooks of the first cycle are illustrated in the Brazos river on the Palo Pinto, Texas sheet, Monongahela river on the Brownsville, Pa. sheet, Canondoquinet creek on the Harrisburg, Pa. sheet, Grant and Platte rivers on the Lancaster, Wis. sheet, and Osage river on the Tuscumbia and Forsyth, Mo. (Fig. 5) sheets.

Intrenched meanders might, however, in some cases at least, be distinguished from consequent crooks by the presence of outer valley walls. If the meander belt is located within outer valley walls and the stream is intrenched, the curves would seem to have been inherited from the meanders of an old age stage of valley development in a previous cycle. With this exception, which would rarely apply except in the early stages of a second cycle following a cycle which was interrupted before the valley walls became indistinct, intrenched meanders as evidence of more than one cycle in the erosional history of a surface would seem to have little if any value. Only in combination with other and more decisive evidences would they rise in other cases above the rank of mere suggestion.

Associated Sets of Straight and Crooked Streams

Although it seems impossible to distinguish intrenched meanders from other stream curves by a study of the curves themselves, comparison of a stream and its own tributaries will, in some cases at least, determine whether or not a crooked stream is in its second cycle. When a stream is old it meanders and has only a few tributaries which also meander. After rejuvenation, many other tributaries are developed, which do not meander. The early stages of a second cycle then would exhibit two sets of streams, one of which includes only a few large, conspicuously crooked streams, and the other set a large number of small, relatively straight streams. If all the streams of a region were formed in the same cycle under the same conditions, they should all show the same general character and degree of crookedness. If one set is curved and the other set straight, both cannot have been developed in the same cycle. (Fig. 6)

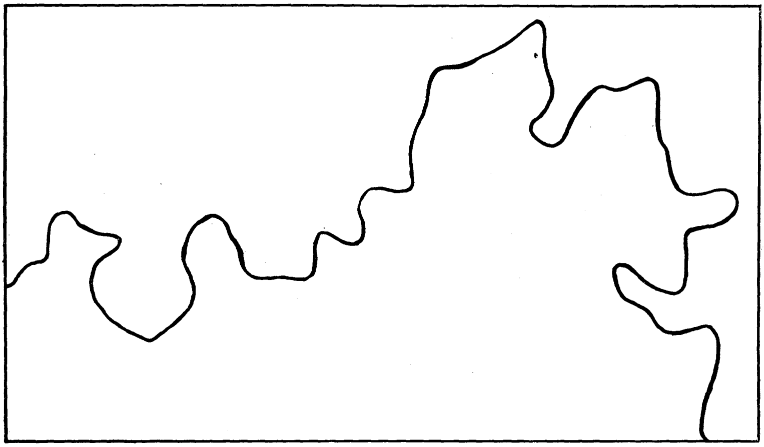

Fig. 5. A plat of the course of White river taken from the Forsyth, Missouri topagraphic map. The stream flows in a young valley, and its course has been interpreted to be a series of intrenched meanders. Reference to Figure 4 brings out the danger in such interpretations. So far as the curves themselves are concerned, they might not be intrenched meanders, as that term is commonly applied, and the surface might have suffered only one cycle of erosion.

It seems, therefore, that this association of one set of streams which meander and a second set the members of which are conspicuously more nearly straight affords strong evidence that the surface on which the two sets are thus associated is not in its first cycle of erosion.

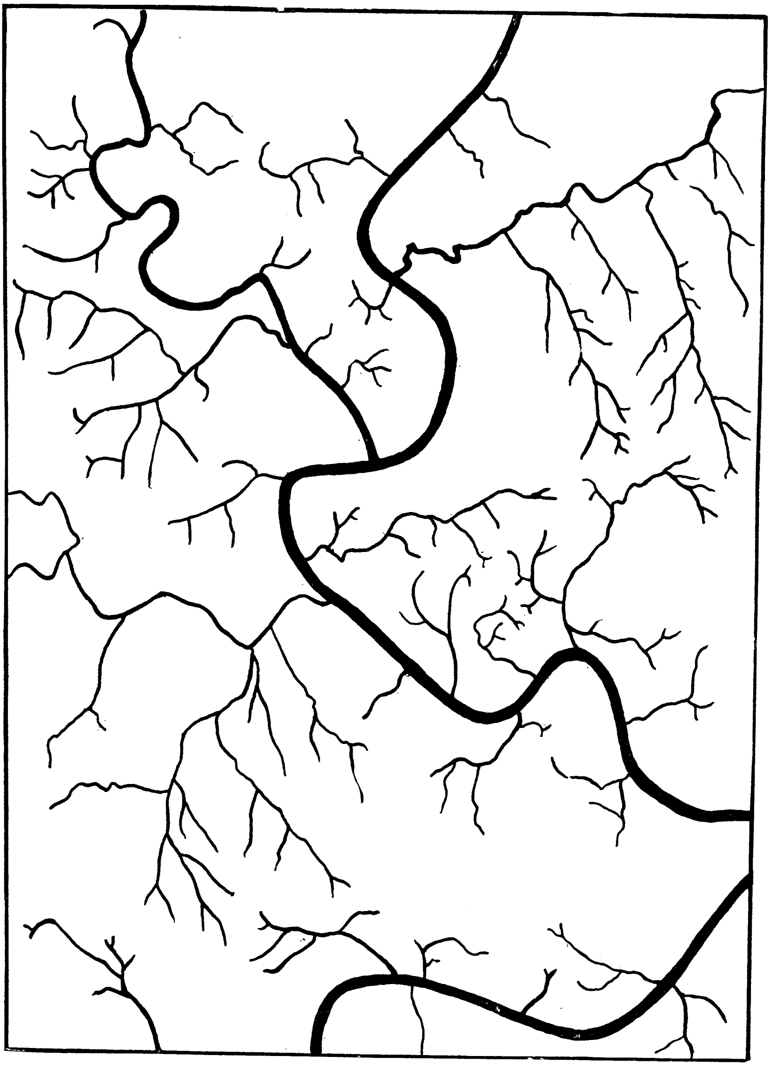

Fig. 6. A plat of the drainage of the Pittsburg Quadrangle. There are two distinct sets of streams, one including the large and most crooked streams, and the other the smaller and straighter ones. The large streams have a sort of curve different from that of the small ones. It seems that the large streams must have been developed to something like their present sizes and must have had their present courses before the small streams were started. The interpretation seems warranted that the courses of the large streams were established in old age of the first cycle of erosion and the small streams in the second cycle.

Antecedent Streams

The value of antecedent streams as evidences of more than one cycle of erosion in a region depends upon the definition of the term antecedent. The term was originally applied by Powell[1] to streams which hold previously established courses as their beds are warped, folded, or faulted. The streams were supposed to degrade their beds as rapidly as the beds were warped up. Such a history does not necessarily involve more than one cycle of erosion, except in the places where up-warping occurs.

Later the definition of antecedent streams was greatly broadened by Davis, Willis, and Hayes and Campbell, who applied the term to the Potomac, Susquehanna and other rivers of the Appalachian mountains. This whole region was folded and then peneplained, the rivers acquired their present courses on the peneplain, and then uplift of the whole surface took place and the streams intrenched themselves in their old courses. According to this definition antecedent streams are those which develop courses independent of rock structures in old age of an erosion cycle and hold those courses after uplift. Such streams are important evidences of more than one cycle.

In a folded region, such as the Appalachian mountains at the end of the Paleozoic era, streams adjust their courses in several distinct stages during the first cycle of erosion. In stage I, the main streams flow parallel with the strike of the strata in the axes of the synclines and the tributaries flow down the limbs of the anticlines parallel with the dip and at right angles to the main streams. In this first stage the slope of the land controls the courses of the streams. In stage II, those streams acquire an advantage, which first penetrate resistant layers and come to flow on non-resistant layers parallel with the strike. In this stage the main drainage lines shift to the limbs or axes of the anticlines. (Fig. 7). Now it is the resistance of the rock and the rock structures which control the courses of the streams. Finally when old age has been reached and all or most of the rocks

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[1] Powell. J. W., *"Explorations of the Colorado River of the West and Its Tributaries,"* p. 163. 1875.

have been reduced to grade, those streams which flow the shortest distance to the sea will have higher gradients than others and will therefore gradually absorb these other streams. The result is a drainage system in which the main streams flow the shortest distances to the sea irrespective of rock structure or hardness, and even the tributaries flow into the mains by the shortest routes (Stage III, Fig 8). Near the divides where the streams are not at grade, tributaries may still be flowing parallel with the strike, controlled by the structure. In this third and final stage of adjustment the courses of the streams are again controlled by the topography, but the topography is not the same as it was in the first stage. Roughly, Stage I would correspond with youth of the cycle of erosion, Stage II with maturity, and Stage III with old age.

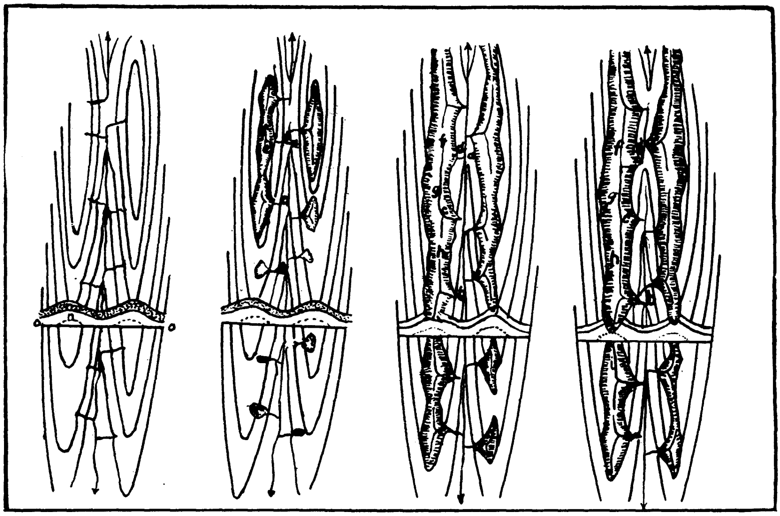

Fig. 7. Diagram to illustrate the change from Stage I to Stage II of stream adjustment in regions of folded strata. (After Davis).

If a region in which the streams have gone through the three stages of adjustment, be uplifted relative to the sea and the streams hold their courses during and after uplift, the streams in the second cycle would be antecedent according to the more recent use of the term. In a region of folded strata *during maturity,* streams which have courses parallel or oblique to the dip and flow the shortest distance to the sea, afford good evidence that the region has suffered more than one cycle of erosion.

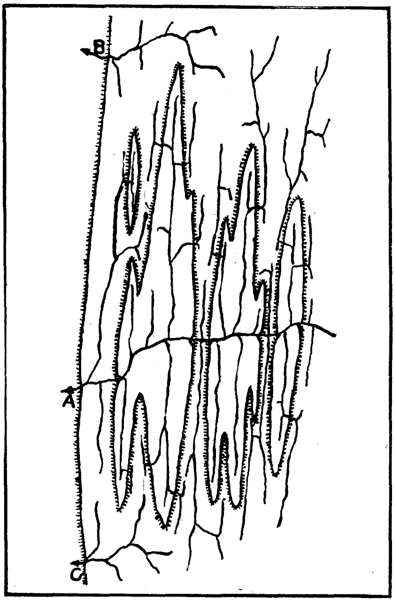

Fig. 8. Diagram illustrating Stage III of stream adjustment. (After Davis).

In case a region under investigation is not one of folded structures, the same general methods as outlined above may be applied. The stages of adjustment can be worked out and the corresponding stage of reduction. If the stage of reduction and stage of adjustment do not harmonize, the stream courses furnish evidence of more than one cycle of erosion.

It must be recognized that by extremes in slope streams might work headward through hard rocks and that by extremes in non-resistance, they might extend headward through topographic elevations so as to flow through water-gaps, all in the first cycle. It is not probable, however, that anything but the smaller streams of a region would in this way develop courses which would appear to be out of harmony with rock resistance and existing topography in a single cycle of erosion.

Another case of antecedent streams involves *superimposition.* Streams which develop courses on newly formed surfaces, such as lava plains, emerging sea bottoms, or surfaces of glacial drift, may cut through superficial deposits and become superimposed upon previously existing, irregular, buried surfaces. Such streams may have courses entirely out of harmony with the resistance, structure and topography of the old surfaces. Superimposed streams are antecedent but they do not indicate that the youngest surface degraded has been reduced in more than one cycle of erosion.

From the foregoing, it is seen that certain antecedent streams are significant of more than one cycle of erosion. If the main streams of a region show evidence of having reached a late stage of stream adjustment but if they are not in a late stage of erosion in the present cycle, they offer valuable and almost indisputable evidence of more than one cycle. The Susquehanna river shown in Fig. 9 practically proves that the region in which it has its course is not in its first cycle of erosion, if local warping under the stream and superimposition can be eliminated.

Windgaps

It has long been the prevalent opinion that most, if not all, windgaps are the result of diversions by piracy of streams flowing in narrows or watergaps across hard ridges, leaving the watergaps without water. If this is the origin of windgaps, they have some value as evidences of more than one cycle of erosion in the region in which they are found. Let a region of folded strata go to old age of a cycle of erosion and let the streams attain a final stage of adjustment following the shortest routes to the sea parallel or oblique with the dip of the strata. After uplift of the surface, new streams will be started which will adjust parallel with the strike on the less resistant formations. These streams under the new conditions will have the advantage of the antecedent streams oblique to the strike and will behead the antecedent streams. This leaves windgaps where the antecedent streams flowed across hard formations, provided these streams intrenched themselves in their old courses before piracy took place.

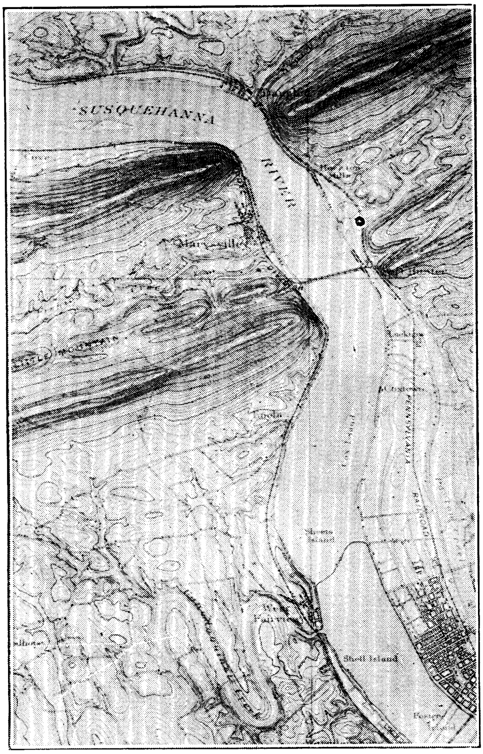

Fig. 9. Part of the Harrisburg, Pa. topographic map, showing the antecedent course of the Susquehanna river. Such a relation between stream course, topography, and rock structure proves that the surface has suffered more than one cycle of erosion.

In regions of folded strata there is possibility of piracy and the formation of windgaps in the first cycle of erosion. In passing from Stage I to Stage II of adjustment the main streams are diverted from courses on the synclines to courses on the limbs or axes of the anticlines, giving rise to drainage systems some portions of which are parallel with the strike and other portions parallel with the dip. This stage is reached before the streams have reached their depth limits, and piracy may occur. Indeed, the change from Stage I to Stage II is not accomplished without piracy. In such cases streams parallel with the strike have the advantage of streams flowing across the strike and windgaps are formed which might be indistinguishable from those due to piracy in the second cycle.

Windgaps are not conspicuous in regions of horizontal strata nor in regions of massive rock, a fact which practically limits the application of windgaps to regions of folded or tilted strata.

Another limitation in the use of windgaps as criteria for more than one cycle of erosion has recently been emphasized by Miller[1] who explains that windgaps may be formed by two streams working headward from opposite sides of the same divide, developing a permanent divide between their heads and forming a col. Such a col could hardly be distinguished from gaps which had once been occupied by streams and then abandoned. A study of the relative sizes and gradients of the streams on either side of the divide might aid in determining the histories of such gaps.

So difficult is it to distinguish wind gaps resulting from piracy in the second cycle from those developed during ordinary adjustment or in the establishment of permanent divides in the first cycle that it is doubtful if they would ever, even under the most favorable circumstances afford important evidence of more than one cycle, taken alone.

Even-crested Summit Areas

Perhaps the fact that the uppermost surfaces of some regions approximate planeness and that the summit divides all come up to a nearly uniform level, has been more generally used as a criterion of more than one cycle of erosion than has any other evidence. But the principle has been abused. Various terms have been used in connection with this point, such as "even-crested hogbacks," "even-crested ridges," "upland plains," "accordant summit levels," "even-

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[1] Miller, A. M., "Windgaps," *Science*, Vol. 42 (1915), pp. 571-573.

crested divides," "even-crested uplands," and "even-crested skylines." The term "even-crested summit areas" seems to include every phase of the subject and to exclude *intermediate plains,* which might be included under some of the other terms and which constitutes a separate point.

Study of the principles involved in the formation of topographies in which the highest elevations are flat-topped and have about the same altitude, shows that such even-crested summit areas constitute better evidence of more than one cycle if the rocks involved are folded or tilted or massive, than if they are horizontal or nearly horizontal strata.

In Regions of Folded Strata: A plain which bevels folded strata might be interpreted as recording the following events: (1) the folding of the strata, forming a topography of high relief with anticlinal ridges and synclinal troughs; (2) erosion of the surface until a large part is brought to grade, leaving the surface relatively flat; (3) uplift of the land relative to sea, renewed degradation by streams and the relatively rapid removal of the non-resistant materials, leaving the outcrops of the harder formations as ridges or hogbacks, the tops of which are remnants of the peneplain developed in the first cycle.

It seems difficult to the writer to assign any other history than that outlined above to topographies illustrating even-crested summit areas in regions of folded strata. Other possible interpretations may be mentioned. Tarr[1] has objected to the idea that the more or less even-crested ridges of the Appalachian region represent an ancient peneplain and points out (1) that they are by no means of a common level and (2) that elevations made of about equally resistant rock, starting with their summits above timberline, would be eroded rapidly and about equally to timberline, and then acquire more or less uniform levels, all in a single erosional cycle. It should be noted that these even-crests are not at timberline. Other investigators[2] have proven,

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[1] Tarr, R. S., *Am. Geol.,* Vol. 21, pp. 351-370.

[2] Davis, W. M., *Am. Jour. Sci.*, 1889, Vol. 37, p. 430; Willis, Bailey, *Physiography of the United States,* pp. 169-202; Hayes and Campbell, *Nat'l Geog. Mag.,* Vol. 6, pp. 65-126.

by the application of a combination of other evidences, that the Appalachian mountains have been eroded in more than one cycle and that at the accordant summits of the ridges there are remnants of a surface formed in a cycle previous to the present one.

It has also been argued that mountain ridges can maintain only a certain elevation because the surrounding area is not able to support the greater pressure which would operate if the ridges were higher. This is a part of the theory of *isostasy.* No discussion of this theory is in place here. It need only be said that the structure of the rocks in most areas where there are accordant summit levels is such as to prove that the elevations were once much higher than they now are and that they have been reduced by streams.

It is also possible to assume, until proven otherwise, that accordant summit levels in a folded region are remnants of a plain of marine denudation. The criteria for distinguishing remnants of such a plain and remnants of a true peneplain are clear. If the sea cut its way on the land for any considerable distance, portions of the wave-cut terrace would become sites of marine deposition and when the sea-denuded plain became land, it would be covered with marine sediments, which of course might be removed later. Also the border of an old plain of marine denudation would be a shoreline and erosion remnants on its surface would have the contour of islands. It has never been proven that plains of wide extent are made by this method, especially if the plain be inland, and no even-crested summit areas have ever been proven to be remnants of plains of marine denudation.

It should not be said that even-crested summit areas in regions of folded strata considered alone, prove more than one cycle of erosion, but they afford strong corroborative evidence to that effect.

In Regions of horizontal or nearly horizontal strata: Accordant summit levels, where strata are horizontal or nearly so, afford possibilities of interpretation not applicable in regions of folded strata. In a previous article by the writer[1] an upland plain in northwestern Illinois was conceived to be (1) an original marine plain of deposition; (2) a marine plain of erosion; (3) a structural plain; or (4) a true peneplain. Only in case such upland plains can be proven to be true peneplains do they constitute proof of more than one cycle in the erosional history of a region. For the detailed discussion of the characterizing features of plains formed in the four ways outlined above, readers are referred to the article cited. A plain of marine deposition should be parallel with the rock strata and should not have on its surface deposits of any sort younger than the marine formations which underlie it. A plain of marine erosion should be bordered by higher land and separated from this land by a shoreline. It should bevel the edges of rock formations; its surface should contain marine deposits younger than the formations which the plain bevels and any remnants which stand above it should be isle-like. A structural plain would be located on a resistant formation and would be parallel with the dip of that formation. If upland flats are remnants of a true peneplain, the surface represented by them when reconstructed should not, except in unusual cases, be parallel with rock structure, should be more or less uneven, have dendritic erosion remnants above it, and have fluvial deposits on its surface. There might be cases in which it would be impossible to determine the correct one of these four origins of upland plains, but if they be studied carefully enough and over sufficiently wide areas, correct interpretation should be possible.

Recently, Martin[2] has expressed the opinion that features of the topography of the Driftless Area of Wisconsin, which have been most generally interpreted as even-crested summit areas representing an old peneplain, can better be explained by assuming that the topography is due to the unequal erosion in a single cycle of series of unequally resistant rock formations having a slight monoclinal dip. After defining a *cuesta* as "an upland with a short steep descent,

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[1] Trowbridge, A. C., *Jour. Geol.*, Vol. 21, pp. 731-738.
[2] Martin, Lawrence, Bull. No. 36, *Wis. Geol. and Nat'l Hist. Surv.*, pp. 63-70.

or escarpment, on one side and a long, gentle slope on the other," and stating that "the gentle slope usually corresponds to the inclination or dip of slightly inclined sedimentary rocks[1]," he contends that the upland plains in the Driftless Area are simply the gently sloping surfaces of cuestas. If this is the correct interpretation of such upland surfaces, (1) the slope of any individual patch of summit area should correspond in direction and amount with the dip of the rock formations, (2) each upland area should be formed by resistant rocks, and (3) the altitude of the summit of any given cuesta should depend upon the resistance of the rocks forming it and the length of time it had been exposed to erosion after the removal by streams of all overlying rock formations.

Any considerable areas of summit flats now poorly drained and forming broad divides between present streams would hardly be formed in this way in a single cycle of erosion. If individual summit areas were found to bevel the edges of layers or formations, if these areas are large and far from present streams, if some of the rock formations bevelled by the surfaces are non-resistant, and especially if a surface reconstructed by filling the lowlands to the summit areas is found to have a uniform slope in direction and amount, if this slope be uniformly greater or less than the dip of the beds, and if irregularities in rock structure and rock resistance do not influence this surface, the even-crested summit areas could hardly be considered to be merely a series of cuestas.

In Regions of Igneous Rocks: If massive igneous rocks solidified below the surface of the lithosphere be eroded in such a way as to leave flat-topped and accordant elevations, it seems that at least two cycles must have been involved in the history of the topography, except in cases where the massive rock had a flat surface to begin with. In the normal case it would require a cycle of erosion to remove overlying rocks and flatten the surface of the igneous rocks, and

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[1] *Op. Cit.*, p. 42.

a second cycle to degrade some of the land further and leave the previous surface represented by the flat summit areas. It seems that accordant summit levels would be as strong evidence of more than one cycle in regions of massive igneous rocks as in regions of folded strata.

Extrusive lava sheets and intruded sills might form flat-topped hills, when eroded, without offering more than a bare suggestion of more than one cycle of erosion.

In any case there is an unanswerable question as to how flat upland surfaces must be and how nearly to a common level their remnants must come before weight is given to them as evidences of more than one cycle of erosion. Even in the regions which have suffered more than one cycle there are several causes of irregularity in the topography of the upland plain. In the first place most peneplains at the close of the first cycles are not flat. A total relief of several hundred feet would not be incompatible with the term peneplain, provided large portions of the surface had been brought to grade. Secondly, the surface might be warped, folded, tilted, or faulted as it is uplifted. Finally, erosion might roughen the upland surface after rejuvenation of the streams, without entirely destroying its former characters. The larger and flatter summit areas are, and the more nearly accordant they are, the more definitely can the term "even-crested summit areas" be applied to them, and the more certainly can the erosional histories of regions be read from them. The failure of accordance in the uplands of a region could under no circumstances be taken as proof that the region had not been eroded in more than one cycle.

Even-crested summit areas should be used as evidence of more than one cycle of erosion only after complete and careful study.

Intermediate Plains

The term *intermediate plain* has not been used before as an evidence of more than one cycle, but the principle involved has been used extensively and to good advantage, without previously having been named. In the present connection an intermediate plain may be defined as one having a position intermediate between the summits of the highest elevations and the bottoms of the deepest valleys (Fig. 10). Or intermediate plains might be defined as plains above which stand erosion remnants and below which are valleys. The erosional history of such a region as is shown in Fig. 10, would seem to involve two cycles of erosion and to be somewhat as follows: (1) the formation of a land surface at levels at or above the present summits, (2) the reduction of the region and the formation of a peneplain, (3) the uplift of the region, rejuvenating the streams, and (4) the development of the valleys. This sort of topography seems to be and is strong evidence of more than one cycle of erosion, although it hardly amounts to proof.

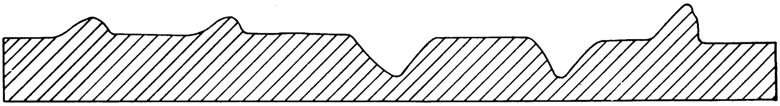

Fig. 10. Diagrammatic section illustrating an ideal intermediate plain.

Plains having similar relations to erosion remnants and valleys might be structural. It is conceivable that streams might cut through soft surficial material, to a thick, hard formation of rock, then find further degradation retarded to such an extent that by processes of widening, the soft material might be removed over wide areas before the hard formation is cut through, leaving only a few remnants above the level of the top of the resistant formation. The surface in this stage might resemble a peneplain. Finally, the streams might sink themselves below the hard formation and develop valleys at levels below the structural plain. However, it seems difficult to conceive that, even under the most favorable circumstances, intermediate plains of wide extent could be formed in this way. Rock terraces might be so formed, but hardly plains which spread across divides from valley to valley. Such structural plains, also, should be parallel with rock structure and everywhere located on rocks more resistant than their surroundings.

Intermediate plains might be remnants of a plain of marine erosion, but the erosion remnants above it should be isle-like and its surface should contain marine deposits. Obviously no intermediate plain of great extent could be an original marine plain of deposition. Neither is it clear that the remnants of an intermediate plain could be the surface of a series of cuestas formed in a single cycle. If a rough topography were developed by streams and then the lowlands were filled, but not to the level of the summit areas, by glacial material or lava flows having a flat surface, streams might so dissect the glacial or volcanic fill as to leave remnants of an intermediate plain which would not record more than one cycle of erosion, in the usual sense at least.

Fluvial Deposits on Uplands

Where stream deposits are found occupying topographic positions distinctly above present stream beds, whether they lie on summit areas or areas of intermediate plain, on divides or on slopes above drainage, there is evidence that streams which once deposited, ceased depositing and began to degrade. As old streams most commonly aggrade and young streams degrade their beds, there is suggestion in such relations of deposits to stream beds, that the streams were once old and deposited and became young again, carving out the valleys below the levels of the deposits. That is, such a relationship suggests that the land was uplifted after some portions at least had been brought to grade and that more than one erosion cycle was involved in the history of the topography in which such relationship exists.

In case of upland or intermediate plains due to structure, streams flowing from soft material to the hard rock which forms the plain may be held at temporary grade on the soft material while degradation of the hard rock is in progress, and might deposit on the upstream side of the hard rock. Later in the same erosion cycle, when the hard formation has been cut through, the streams might cut down, leaving the deposits on the structural plain. It is hardly conceivable, however, that deposits which have had such histories would be found widely spread over upland surfaces.

It is possible for a stream not at grade to deposit, to shift its course slightly, and to sink its channel deeper, leaving its deposits in small areas as pockets or patches on upper slopes. Small patches of fluvial gravel or sand found on slopes above present drainage might be explained in this way, but thick fluvial deposits spread widely over upland flats could not be so explained.

The application of this point is also limited by the difficulty in distinguishing fluvial deposits from marine or eolian or glacial or lacustrine deposits, especially after long exposure.

Undoubted fluvial deposits spread widely over upland surfaces would disprove that those surfaces represent plains of marine deposition or of marine erosion or are merely the tops of cuestas. They would almost or quite disprove the structural hypothesis for the origin of the upland plain on which they lie. Therefore, they constitute strong evidence of more than one cycle of erosion.

Combinations

If the analysis of each of the evidences of more than one cycle of erosion has been followed up to this point, it is clear that no one of these evidences, in the abstract and taken alone, can be said to prove more than one cycle in the erosional history of a region. However, the study of concrete cases of individual points may yield such proof. Some of the evidences usually assigned merely suggest more than one cycle of erosion if taken abstractly, but become strong evidence when properly restricted by the elimination of other possible interpretations. Others are strong evidence in the abstract, and amount to proof if properly applied and limited. The relative values of these evidences are summed up in the accompanying table.

Interrupted profile and stream terraces could hardly amount to more than a suggestion of more than one cycle of erosion unless all other possible interpretations had been eliminated by careful study in the field.

So nearly impossible is it to distinguish the meanders of old age from other crooks in streams that intrenched meanders afford no more than a suggestion of more than one cycle. Associated sets of straight and crooked streams, on the other hand, are strong evidence of more than one cycle.

TABLE SHOWING THE RELATIVE VALUES OF THE VARIOUS EVIDENCES OF MORE THAN ONE CYCLE OF EROSION IN REGIONS

No.	Name	Proof	Strong Evidence	Mere Suggestion
1	Interrupted Profile		X?	X
2	Stream Terraces		X?	X
3	Intrenched Meanders			X
4	Associated Sets of Straight and Crooked Streams		X	
5	Antecedent Streams	X?	X	X?
6	Windgaps		X?	X
7	Even-crested Summit Areas		X	X
8	Intermediate Plains	X?	X	
9	Fluvial Deposits on Uplands	X?	X	

Those antecedent streams which can be proven to have gone to the final stage of stream adjustment and are not now in adjustment prove more than one cycle of erosion; any antecedent stream, except one in which warping has followed establishment of the stream course or one which is due to superimposition, is strong evidence of more than one cycle. Windgaps made by the abandonment of watergaps in the changing of streams from antecedent to adjusted courses form strong evidence and other windgaps merely suggest more than one cycle. Especially even-crested summit areas in regions of folded strata, are good evidences of more than one cycle of erosion, but from these ideal conditions the value deteriorates almost to zero in regions of horizontal strata or where accordance of summit areas is more imaginary than real. It is believed that carefully investigated intermediate plains may prove more than one cycle and that any intermediate plain of wide extent is strong evidence. Fluvial deposits either on intermediate plains or on summit areas might prove more than one cycle under certain conditions and would be valuable evidence in any case. It is to be noted that most of the abstract evidences have more weight in regions of folded strata than where strata are horizontal.

But the investigator must depend upon certain *combinations* of the various evidences, rather than upon single points, if he is to prove or disprove that given regions have suffered more than one cycle of erosion. It is unlikely that a surface which has been peneplained and then uplifted relative to the sea would show only one of the evidences of having had such a history. The sequence of events which involves two erosion cycles, and which gives rise to one of these lines of evidence, may give rise to all. If a region shows only one of these evidences the value of that one should be discounted because none of the others is shown. On the other hand a combination of several of these evidences in a region furnishes a progression toward definite conclusions which is geometrical rather than arithmetical.

Referring again to the table above, Nos. 5, 8 and 9, all found together in a region, even without special analysis, would come near to proving more than one erosion cycle in the history of the surface, and if properly analyzed the combination might prove such a history beyond the possibility of a doubt. Similarly, proof might be obtained through the combinations of Nos. 4, 7 and 9; or Nos. 5, 6 and 8; or Nos. 4, 5 and 7; or perhaps by a combination of 8 and 9, or 5 and 7. Combinations of 4 and 8, 7 and 9, 4 and 6, or 1, 4 and 7 might under certain topographic conditions afford strong evidence or even proof. Even Nos. 1 and 2 combined might under certain circumstances be strong evidence of more than one cycle.

It therefore seems clear that by distinguishing these various features in the topographies of regions, by the proper analysis of their possibilities and limitations under existing conditions, and by certain combinations, it is possible to determine that (1) regions have *certainly* suffered more than one cycle of erosion, or that (2) they have *probably* suffered more than one cycle, or that (3) they have *possibly* suffered more than one cycle. If careful study of a topography reveals no one of these evidences, or if it reveals only one or two whose origin after analysis is found not to involve more than one cycle, it could be concluded that (4) the surface has *probably not* been eroded in more than one cycle. There would be cases where it would be entirely impossible to demonstrate that (5) the surface had *certainly not* been eroded in more than one cycle.

If the deposits laid in a near-by sea during the erosional history of a land surface are available for study, evidence of more than one cycle of erosion on the land might be found in them. If a series of formations graded upward from conglomerate at the base through sandstone, shale, and limestone to another conglomerate, it would seem that the lower series including coarse, medium, and fine materials would correspond respectively with youth, maturity and old age of an erosion cycle on the land and that the upper conglomerate would record an uplift of the land and the inauguration of a youthful stage of a second cycle.

However, such gradations in marine sediments might be due to gradually changing climates, changing depth of water without affecting land and sea relations, or slightly migrating shorelines which do not materially effect the height of land relative to sea.

Alternation of sediments might be used to good advantage in some cases to check the topographic evidences of erosion cycles. For instance, the Cretaceous and Tertiary deposits of the Atlantic Coastal Plain should and do, at least roughly, check in this way the erosional history of the Appalachian mountains as stated by Willis, Hayes and Campbell, and Davis. Similarly it is believed that the Tertiary and Quaternary deposits of the Gulf Coastal Plain of Texas will help in interpreting the erosional history of the Cordillera.

MORE THAN TWO CYCLES

When it has been demonstrated that the erosional history of a given surface has involved more than one cycle, the question of the number of cycles arises. Theoretically the number of erosion cycles in a region is limited only by the length of time during which the surface has been subjected to fluvial processes and the frequency of positive diastrophic movements during that time. So far as geologic time and the frequency of land-forming diastrophic movements may be conjectured, there is no known limit to the number of cycles which might have effected a topography. Such regions as the Piedmont Plateau or portions of the Laurentian Shield, which are thought to have been land since the beginning of the Cambrain period, have probably been peneplained and uplifted many times, although the detection of so large a number of cycles would be extremely difficult, if not impossible. On the other extreme, surfaces fashioned by the Wisconsin ice sheet have probably nowhere been eroded in more than one cycle, so short has been the time since the retreat of the ice.

The number of cycles of erosion which has affected a given region is to be determined by the number of *sets* of evidences of more than one cycle. For instance, in the Appalachian mountains, even-crested summit areas, antecedent streams, windgaps, intrenched meanders, associated sets of straight and crooked streams, intermediate plains and fluvial deposits on uplands, all are in evidence, and the combination proves more than one cycle of erosion in the history of the region. Obviously, even-crested summit areas which are the remnants of an old peneplain, and an intermediate plain representing an old peneplain, cannot belong to the same set of evidences if they both occur in the same region. Most of the antecedent streams and some of the windgaps of the Appalachian region belong with the set of evidences represented by the even-crested summit areas, and most of the intrenched meanders and associated sets of straight and crooked streams, and all of the fluvial deposits are clearly correlated with the intermediate plain. There seem to be two sets of intrenched meanders and two sets of antecedent streams, one set of each related to the upper plain and the other set to the intermediate plain. Thus, the older set of evidences includes even-crested summit areas, antecedent streams, windgaps and intrenched meanders, and the younger set consists of intermediate plain, fluvial deposits on divides, intrenched meanders, associated sets of straight and crooked streams, antecedent streams and windgaps. Each of these sets includes the proper combination of evidences to prove more than one cycle, hence it is concluded that the region is now in its third cycle, the first set of evidences being proof of the first cycle, the second set proving that there was a second cycle carried to a late stage. The evidence of the beginning of the third and present cycle is found in the fact that the second set of evidences is related to a surface distinctly above the present streams. There are certain terrace-like features between the summit areas and the intermediate plain which suggest an additional cycle between the first and second, but as these benches have been proven to be structural and as there are no other evidences in the set, it is concluded that the mountains are in the third, rather than the fourth cycle.

The method of procedure then, in determining the number of distinguishable cycles which have been involved in the erosional history of a region is as follows: (1) Determine how many of the evidences of more than one cycle of erosion the topography exhibits; (2) sort these evidences into the proper number of sets; (3) conclude that the *total number of distinguishable cycles is the number of sets of evidences plus one.* The degree of certainty with which the number of cycles is determined depends upon the certainty with which the various sets of evidences record the individual cycles.

THE DETERMINATION OF DIASTROPHIC EVENTS

Because diastrophism is involved in the formation and renewal of lands, the interpretation of the history of land surfaces includes also the diastrophic history.

The Number of Movements

In regions in which the land surfaces were originally formed by diastrophism the number of positive diastrophic movements is the same as the number of cycles of erosion. For instance, the Appalachian mountains were formed first by folding; this is movement No. 1. Movement No. 2 interrupted the first erosion cycle and inaugurated the second cycle; movement No. 3 started the third cycle. The region has suffered parts of three erosion cycles and there have been three upward diastrophic movements.

Some surfaces, such as those formed by glaciation, by lava flows, or by the draining of lakes, have no genetic relation with diastrophism. On such surfaces the number of diastrophic movements is one less than the total number of cycles.

The Nature of Movements

Not only the number but the nature of diastrophic movements should be determinable in an interpretation of the erosional history of a region. There are several possible cases: (1) uniform uplift of the whole surface; (2) uplift with tilting; (3) uplift with warping; (4) uplift with faulting; (5) subsidence of the surface, with the four possible phases as outlined for uplift.

Uniform Uplift: If a peneplain were formed and then uplifted uniformly, there would be a change in altitude but not in attitude. If the general slope of an old erosion surface, be its remnants on the summits or at intermediate levels in a topography, is approximately the same in direction and amount as the slopes of other graded erosional surfaces in the region, the inference would be that the uplift had been uniform. The difficulty with this point lies in the fact that no old erosion surface is perfectly flat, and it is difficult to determine whether consecutive graded surfaces are parallel. Also a graded plain might be uplifted uniformly and yet not be parallel with a younger peneplain if the streams had higher or lower gradients at the close of the second cycle than at the close of the first.

However, if a peneplain represented by even-crested summit areas is practically parallel with an intermediate plain, and with present valley flats on which streams are at grade, the conclusion would be warranted that both the uplift which inaugurated the second cycle and the uplift starting the third cycle were practically uniform.

Uplift with Tilting: If a raised and partly dissected surface which was once a peneplain has a generally uniform slope throughout a given region, but is not parallel with an intermediate peneplain or with graded streams below it, either because its angle or direction of slope is different, the conditions suggest that the uplift which inaugurated the dissection of the upper plain was accompanied by tilting. If an upland peneplain and an intermediate peneplain are essentially parallel, but are not parallel with an existing and undissected peneplain, the uplift which started the second cycle was probably uniform and the movement starting the third cycle was a tilting movement. The best evidence of tilting in the renewal of lands by diastrophism is a lack of parallelism between uniformly-sloping, consecutive, graded, erosion surfaces.

As in most rules, there are limitations in the application of this one. Lack of parallelism between consecutive erosion surfaces, provided it is a matter of amount rather than direction of slope, may be due to difference in the gradients of final grades of the drainage system under different conditions at different times. At the close of a first cycle the streams may have been small and carrying heavy loads, with resulting high gradients and a relatively steeply sloping peneplain. The uplift may have been uniform, but in the second cycle larger streams carrying lighter loads may have developed gradients lower than those of the first cycle, and the two erosion surfaces would diverge upstream. By the reversal of the sequence, two peneplains might be caused to converge upstream, without tilting.

Even differences in the direction of slope of two peneplains in a region might be obtained without tilting, if conditions of structure, proximity to the sea or climate were so changed, during uplift, as to cause reversal or diversion of drainage in the second cycle.

It is probable that these exceptions might lead to conclusions that tilting has taken place where it has not in some cases, and that tilting has not taken place where it has in others. Perhaps only the more pronounced cases of tilting can be distinguished by this method.

Uplift with Warping: Warping during uplift of a plane erosion surface would result in an irregular obliquity between this surface and lower peneplains. The two erosion surfaces would converge and diverge in many directions and at many angles. In a region where such obliquity exists between a summit plain and an intermediate plain, but with the intermediate plain parallel with an undissected peneplain or with graded streams, the first recorded movement seems to have involved warping and the second uplift was uniform. If the upper plain and the intermediate plain are parallel, but with irregular obliquity related to present graded streams, the first movement was uniform and the second one was accompanied by warping.

This method of interpretation lacks much of being decisive. In the first place the warping or folding of an erosion surface destroys accordance of levels and makes it extremely difficult to decide whether the surface was once smooth and has been warped, or whether it was never smooth. In the latter case there would be little evidence that there has ever been more than one erosion cycle. The warping of a surface is likely to destroy evidence that there has been any moveemnt at all. There would have to be some evidence beyond the accordance of levels to prove that the surface actually was a peneplain. However, such evidence might consist in fluvial deposits on remnants of the warped surface, or in antecedent streams cutting across the folds of the surface.

Another difficulty with the interpretation of warping movements grows out of the fact that no erosion surfaces are altogether flat and that there is therefore an irregular obliquity between two consecutive surfaces whether warping has taken place or not. However, departures from parallelism due to erosional irregularities in the surface would show themselves in topographic details and those due to warping would be more general; that is, they would be differences between averages rather than between specific points. Careful study of the valleys cut in the old erosion surface during the next cycle should also aid in determining whether the irregular lack of parallelism is due to warping or to erosional irregularities. If the valleys vary in depth or width or stage of development from point to point warping could be called in to explain such variations.

After all probably the best evidence of warping of peneplains is found when it is determined that the individual peneplain reconstructed varies in altitude above sea, that it has on its surface stream deposits distributed without reference to the variations in altitude, that the variations are due to flexures rather than to erosional irregularities, and that streams have antecedent courses at right angles or oblique to the flexures.

Warping may have occurred in regions where there is no evidence of movement of any kind. There may also be suggestions of warping where uplift was uniform. There are doubtless regions, however, such as the Appalachian mountains, where warping movements have taken place and where, by application of the principles outlined above, such movements can be proven to have taken place. These principles, therefore, are usable, but their use is attended with difficulty and may result in uncertainty.

Uplift with Faulting: One of the best known illustrations of a cycle of erosion having been interrupted by faulting is found in the mountains and valleys of eastern California. Here an ancient erosion surface which is characterized by mid-Tertiary stream gravels which lie on the remnants of the old surface in many places, slopes up from low levels on the west flanks of the Sierras and reaches altitudes of more than 14,000 feet at the crest of the range where it is broken by the great fault whose scarp forms the east slope of the mountains. East of this line the surface seems to be buried under the late Tertiary and Pleistocene sediments of Owens Valley below altitudes of 2,000 feet. The surface and its gravel deposits appear again in the Inyo mountains east of Owens Valley, reaching altitudes close to 10,000 feet, where the surface is broken by another fault on the east side of these mountains. The evidence of faulting in this case is a series of tilted blocks, each one of the series being sharply set off from the adjacent one by a fault scarp.

It seems that cases of uplift with faulting could be certainly interpreted only where the old erosion surface is distinguishable in spite of great relief within short distances, where the separate blocks are distinct and where differences in altitude of the surface are too abrupt to be accounted for on the basis of warping.

Subsidence: It is a quibble whether or not the subsidence of a surface starts a new cycle of erosion. However, the study of the erosion cycles in a region may yield evidence of subsidence. If it can be proven that all the graded streams of a region have their beds at levels far above beds which they previously occupied, it seems most likely that the surface of the region has subsided. If the establishment of grades below previous grades indicates uplift, the establishment of new flood plains above previous erosional surfaces is an equally strong indication of subsidence. If uplift raises a previously graded surface above grade, subsidence lowers valley bottoms below the level of grade.

This principle seems to be illustrated in the upper Mississippi valley region, where the Mississippi river and its main tributaries are at grade 100 feet or more above the bedrock beneath. The fills in this region consist of glacial and fluvio-glacial drift. It seems likely that the surface subsided after the deep valleys were cut.

Another possible interpretation is that the streams were not so heavily loaded before the filling as now, or were larger then than now, and consequently were able to reduce their valleys to a lower depth limit in relation to the Gulf of Mexico than is possible now.

By the application of the principles outlined above for uplift, it might be determined whether subsidence was uniform or was accompanied by tilting, warping or faulting.

The Amount of Movement

The interpretation of erosional histories furnishes some basis for determination of the amount of each diastrophic movement. Streams which have reached their depth limits in a first cycle of erosion may degrade their beds below these old graded levels in the second cycle by approximately the amount of the uplift which rejuvenated them. The difference in altitude between two consecutive graded surfaces, therefore, is roughly the measure of the amount of the uplift which interrupted the one cycle and started the other. In a region in which there is a summit peneplain at 2,000 feet, an intermediate peneplain at 1,000 feet and graded flats at 500 feet, it could be inferred that there had been an uplift of approximately 1,000 feet, and a second one of about 500 feet.

This method of interpretation seems simple enough but its application to field conditions involves possibilities of error. Differences in altitude between remnants of consecutive graded plains vary from point to point in any region, (1) if uplift was accompanied by tilting, warping, or faulting, (2) if either surface was irregular, (3) if final grades differed because of changes in volume or load of the streams. These being common conditions, it seems possible to get accurate figures on the amount of uplift for individual districts only, and even this is subject to error. For whole regions, only approximate averages are possible.

THE DETERMINATION OF DATES

The complete history of a surface involves dates as well as events and sequences. Various criteria have been used for the determination of the geologic dates of the various events in the histories of land surfaces. Some of these criteria are readily applicable and accurate if properly applied. Others are not so valuable. The problem involves the ages of old erosion surfaces, the dates of diastrophic movements, the duration of time involved in erosion cycles, etc.

The Age of Old Erosion Surfaces

It has been customary in designating the ages of raised peneplains to refer to the date at which the plain was completed and still intact rather than the whole time during which it was in process of formation. For instance, the Kittatinney peneplain in the northern Appalachians is referred to as the Cretaceous plain, not because its formation was accomplished during the Cretaceous period only, but because it was believed to have been completed during that period. The cycle during which it was formed was probably inaugurated long before the Cretaceous. Although this departs in a way from the usage of time terms in relation to rock formations, with this statement, the writer considers it best to continue the custom.

Various methods may be used in determining the periods or epochs to which certain raised peneplains belong, the method used depending upon the conditions existing in the region under investigation. Some of these methods are here mentioned: (1) Any graded erosion surface is younger than the youngest formation which it cuts, and (2) younger than any structure it bevels. The youngest system forming the oldest peneplain surface in the Appalachian mountains is the Pennsylvanian, and the folds and faults across which the surface is developed took place in the Permian. The peneplain is therefore not only post-Pennsylvanian, but is post-Permian. (3) An old erosion surface is younger than any formation of which there are distinguishable fragments or fossils in fluvial deposits on the surface. This is illustrated in the Driftless Area where stream gravels containing chert pebbles and fossils of Niagaran age lie on divides where the uppermost rock is pre-Niagaran; the divides must be remnants of a surface which is at least younger than mid-Silurian. (4) Peneplains are contemporaneous with fluvial deposits which lie on them, (5) contemporaneous with or older than other terrestrial deposits lying on them, and (6) older than marine formations lying on them. Peneplains are (7) older than valleys which have been cut below them. An old peneplain is (8) younger than rocks forming erosion remnants above the plain and (9) older than deposits in valleys below it. A peneplain is (10) younger than any adjacent peneplain which stands at a higher level and (11) older than any lower adjacent graded plain. In the case where subsidence has taken place and streams have been caused to develop grades at levels higher than was possible before subsidence occurred, points (10) and (11) would be reversed. The higher of two graded surfaces in this case would be the younger. The lower one would be buried and would only in the rarest case be distinguishable. (12) If an erosion surface has been uplifted by tilting, warping, folding or faulting, and there are deposits which have not been disturbed, the surface is older than those deposits. (13) A less accurate method has been used in determining the ages of old erosion surfaces. It has been concluded that a given peneplain is Cretaceous because it is known to be post-Triassic, and because its formation is assumed to have required all the Jurassic, Comanchean, and Cretaceous periods. Or it might be stated that a peneplain is of Eocene age because Pliocene deposits lie in valleys below it and it would have taken the Oligocene and Miocene periods to cut the valleys. The inaccuracy in such criteria is due to the varying rates of degradation by streams under varying conditions and to a general lack of knowledge of the duration of the various geologic periods.

Not all of the above-mentioned means of determining the ages of raised peneplains are likely to be applicable in any one region, but it seems that among so large a number of possible criteria, enough would be usable to lead to conclusions giving at least the approximate age of an old erosion surface.

Once the age of an upland plain is established it may become a valuable horizon marker by which the ages of associated topographies and deposits and structures may be determined. If a peneplain known to be of mid-Eocene age is uplifted uniformly and partly dissected, all topographies and deposits which lie above it are early Eocene or pre-Eocene and all topographies and deposits lying stratigraphically below it are late Eocene or post-Eocene. Similarly, structures which the plain bevels are pre-Eocene and structures in which the surface of the plain itself is involved are late Eocene or post-Eocene.

The extreme care with which all these points should be used and the difficulties in the way of accurate interpretation are emphasized in the discussion among Umpleby, Atwood, Blackwelder and Rich, references to which were given on page 8.

The Dates of Movement

The dates of diastrophic movements in the erosional histories of surfaces can be determined in a general way at least from the ages of the different erosional surfaces. For instance, if it has been proven that an upland peneplain in a given district is Cretaceous in age and there is an intermediate plain below it which is Eocene, it is a short and simple step to the conclusion that the uplift of the upper plain took place at or near the close of the Cretaceous period. But if two consecutive erosion surfaces are more widely different in age, as late Cretaceous and early Pleistocene, the uplift of the Cretaceous plain may have taken place at any time between the two periods; that is at the end of the Cretaceous, or during or at the end of the Eocene, Oligocene, Miocene or Pliocene.

In such cases as the last the student is likely to fall back on an estimate of the amount of time it must have taken to produce the second plain after the uplift of the first. If it seems that it would have required the Miocene and Pliocene periods to produce the lower plain, it might be assumed that the uplift took place at the end of the Oligocene, but this assumption would not be without possibility of serious error. If the conclusion was reached that the uplift of the older plain did take place at the close of the Oligocene, this plain would probably thereafter be called the Oligocene rather than the Cretaceous plain, for the period name given it would be that designating the latest period at which the plain is believed to have been intact.

The conclusion arrived at is that the dates of diastrophic movement can be told in a general way from the ages of consecutive erosion surfaces, but that the closer together the surfaces are in age the more accurately can the date of the diastrophism be determined.

Duration of Geologic Time

A rough estimate of the duration of certain geologic periods might be made if the ages of consecutive erosion surfaces and the dates of uplift are known. For instance, if an upland plain with remnants at an average altitude of 2,000 feet is of Miocene age and is known to have been uplifted at the end of the Miocene period, and if in the same district there is an intermediate plain of early Pleistocene age at an average altitude of 1,000 feet, the conclusion is warranted that the land was degraded 1,000 feet during the Pliocene period. If it be assumed that all this degradation took place at a rate which is average for all lands through all times and that this average rate is 1 foot in 9,000 years, the duration of the Pliocene period would be estimated at 9,000,000 years. The estimate, of course, would be subject to large error in each of the two points of the assumption. However, this method of estimating the duration of geologic time, duly considered and qualified, might be as accurate as estimates based on the rate of accumulation of sediments, the rate of increase of salinity in the sea, the rate of life evolution, or the rate of radio-active changes.

CONCLUSION

From the foregoing discussions it seems clear that there are many rules for determination of the various events in the erosional histories of regions, that all of them are open to exception and some of them to serious and frequent exceptions, that the full interpretation of erosional history is attended with great difficulty, that such interpretation is safe only after wide areas have been studied closely, and with all criteria and limitations in mind, but that on the whole fairly accurate conclusions may be drawn by the student of diligence, persistence and analytic mind.

PART II

MESOZOIC AND CENOZOIC HISTORY OF THE DRIFTLESS AREA

CONTENTS

PART II

MESOZOIC AND CENOZOIC HISTORY OF THE DRIFTLESS AREA

In Part I the various principles involved in the erosional histories of regions were outlined and each principle was analyzed, without special reference to any given region. In Part II it seems possible to summarize and emphasize the principles discussed in Part I and at the same time to contribute something to the history of a region in which much work has been done, on which much has been written, but concerning which there has been some difference of opinion.

All who have worked in the Driftless Area within recent years have noticed that many of the divides within small districts are roughly accordant in level. Most students of the region have concluded that the even-topped divides are remnants of raised peneplains and that more than one cycle was involved in the erosional history of the surface[1]. There

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[1] Bain, H. F., "Zinc and Lead Deposits of Northwestern Illinois," *Bull. U. S. Geol. Surv.*, No. 246, pp. 13-16.
Calvin, Samuel, "Geology of Allamakee County." *Ia. Geol. Surv.*, Vol. IV, pp. 41-44.
Grant, U. S. and Burchard, E. F., *Lancaster-Mineral Point Folio, U. S. Geol. Surv.*, pp. 1 and 2.
Hershey, O. H., "The Physiographic Development of the Upper Mississippi Valley," *Am. Geol.*, Vol. 20, pp. 246-268.
Howell, J. V., "The Occurrence and Origin of the Iron Ores of Iron Hill, near Waukon, Iowa," *Ia. Geol. Surv.*, Vol. XXV, pp. 54-62.
Hughes. U. B., "A Correlation of the Peneplains of the Driftless Area," *Proc. Ia. Acad. Sci.*, Vol. 23, pp. 125-132.
Leonard, A. G., "Geology of Clayton County," *Ia. Geol. Surv.*, Vol. XVI, pp. 220-233.
MacClintock, Paul, *The Wisconsin River Valley Below Prairie du Sac*, Unpublished paper.
Salisbury, R. D., "Preglacial Gravels on the Quartzite Range near Baraboo, Wisconsin," *Jour. Geol.*, Vol. III, pp. 655-667.
Salisbury, R. D. and Atwood, W. W., "The Geography of the Region about Devils Lake and the Dalles of Wisconsin," Bull. No. 5. *Wis. Geol. and Nat'l Surv.*, pp. 60-64.
Shaw, E. W. and Trowbridge, A. C., "Galena-Elizabeth Folio," *U. S. Geol. Surv.*, pp. 9 and 10.
Shipton, W. D., "The Geology of the Sparta Quadrangle, Wisconsin," Master's Thesis, Univ. of Iowa, unpublished.
Trowbridge, A. C., "Some Partly Dissected Plains in Jo Daviess County, Illinois," *Jour. Geol.*, Vol. XXI, pp. 731-742.
"Preliminary Report on Geological Work in Northeastern Iowa," *Proc. of the Ia. Acad. Sci.*, Vol. 21, pp. 205-209.
"Physiographic Studies in the Driftless Area," Abstract, *Bull. Geol. Soc. Am.*, Vol. 26. p. 76.
"The History of Devil's Lake, Wisconsin," *Jour. Geol.*, Vol. XXV, pp. 344-372.
Trowbridge, A. C. and Shaw, E. W., "Geology and Geography of the Galena and Elizabeth Quadrangles," Bull. No. 26. *Ill. Geol. Surv.*, pp. 126-146.
Williams, A. J., "Physiographic Studies in and around Dubuque, Iowa," Master's Thesis, University of Iowa, unpublished.

has, however, been disagreement concerning the number of cycles, and the dates of historical events. Recently, doubt has been expressed that these upland surfaces represent old peneplains, and the belief advanced that all the features of the topography have been formed in a single erosional cycle[1]. Most of the papers so far published on this subject are the results of work done in small and isolated districts within the general region. Therefore it is not strange that agreement has not been reached, and that some of the conclusions are incorrect. The writer has seen all of the Driftless Area which lies in Iowa and Illinois and much of that which lies in Wisconsin and Minnesota, and it now seems possible to bring together material from which accurate conclusions may be drawn.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge, with appreciation, the assistance of several scores of students in the Universities of Iowa and Chicago, who have used the Driftless Area as a field of instruction under his direction in the ten years during which he was actively engaged in teaching and research work there. Special mention is made of A. J. Williams, Jesse V. Howell, W. D. Shipton, Urban B. Hughes, Leroy Patton and Paul MacClintock, each of whom has prepared a report on the general geology of some assigned portion of the Driftless area, following detailed field work. Most of these reports have constituted Master's or Doctor's theses. Not all have been published. Mr. Williams and Mr. Howell did their work in the Iowa portion of the region, Mr. Shipton in the Sparta quadrangle of Wisconsin, Mr. Hughes in the Richland Center quadrangle of Wisconsin, Mr. Patton chiefly in the southeastern counties of Minnesota, and Mr. MacClintock along the lower Wisconsin river valley. In all the work special attention was given to stratigraphy and structure and to their relations with physiographic forms. The results have been freely drawn upon in the preparation of Part II of this paper.

Thanks are also due to R. D. Salisbury, W. C. Alden and

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[1] Martin, Lawrence, *Wis. Geol. and Nat'l Hist. Surv.*, Bull. 36, pp. 55-70.

Frank Leverett, who spent several days in northeastern Iowa with Mr. Williams and the writer in 1915, going over some of their data and listening with interest to some of their interpretations. For these interpretations, however, the writer assumes full responsibility.

The previous work of Grant and Burchard in the Lancaster and Mineral Point quadrangles, resulting in Folio No. 145 of the U. S. Geological Survey, were particularly useful.

Finally to R. D. Salisbury, M. M. Leighton and Leroy Patton, thanks are offered for thorough criticism of the manuscript of Part II as well as Part I of this paper.

ROCK FORMATIONS

The rock formations of the Driftless Area range from Huronian to Silurian in age. Hard pre-Cambrian quartzite and igneous rocks outcrop in various places in Wisconsin, as at Baraboo, Wausau, Necedah, and Black River Falls and appear to underlie Paleozoic sediments throughout the area. The Paleozoic group consists of Cambrian, Ordovician, and Silurian formations, the names, thicknesses and relative resistance of which are shown in the accompanying table. The Decorah shale is variable in thickness but

TABLE SHOWING THE ROCK FORMATION OF THE DRIFTLESS AREA

System	Formation	Kind of Rock	Thickness in feet	Resistance to erosion
Silurian	Niagaran	Cherty dolomite	200	Resistant
	Alexandrian	Thin-bedded limestone	0-80	Nonresistant
Ordovician	Maquoketa	Shale	100-200	Nonresistant
	Galena	Cherty dolomite	240	Resistant
	Decorah	Shale	0-30	Nonresistant
	Platteville	Limestone	80	Resistant
	St. Peter	Sandstone	20-300	Nonresistant
	Prairie du Chien	Cherty dolomite	0-300	Resistant
Cambrian	St. Croix (Potsdam)	Sandstone, limestone, shale and dolomite	1000	Nonresistant
Pre-Cambrian		Quartzite, dolomite, slate, various igneous rocks	5000+	Resistant

thin in all places, and, lying as it does between two resistant formations, does not affect topography greatly. So far as their effect on topography is concerned the Platteville and Galena formations are a unit. The Alexandrian formation varies in thickness and resistance and affects topography in such a way as to be inseparable from the Niagaran formation in some places, and from the Maquoketa in others. There is an unconformity between the St. Peter and Prairie du Chien formations, which causes both to vary in thickness, but the sum of their thicknesses is nowhere far from 300 feet[1]. The Cambrian formations are all weak but vary slightly in resistance. Devonian and Pennsylvanian formations were perhaps deposited over part or all of the region, but, if so, they have been eroded away. The erosional history of the present surface started with the final withdrawal of the Paleozoic seas and continued through the Mesozoic and Cenozoic eras.

STRUCTURE

Although in most of the Driftless Area the strata dip in a general southwesterly direction, there is a northeast-southwest axis crossing the Mississippi river between La Crosse, Wisconsin, and Winona, Minnesota, and passing north of Sparta, north of which the beds dip northwesterly. In other words, the structure is that of a low anticline with its axis near the north edge of the region, plunging to the southwest, with a long limb to the south and a relatively shorter limb, so far as the Driftless Area is concerned, to the north. Most of the work on which this paper is based has been done south of the crest of the arch and the relationships between topographic forms and structure are consequently best known there. However, Mr. Patton and the writer worked in the axial area and to some extent north of the axis in Minnesota and Wisconsin in 1917.

The average direction of dip of the formations south of Winona and Sparta, as determined by twenty-eight computations is S. 26° W., and the average amount 14.6 feet per

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[1] Trowbridge, A. C., *Ia. Acad. Sci.*, Vol. XXIV, pp. 177-182.

mile. Four computations in the area north of the arch show an average dip there of N. 35° W. in direction and 6.9 feet per mile in amount.

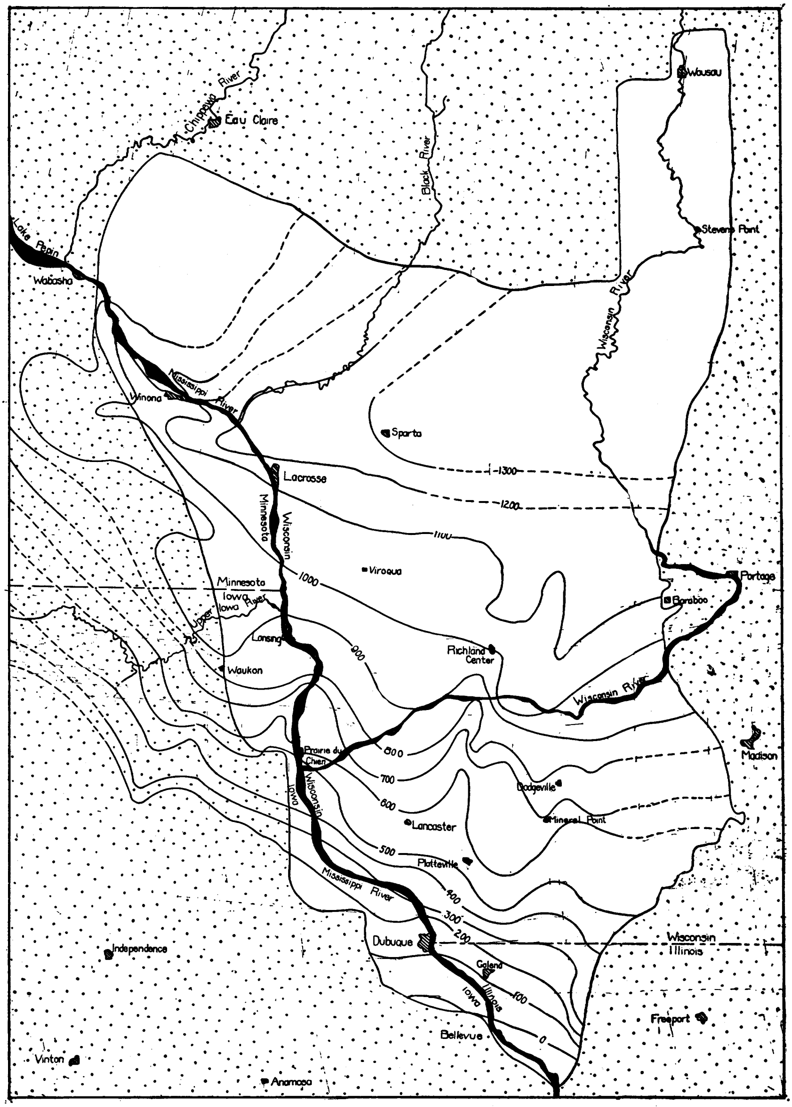

Fig. 11. Sketch map of the Driftless Area and its environs showing structure contours on the contact between Prairie du Chien and Jordan formations. Structural contour interval equals 100 feet. Horizontal scale 1/500,000. Contours are broken where courses are conjectural.

Both the south-dipping and the north-dipping monoclines and to an extent also the nearly horizontal structures of the axial area are interrupted in many places by low anticlines and shallow synclines. The whole composite structure of the Driftless Area might be said to be a low anticlinorium, plunging southwestward. For additional details see Fig. 11.

THE STAGE OF EROSION

In the present cycle of erosion the general surface of the Driftless Area is in late youth or early maturity, although small portions exhibit a later stage of development. The valley of the Mississippi and the valleys of its larger tributaries, such as the Wisconsin, La Crosse, and Upper Iowa rivers, appear to be mature, but if the thick deposits in them were removed the valleys would have a much more youthful appearance. Most of the valleys in the area are young. There are considerable areas of unreduced flattish land on the highest divides and still greater areas at lower altitudes well above the valley bottoms. It is these unreduced upland surfaces which form the chief physiographic problems of the region and which at the same time give the investigator his best clue to the history of the surface. Along the main drainage lines there are narrow graded valley flats which are valuable for comparison with the upland flats. The topography has a relief of over 600 feet within short distances, and before the valleys were partially filled the relief was over 800 feet.

EVIDENCES OF MORE THAN ONE CYCLE OF EROSION

Of the several lines of evidence for more than one cycle of erosion which have been used in determining the erosional histories of various surfaces and which were discussed in Part I, the Driftless Area shows seven, in different degrees of perfection and significance.

Even-Crested Summit Areas (the Dodgeville Plain)

In most portions of the Driftless Area the highest divides are noticeably flat on their summits. These flat surfaces forming the summit areas are the sites of cities, towns, villages, farms, wagon roads and railroads. In the Baraboo district of Wisconsin there is an area more than two square miles in extent so nearly flat that the drainage on its surface is poor, and no spot is 10 feet higher or lower than the general elevation of 1400 feet. In the southern portion of the Sparta Quadrangle, Wisconsin, there is much flat land at about 1335 feet A. T., more than 500 feet above main drainage lines, on which are located the villages of Newberg Corners, Middle Ridge and Portland (Fig. 12). Here, in an area of 5 miles square there are approximately 7,000 acres of land under cultivation, supporting a prosperous population of 4,500, all on flat-topped divides. From the south edge of the Sparta Quadrangle a "ridge road" follows a continuous divide for more than 50 miles, passing through the towns of Cashton, Rewey, Westby, Viroqua, Seneca and Eastman, and leaves the crest of the ridge only about a mile from the bluff of the Mississippi and two miles from Prairie du Chien. In this distance the crest of the divide has a relief of less than 100 feet, and the width of the nearly even crest varies from a few feet to a half mile

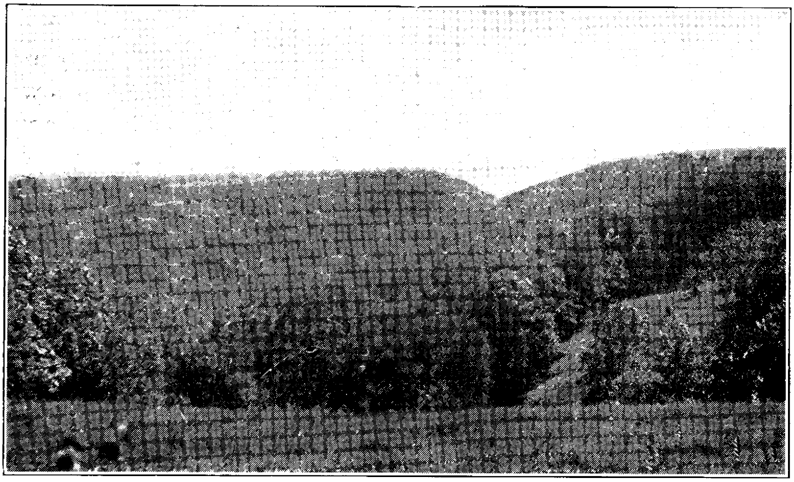

Fig. 12. View of the summit plain in the south portion of the Sparta Quadrangle.

or more. From the main ridge tongues of flat land project out between tributary streams on both sides.

In the southern portion of the Richland Center quadrangle in Wisconsin the summits of many of the divides are nearly flat and noticeably accordant in their levels. These divides are spurs and outliers of a wide, continuous area of gently rolling land known as Military Ridge, extending east and west in the northern part of the Lancaster and Mineral Point quadrangles. Military Ridge is unbroken from Bradtville to Blue Mounds, a distance of over 60 miles. On or near its summit, Bradtville, Patch Grove, Mount Hope, Mount Ida, Fennimore, Preston, Montfort, Cobb, Edmund, Dodgeville and Mount Horeb are located. Connecting these towns are good high roads, whose grades are low and on which bridges are noticeably few in number. From Fennimore to Blue Mounds, the ridge is utilized for the road bed of a branch of the Chicago and Northwestern Railway.

In the north half of the Galena and Elizabeth quadrangles in Illinois, the highest surfaces are the tops of isolated mounds or short dendritic ridges which include only very small patches of flat land, but which have accordant levels at about 1150 feet A. T. In the south part of these two quadrangles there are many long, continuous, dendritic, flat-topped ridges whose summit areas are the sites of homes, farms and ridgeroads. These ridges have an average altitude around 1,000 feet. At about this altitude there are thousands of acres of excellent farm land. In the north part of these quadrangles the summit levels are 450 feet above the beds of the main streams, and in the south part they are 350 feet above drainage.

There are no extensive summit levels in Iowa, although upland plains exist. Between Waukon and Church and extending west from Waukon toward Decorah, east through Elon, and southeast to Rossville, there are dendritic stream divides whose summits are much more nearly flat than the surrounding surface, and are the sites of villages, main roads and farms. The maximum relief of this surface is less than 100 feet (1200-1300). Upland flats are also known at Monona, Luana and Watson in the southeastern part of the Waukon quadrangle, at National, Garnovillo, Upde-Graff, Colesburg, an area east of Graham, Luxemburg and other points in the Elkader quadrangle, and at or near Holy Cross, Sherrill, Rickardsville, Bankston, Balltown, and Tivoli in the Iowa portion of the Lancaster quadrangle. In the extreme southern part of the Driftless Area in the Iowa portion of the Galena quadrangle there are considerable areas of flat land on high divides, which are used for upland farms and roads.

Flat summit areas with accordant levels are not extensive in Minnesota. They are best developed in the western parts of Winona and Houston counties. In Winona county a strikingly flat plain of about 15 square miles in area lies between Utica and St. Charles and to the south from there. It is approximately 1300 feet above sea level. Near Spring Grove, Houston county, at an elevation of approximately 1325 feet, the summit plain is represented by extensive prairie-like uplands, spurs of which ramify from the main area. Similar conditions occur also in the neighborhood of Caledonia.

From the foregoing descriptions, the significant facts concerning the topography of the summit surfaces in the Driftless Area may be summarized as follows: (1) There are many divides whose summits are noticeably even. (2) Some of these areas of upland flat are long and broad. (3) The various areas of upland flat have such slight irregularity in comparison with the rest of the topography that they are favorable sites for farming. (4) If the elevations of isolated summit areas in a given district be compared, they are found to be strikingly accordant, though not identical. (5) Accordant summit levels are known in practically all portions of the Driftless Area. (6) The districts where the summit plains occur are close enough together to warrant correlation from one district to another; from Baraboo, through the Richland Center and Mineral Point quadrangles to Jo Daviess County, Illinois; from Baraboo to Sparta; from Sparta through Viroqua and Prairie du Chien to Iowa; from Dodgeville via Bradtville to National, Iowa;

from Iowa into Winona and Houston counties in Minnesota; from the Minnesota line in Iowa to Dubuque; from the Galena quadrangle in Illinois to the area south of Dubuque in Iowa. (7) If the several summit areas of a district be projected until they meet, a surface is constructed which has a relief of something less than 200 feet. (8) If the constructed summit plains of the several districts of the Driftless Area, as explained in (7) be projected across intervening areas where summit flats are wanting until they meet, an almost reliefless, gently south-sloping plain results which covers practically the whole Driftless Area. Because the surface so reconstructed is well represented at Dodgeville, because there is at Dodgeville a large area of upland flat, and because, from Dodgeville the flat may be traced with certainty in all directions, this uppermost plain, reconstructed by projecting the upland flats until they meet, is hereafter called the *Dodgeville plain.*

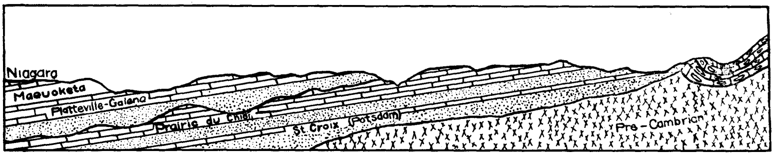

Fig. 13. An idealized north-south section in the Driftless Area, showing the general relation of the Dodgeville plain to the rock formations. The upland surfaces are found in large areas on the resistant Prairie du Chien, Platteville, Galena, and Niagara formations, but are wanting on the relatively nonresistant Cambrian sandstones, St. Peter sandstone and Maquoketa shale.

Topography and rock structures are so intimately and fundamentally related that it is always unsafe to draw important conclusions from analysis of topography before these relations are understood. It is therefore necessary that a careful study be made of the rock formations on which the Dodgeville plain lies, the structure of these formations, and the relative attitudes of plain and formations, before interpretation of the Dodgeville plain is attempted. Failure to give due weight to these relationships seems to be responsible for certain errors of the past.

The Dodgeville plain is underlain by different rock formations at different places. In the Baraboo district of Wis-

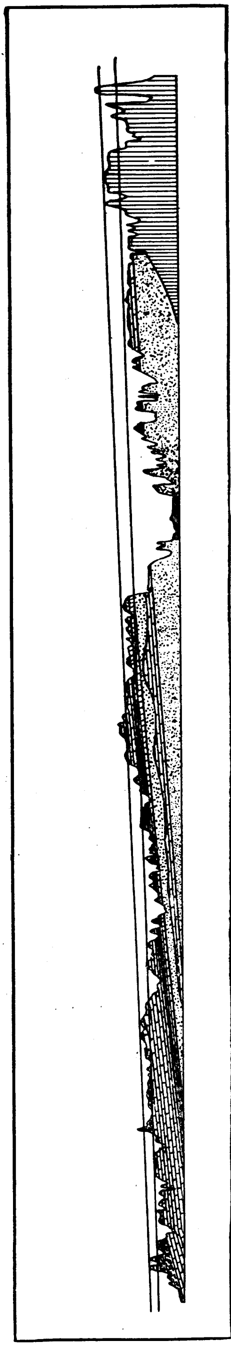

Fig. 14. An accurate topographic profile and structure section taken in a curved line from the Baraboo district to Jo Daviess County, Illinois, crossing the Baraboo, Denzer, Richland Center, Mineral Point, and Elizabeth topographic atlas sheets. The uppermost straight line represents the reconstructed Dodgeville plain. (After U. B. Hughes).

consin it lies on Huronian quartzite and in the Sparta district on the Prairie du Chien and St. Peter formations. Military Ridge and its spurs are capped by Galena dolomite, as are also the upland divides around Waukon in Iowa. South of Turkey river in Iowa, and south of Lancaster in Wisconsin and Illinois, the plain lies on Niagara dolomite. In southeastern Minnesota it lies for the most part on the Platteville formation but it places cuts across to St. Peter. In a general way the Dodgeville plain bevels the south-dipping formations, lying on progressively younger beds from north to south. Either because of a decrease in the slope of the plain north of the Iowa line, because of a change in the direction of slope, or because the plain has been very slightly warped since its formation, its remnants are not greatly higher in Minnesota than in Iowa, and its stratigraphic position is somewhat but not much lower in Minnesota than farther south. It also bevels the crest of the arch. No remnants of the plain have been observed north of the axis and therefore it cannot be definitely stated that the north-dipping beds are also bevelled by it, although such is probably the case. It is noticeable, however, that only the more resistant formations are found capping the highest divides where these divides are flat-topped and accordant in their levels. Wide areas of the plain lie on the Prairie du Chien, Galena, Platteville and Niagara formations respectively. The St. Peter sandstone underlies patches of the plain in very small areas only, and the Maquoketa formation is not known to form summit flats at all. In traveling from north to south three distinct belts are crossed, in each of which there are large upland remnants of the Dodgeville plain and between which there is none. (Figs. 13 and 14)

Assuming that the Dodgeville plain is a geometrical plane, it is possible to ascertain its dip and strike if the relative positions and altitudes of three points on the plane forming a triangle are known. If the elevations of a certain stratigraphic horizon under the three points on the plain can be ascertained it is also a simple matter to compute the dip and strike of the strata and get the relative directions and amounts of dip of plain and strata (Fig. 15).

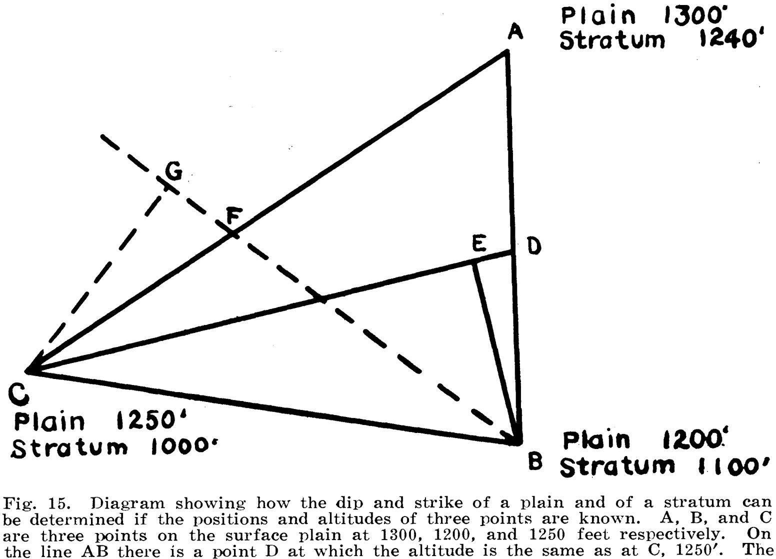

Fig. 15. Diagram showing how the dip and strike of a plain and of a stratum can be determined if the positions and altitudes of three points are known. A, B, and C are three points on the surface plain at 1300, 1200, and 1250 feet respectively. On the line AB there is a point D at which the altitude is the same as at C, 1250′. The line CD is the strike of the plain. The direction of dip is obtained by constructing line EB at right angles to CD through B. Reading the direction of EB the dip is found to be S 14° E. From E to B the surface falls 50′. Scaling EB the amount of dip of the plane is found to be 4.4′ per mile.

Knowing the elevations of a stratigraphic horizon under points A, B, and C to be 1240, 1100, and 1000 feet respectively, locating the 1100′ point on AC at F, BF becomes the strike of the strata, the dip CG is S 37° W, and the amount of dip is 7′ per mile.

The results of 13 such computations, based on points south of the axis of the arch are given in the following table.

TABLE OF RESULTS OF COMPUTATIONS OF DIP AND STRIKE OF DODGEVILLE PLAIN AND ROCK STRATA

General Location	Location of Points	Direction of Dip of Plain	Amount of Dip of Plain	Direction of Dip of Strata	Amount of Dip of Strata
South part of Sparta Quadrangle Wisconsin	A-C Sec. 20 Leon Twp. B-C Sec. 8 Portland Twp. C-NC Sec. 21 Washington Twp.	N 57°W	5.3′	S 59°W	14′
Whole Sparta Quadrangle Wisconsin	A-Castle Rock B-Middleridge C-SC Sec. 18 Jefferson Twp.	N 43°W	2.6′	S 38°W	10.7′
Lancaster, Mineral Point and Richland Center Quadrangles, Wis.	A-Fennimore B-Dodgeville C-7½ mi. S. of Wyoming	N 20°W	9.4′	S 13°W	14.2′
Elizabeth Quadrangle, Illinois	A-Wc Sec 19 Thompson Twp. B-Sw Sec. 31 Woodbine Twp. C-Nc Sec. 33 Stockton Twp.	S 14°W	7.3′	S 28°W	34.4′
Northern Iowa, Waukon Quadrangle	A-Waukon B-Church C-Rossville	S 56°E	10.9′	S 49°E	8.4′
Iowa-Wisconsin	A-Church B-Updegraff C-Mt. Ida	S 76°E	1.2′	S 40°W	17.1′
Wisconsin-Iowa-Illinois	A-Sparta B-Waukon C-Stockton	S 20°E	2.9′	S 22°W	9.1′
Wisconsin-Iowa	A-Sparta B-Waukon C-Dodgeville	S 4°E	1.8′	S 20°W	9.5′
Iowa-Wisconsin-Illinois	A-Waukon B-Mineral Point C-Stockton	S 21°W	9.6′	S 18°W	8.3′
Wisconsin-Iowa-Illinois	A-Sparta B-Bankston C-Stockton	S 51°E	3.5′	S 37°W	12.8′
Iowa-Illinois	A-Waukon B-Updegraff C-Stockton	S 86°E	3.2′	S 32°W	16.4′
Iowa-Wisconsin	A-Waukon B-Dodgeville C-Bankston	S 1°E	1.8′	S 19°W	12.9′
Wisconsin Iowa	A-Denzer B-Waukon C-Updegraff	S 29°W	2.2′	S 12°W	10.8′

These computations bring out certain facts. The plain constructed by connecting areas of summit plains across intervening areas is by no means a geometrical plane, for it dips in different directions and by different amounts in different places. In small districts, widely differing results can be obtained by taking different sets of points as bases for computation. Local irregularities obscure the general slope. If the results of all the available computations are considered, the average slope of the plain is in the direction S 75° E to an amount of 4.7 feet per mile. If the local estimates be eliminated and only those which involve long distances be included, the effect of local irregularities is minimized and the general slope of the plain is found to be S 23° E, 3.3 feet to the mile. The direction and amount of dip of the strata are much more nearly constant and average S 28° W and 14.2 feet per mile recpectively. Nowhere are the plain and the strata parallel. The angle between their respective average directions of dip is 51° and the strata dip more than three times as steeply as the plain slopes. Even in small districts where upland plains are broad and cover a considerable distance in directions at right angles to the strike of the strata, the slope of the plain and the beds are not parallel. The lack of parallelism between the Dodgeville plain and the strata which underlie it is expressed in the fact that progressively younger beds are bevelled by the plain from north to south on the south limb of the arch.

As outlined in Part I such a plain as the Dodgeville plain is open to several possible interpretations: It might be the original marine plain of deposition, a plain of marine erosion, or a structural plain on a single hard stratum. The apparent accordance of levels might be due to the erosion in a single cycle of a surface underlain by gently south-dipping and unequally resistant formations, developing a series of somewhat even-topped cuestas whose summits were never parts of a plain now dissected. Or, the Dodgeville plain might be a true peneplain.

The Dodgeville plain cannot be the sea bottom uncovered by the withdrawal of the Paleozoic sea, for it is known that

Niagara dolomite was deposited in this sea over the whole region, and the plain is directly underlain by Huronian rocks at Baraboo, the Prairie du Chien formation at Sparta, the Galena formation at Church and Waukon and on Military Ridge. From these portions of the surface younger rocks must have been eroded. Also there are monadnocks standing above the level of this surface at several places, for instance, Sauk Point in the Baraboo district, Blue Mounds at the east end of Military Ridge, and Sherrill and Sinsinawa Mounds farther south.

Neither is the Dodgeville plain the result of marine denudation. The erosion remnants above it are not isle-like, nor is it bordered anywhere by shore features. A still more significant fact is that marine deposits, younger than the rock formations across the edges of which the plain is developed, are wholly wanting on the summit surfaces of the region, although other deposits have been preserved there. It is also extremely doubtful if such broad wave-cut terraces have ever been developed anywhere, especially far in the interiors of continents.

The theory that the Dodgeville plain was formed on the surface of a single especially hard formation is untenable for the reasons that the plain lies on different formations at different places, that not all the formations are resistant, and that the plain slopes southward at a considerably lower angle than the angle of dip of the rock formations.

The idea that the Dodgeville plain consists of a series of unrelated structural plains is incoroprated in the theory that the plain is a series of cuesta tops, and this theory is next to be considered.

The Cuesta-Single Cycle Theory

Of the first four possible interpretations outlined above, the idea which has been advanced that the Dodgeville plain, as described on previous pages, does not exist and never did exist, but consists merely of a series of unrelated cuestas, is more probable than any of those thus far considered, and is to be accepted or rejected only after the most careful study of the field conditions. A possible source of confusion should be eliminated at once by the statement that whatever has been the history of the upland surfaces they do constitute cuestas. Martin[1] has defined a cuesta as "an upland with a short, steep descent, or escarpment, on one side, and a long, gentle slope on the other." The three belts containing areas of summit flats answer the definition perfectly, and they are cuestas. The problem remains, however, as to whether their more or less even crests, related as they are to rock structures, could have been developed in a single cycle of erosion. As Martin points out in describing cuestas, "the gentle slope usually corresponds to the inclination or dip of slightly-inclined sedimentary rocks and one resistant layer, as of limestone, may determine the whole dip slope."

Following this definition and description the characteristics of cuestas which have had a history involving only one erosion cycle are illustrated in Fig. 16.

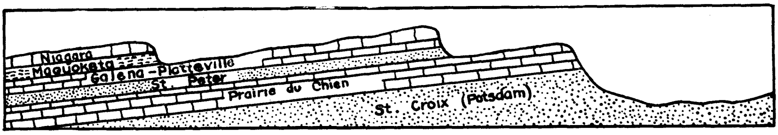

Fig. 16. Diagram illustrating the topography of the Driftless Area as it should be if the summit areas are the back slopes of normal cuestas developed in a single cycle of erosion.

There are several points which seem to favor the theory that the upland surfaces included in the Dodgeville plain are merely the tops of cuestas, developed, together with the rest of the topography, in a single cycle of erosion. (1) The belts in which the upland surfaces are considerable are cuestas. (2) The upland surfaces are practically confined in their distribution to the areas of outcrop of resistant rock formations. (3) There are three resistant formations and there are three conspicuous belts containing upland surfaces south of the anticlinal axis. (4) In individual districts, and in the region as a whole, the upland surfaces have a general southerly slope and the strata dip generally south. However, these arguments are superficial, for their

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[1] Martin, Lawrence, *Wis. Geol. and Nat'l Hist. Survey*, Bull. 36, p. 42.

features can be explained as well on the basis of more than one cycle as on the basis of a single cycle. There are also several points now to be brought out by a more careful study of topography, especially in its relations with structure, which cannot be explained on the cuesta-single cycle theory and are in keeping with the multiple cycle theory.

(1) The south slopes of the upland surfaces are not parallel with the strata as is normal for cuestas. Compare figures 1 and 4. The south slopes of the Dodgeville plain correspond with the dip of the strata neither in direction nor in amount, as shown in the preceding table (p.).

(2) Those portions of the Dodgeville plain which lie on a single rock formation bevel the layers of that formation. Within the bounds of the Sparta quadrangle, the summit of the Prairie du Chien cuesta lies on 35 feet of Prairie du Chien dolomite at Castle Rock, and on constantly increasing thicknesses to the south, until 229 feet of the formation appear below the cuesta top in the southwest corner of the quadrangle. In the Galena and Elizabeth quadrangles in Illinois the surface of the Niagara cuesta cuts from a stratigraphic position 60 feet above the base of the Niagara formation at the north border of the quadrangles to a position 170 feet above the base at the south edge. Likewise the summit of the Galena-Platteville cuesta lies 80 feet above the base of the Platteville limestone near its northern edge in the Richland Center quadrangle and 300 feet above this horizon on one of the south spurs of Military Ridge. This bevelling of different beds in formations by individual cuesta tops is also illustrated between Church and Rossville, and between Updegraff and Monona in Iowa, and at many other localities within the Driftless Area.

(3) In some places at least, two belts of cuesta tops which are roughly parallel with the strike of the strata, are connected by long, continuous, more or less broad summit divides which are roughly parallel with the dip. Such a divide is that connecting the Prairie du Chien cuesta in the south portion of the Sparta quadrangle with the Galena

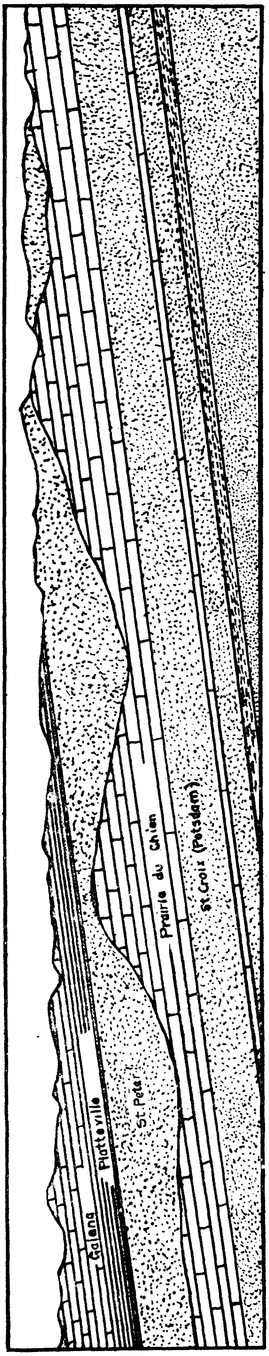

Fig. 17. A cross-section and profile from the Prairie du Chien cuesta near Cashton, Wisconsin, along the crest of the Mississippi-Kickapoo divide, to the Galena cuesta two miles northeast of Prairie du Chien. The horizontal distance is 50 miles. Vertical scale: 1 inch equals 100 feet.

cuesta east of Prairie du Chien. This divide includes much flat land on its summit. Its summit area has a relief of less than 100 feet, and yet it bevels the edges of the Prairie du Chien, St. Peter, Platteville, Decorah, and Galena formations. In its extent of over 50 miles its surface falls from 1300 feet at its north end, to 1200 feet near Prairie du Chien, although a stratigraphic horizon which has an altitude of 1200 feet in the Sparta quadrangle is found at 620 feet at the south terminus of the divide. So independent are the surface and the strata that the change from one formation to another is not expressed in the surface. (Fig. 17) It would be impossible to explain the details of such a ridge on the basis of a single cycle of erosion.

(4) In areas where the summit plains are broad and flat, and such conditions exist in many places in the Driftless Area, it is difficult to conceive a way by which the material from above was removed to make the flats, under the theory that there has been but one cycle of erosion. In the Sparta quadrangle, 200 feet of Niagara dolomite, 100 feet of Maquoketa shale, 320 feet of Galena dolomite and Platte-

ville limestone, 100 feet of St. Peter sandstone, and many feet of Prairie du Chien dolomite have been removed in such a way as to leave thousands of acres of flat land on the divides, 500 feet above present drainage. The three dolomites are cherty and resistant to mechanical wear, although much of the rock is soluble in water. The sandstone and shale are non-resistant physically, but resistant chemically. These same rock formations, in varying amounts, have been removed in making all of the many upland flats of the Driftless Area. On few of these flat surfaces is there any concentration of residual materials such as chert fragments, save those which have been rounded by stream action, although such residual materials are not entirely lacking everywhere. It seems that the removal of the rocks from positions above the flat upland surfaces must have been accomplished by some agent which was capable of removing products of disintegration and of decomposition, even the coarse material. If these surfaces have always been divides, and this must have been the case if there has been no rejuvenation of streams, all of the originally overlying material could not have been removed by streams, for on many of the flats there are now no streams nor stream channels. It is not conceivable that wind degraded the tops of the divides to make flat summits; the region has not been glaciated; waves and currents have been eliminated. It cannot be that solution by ground water has been the method of degradation of these surfaces, for much of the material such as shale, the sandstone, and the chert in the dolomite are practically insoluble. Even if it be conceived that the shale and sandstone constituents were removed by the wind and the soluble portions of all the rocks were dissolved and carried away by ground water, there would be left many feet of residual chert.

(5) It has been made clear that the Dodgeville plain, constructed by joining the various patches of summit plain in each of the three cuestas and the summits of the cuestas across intervening areas, is by no means perfectly flat. But, it is difficult to explain even the rough accordance of summit levels in individual districts and the general slope

of the plain southward, on the assumption that the upland surfaces are merely parts of unrelated cuestas. Estimating that erosion started when the whole region was covered by 1000 feet of strata now gone, and knowing the amount and direction of dip of the strata and the elevation of the various portions of the summit plain, it is possible to estimate what was the original altitude of the surface and to what altitude the upland surface was reduced at any given locality. The dip of the strata is so slight that the altitude of the original surface may be obtained by adding the thickness of the strata removed to the present altitude of the surface, without appreciable error. The results of a series of such computations for a series of localities from north to south and including each of the three cuestas south of the structural axis are tabulated as follows:

TABLE SHOWING THE RELATION OF THE ORIGINAL SURFACE OF THE DRIFTLESS AREA TO THE SURFACE OF THE DODGEVILLE PLAIN

Locality	Original altitude of surface.	Thickness of various formations removed in feet.	Total thickness of rocks removed in feet.	Altitude of present upland surface.
		First Series—Sparta-Lancaster Quadrangle		
Castle Rock north part Sparta Quadrangle	2220	200-Niagara 100-Maquoketa 240-Galena 80-Platteville 100-St. Peter 165-Prairie du Chien	885	1335
Near Portland south part Sparta Quadrangle	2130	200-Niagara 100-Maquoketa 240-Galena 80-Platteville 100-St. Peter 40-Prairie du Chien	760	1370
Near Mt. Hope, north part Lancaster Quarangle	1600	200-Niagara 100-Maquoketa 90-Galena	390	1210
Near Richardsville, Iowa, south part Lancaster Quadrangle	1260	130-Niagara	130	1130
		Second Series—Richland Center, Mineral Point, Elizabeth Quadrangles		
Near Highland, south part Richland Center Quadrangle	1693	200-Niagara 100-Maquoketa 163-Galena	463	1230

Near Montford, north part Mineral Point Quadrangle	1610	200-Niagara 100-Maquoketa 110-Galena	410	1200
Near Platte Mds. west central part Mineral Point Quadrangle	1440	200-Niagara 50-Maquoketa	250	1190
Four miles south of Shullsburg, south part Mineral Point Quadrangle	1375	170-Niagara	170	1205
Near Erie School, north part Elizabeth Quadrangle	1260	130-Niagara	130	1130
Terrapin Ridge, south part Elizabeth Quadrangle	1135	95-Niagara	95	1040

Third Series—Waukon
Elkader Quadrangle in Iowa

Near Church, north part Waukon Quadrangle	1766	200-Niagara 100-Maquoketa 216-Galena	516	1250
Near Monona, south part Waukon Quadrangle	1555	200-Niagara 100-Maquoketa 45-Galena	345	1210
Near Updegraff, central part Elkader Quadrangle	1200	10-Niagara	10	1190

Fourth Series—Baraboo,
Richland Center, Lancaster Quadrangle

Gibraltar Rock, central part Baraboo Quadrangle	1870	200-Niagara 100-Maquoketa 240-Galena 80-Platteville	620	1250
Six miles south of Hillsdale, southern part Richland Center Quadrangle	1815	200-Niagara 100-Maquoketa 240-Galena 5-Platteville	545	1270
Near Preston, northeast part Lancaster Quadrangle	1610	200-Niagara 100-Maquoketa 140-Galena	440	1170
Three miles east of Bankston, Iowa, southeast part Lancaster Quadrangle	1290	140-Niagara	140	1150

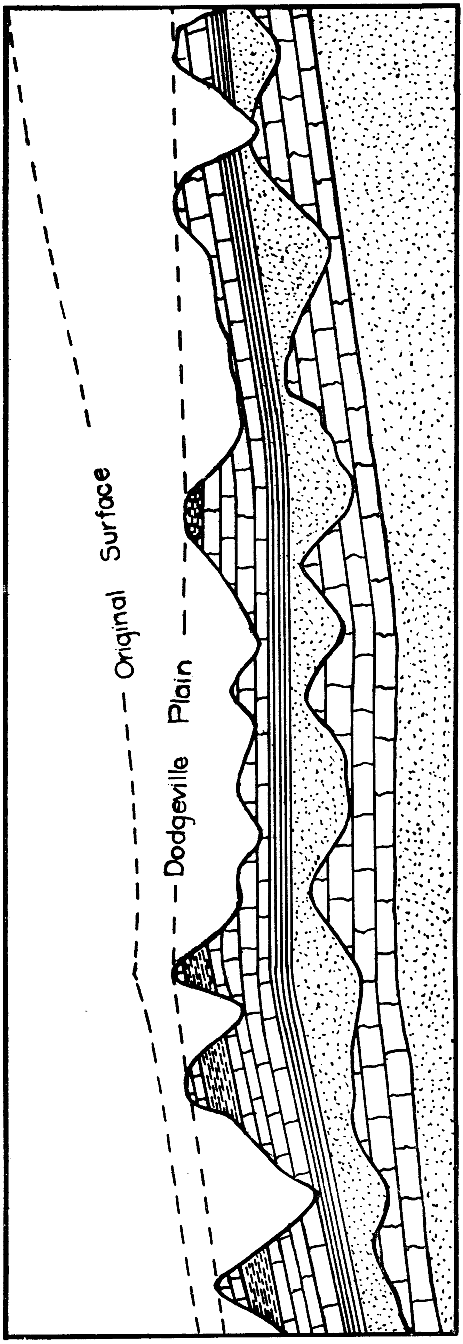

Fig. 18. Diagram to scale illustrating the orderly way in which erosion has progressed in the formation of the accordant summit levels.

These tables show that the original surface was much steeper than the present Dodgeville plain; that the amounts of material removed from the divides decrease by a regular progression to the south; that different proportions of resistant and non-resistant rocks have been removed in different places; and that there is a certain definite order in the relations of original altitudes, amount of rock removed, and present altitudes, irrespective of the relative thickness of resistant and non-resistant formations removed (Fig. 18). It seems improbable that degradation of the tops of divides would take place in so orderly a fashion unless the streams reduced the general surface to grade.

(6) In a region where so much erosion has taken place it would seem that the relative hardness of the resistant formations would express itself in topography if there had been but one cycle. The most resistant of the three should stand the highest, and the least resistant the lowest. But the general southward slope of the Dodgeville plain is uninterrupted by differences in rock hardness, although it is doubtless true that local resistant rocks have influenced local irregularities in its surface. (Compare Fig. 16 with Figs. 13 and 14)

(7) If the upland surfaces in the Driftless Area are entirely structural it would seem likely that the local anticlines and synclines which interrupt the general monoclinal dip would cause undulations in the surface of the Dodgeville plain. In the Galena and Elizabeth quadrangles, where a portion of this plain is well known and where the anticlines and synclines have been carefully mapped, there is no apparent relation between the altitude of the upland surfaces and the folds. The plain bevels the local folds without any expression of the structure in the topography. It is true that there are a few high parts of the upland plain which correspond roughly with anticlines, such as at Waukon, but there are also many high places where there are no anticlines, many high places over synclines, and many low places on anticlines. No general effect of local structure can be observed in the topography of the plain. The higher portions of the upland plain are to be interpreted as resistant portions of the rocks or as original inter-stream areas, not as arched structures.

(8) It is abnormal for the divides of a surface to be lowered greatly before evidences of old age in adjacent valleys appear. During youth of the normal cycle of erosion the main work of the streams is in the development of valleys and the dissection of the original surface. Maturity is ushered in when the upper flat approaches thorough dissection and lasts until lower flats are formed and come to constitute an appreciable portion of the surface. Most of the work of lowering the original divides is accomplished

after the old age of the valleys has been reached. Another principle in the normal erosional cycle is that divides are not degraded much, before permanent divides have been established, that is, before valleys have reached their width and length limits, that is, before the valleys have approached or reached old age. Now the summit divides in the Driftless Area are known to have been degraded by amounts varying from 10 feet to 885 feet (see the fourth column from the left in the above tables), and yet the valleys show few signs of old age, and few of the divides are permanent. If the present surface was formed in a single cycle of erosion, this cycle was not normal.

(9) Assuming that but one cycle has been involved in the erosion of the surface of the Driftless Area, reconstructing the original surface by projecting the Niagara and older formations over portions where they do not now exist, and getting the altitudes of the lowest points reached by streams beneath the present valley fills; it is found that the streams at La Crosse must have reduced their beds from about 2200 feet A. T. to 600 feet in order to reach grade; and the streams in the south portion of the Driftless Area in the vicinity of Dubuque, could have become graded by cutting from approximately 1300 feet to 300 feet. The Mississippi and its tributaries should have reached grade at Dubuque after cutting through 1000 feet of rock of varying hardness long before they brought their beds to grade at La Crosse, where they had to cut through 1600 feet of the same rock, and the topography around Dubuque should now be in a distinctly later stage of development than that in the neighborhood of La Crosse. But the opposite is true. Due to the relative non-resistance of the Cambrian sandstone on which the streams have their courses *at present* in the north part of the area, there is a greater area of lowland there than farther south, and the topography around La Crosse has an appearance of greater age than the surface near Dubuque.

(10) In advance of complete description and interpretation it should be made clear here that there are in many places on the Dodgeville plain considerable areas of gravel

which have undoubtedly been deposited there by streams which could not carry their loads all the way to the sea. These deposits are known near Devil's Lake, Cashton and Seneca in Wisconsin, and near Church, Elon and Waukon in Iowa, as well as at numerous other places within and south of the Driftless Area. This fact is not mentioned by Martin. It seems to the writer to be a fatal objection to the single cycle theory.

The conclusion now has been reached that the Dodgeville plain is not an original plain of marine deposition, nor a plain of marine erosion, nor a simple structural plain. The theory that the plain consists merely of three cuestas whose summits were developed in the present cycle of erosion is untenable.

The Peneplain Theory

It remains to test the fifth possible interpretation. Some of the points in favor of the theory that the plain is an ancient peneplain dissected by erosion in subsequent cycles have been touched upon indirectly in the analysis of the cuesta theory. However, for the sake of definiteness and completeness they are listed below.

(1) The plain includes many upland surfaces so large and so nearly flat that some effective agent of transportation, such as streams, must have operated there in order to remove the large amount of material which originally existed at higher levels. (2) The plain has a slope of about 3 to 5 feet per mile in a general southeasterly direction. Its slope is notably different both in direction and amount from the dip of the strata. (3) The general southerly slope of the plain is obscured locally by irregularities such as old erosional surfaces show. Even locally the slopes of the plain are not parallel with rock structures. (4) The plain bevels the edges of rock formations irrespective of their hardness. (5) In the formation of the plain, thicknesses of rock have been removed, which decrease regularly from north to south, bearing evidence that some sort of a grade was established where the tops of the cuestas now are. (6) The existence of certain continuous north-south ridges

connecting the cuestas, such as the divide from Cashton to Prairie du Chien, described above (Fig. 17), seem to suggest that there was once a plain on non-resistant, as well as resistant material. These connecting ridges are apparently remnants of an upland surface once continuous across inter-cuesta areas. (7) If the Dodgeville plain is an old peneplain there is no necessity for conceiving that the divides have been reduced by hundreds of feet in a cycle of erosion in which the streams have scarcely reached grade. (8) There are distinct erosion remnants standing on the plain, far from present drainage lines. In some cases these remnants consist of material which is more resistant than that outcropping on the adjacent plain. In other cases the rock of the remnant and the rock of the plain are the same. There seems to be no reason why these divides should have been reduced in such a way as to leave remnants above their general flat surfaces, unless the streams reached grade at or near the levels of these surfaces. (9) The presence of stream deposits at many places on the plain not only appears as a fatal objection to the single cycle theory, but it seems practically to demonstrate that the Dodgeville plain is a raised peneplain. (10) Both Cretaceous sediments west of the Driftless Area and Tertiary deposits to the south must have been derived at least partly from erosion in the Driftless Area and both bear evidence that the land of their sources was low and approaching the peneplain stage. (11) The fact that Tertiary deposits of the great Mississippi embayment, extending north toward the Driftless Area, lie in a gently sloping plain which, if projected, would coincide with the Dodgeville plain, is distinctly in favor of the peneplain theory. (12) As will be explained more fully within the next few pages, there are lense-shaped bodies of the softer formations underlying the Dodgeville plain in two or three places, which show that the surface over them was brought to grade. (13) In addition there are within the Driftless Area other strong evidences of more than one cycle of erosion, yet to be described, which in combination with the even-crested summit areas increase the value of these upland flats as evidences and the combination demonstrates that the surface has been eroded in more than one cycle.

Objections which might be advanced to the peneplain theory have been expressed by Martin[1]. Each objection is now to be considered.

(1) Doubt is expressed if the various areas of upland surface making up the plain are large enough, flat enough, close enough together, and sufficiently accordant in their levels to warrant the conclusion that they are the remnants of a once continuous peneplain. As was brought out in Part I, there is no definite degree of flatness which a surface must assume before it can be called a peneplain. Also there are various ways in which such a surface may be made irregular in the second cycle. It is not believed that the Dodgeville plain was degraded to such extremes that the surface was altogether flat. There were doubtless many gently sloping valley walls as well as valley flats. Not all the tributary streams far from the main drainage lines had low gradients. And the facts remain that there are some upland surfaces which are essentially flat; that the upland areas are large enough and numerous enough to furnish thousands of acres of farm land which is notably flat; that the highest recorded slope on the plain is less than 11 feet per mile and the average slope less than 4 feet per mile; and that the Dodgeville plain includes more and larger areas of flat land and is represented by more nearly accordant levels than the Kittatinny peneplain of the Appalachian mountains, the Tertiary peneplain of Idaho or the Miocene peneplain of the Sierra Nevadas.

(2) Martin gives some consideration to the time involved in the erosion of the area and concludes that, although there has been sufficient time since the late Paleozoic for the formation of a peneplain, there has also been time for the destruction of such a plain. The writer does not see that the time involved furnishes points either in favor of or against the peneplain or cuesta theory. So far as the duration of time is concerned, several peneplains could have been formed and destroyed during the Mesozoic and Ceno-

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[1] Martin, Lawrence, Bull. No. 36, *Wis. Geol. and Nat'l Hist. Surv.*, pp. 64-68.

zoic eras. There is, however, no indication in this that some relatively recent peneplain, such an one completed in late Tertiary, could not to-day be represented by remnants.

(3) Believing that sediments must have been derived from the surface of the Driftless Area in the formation of the Dodgeville plain, and not certainly finding such sediments in the Devonian and Carboniferous rock adjacent to the Area, Martin objects to the peneplain theory. Clearly he is laboring under a misconception as to the age of the plain. Whether or not it is an old peneplain, its surface is much younger than the Paleozoic. All of the Paleozoic formations, including the Devonian and Carboniferous are known to be bevelled by the Dodgeville plain south and west of the Driftless Area. Most of those who have previously interpreted it as a peneplain have assigned it to the Cretaceous and the writer will later in the paper present evidence for the late Tertiary age of the plain. Most likely then the sand, silt, and clay derived in the formation of the Dodgeville plain were carried westward into the Cretaceous sea, or most likely southward into the Tertiary embayment. Indeed, both the Cretaceous and Tertiary systems contain materials which must have been derived from erosion in the Driftless and adjacent areas during these periods, and there is evidence that peneplanation was in progress. Thus by reference of the Dodgeville plain to its proper geological period Martin's point of objection to the peneplain theory is converted into an additional argument in favor of that theory.

(4) It is true, as pointed out by Martin, that the Devonian and Carboniferous rocks lie on surfaces of less relief than that of the Driftless Area, and that this does not show that the peneplain of the Driftless Area is projected to lie beneath these sediments. However, it is not to be considered in any way as an objection to the peneplain theory. The plain is clearly much younger than any Paleozoic system. If the Cretaceous or Tertiary sediments could be proven to lie on a projection of the Dodgeville plain, strong evidence would be offered that it is a peneplain. The Cretaceous rocks of Minnesota are bevelled by the plain and

therefore do not lie on its projection. Salisbury[1] has presented evidence that the plain does slope down beneath the Tertiary deposits of the lower Mississippi valley and that those deposits lie on a plain similar to and continuous with the Dodgeville plain in the Driftless Area. This point affords strong evidence in favor of the peneplain theory.

(5) Martin concludes his objections to the peneplain theory by stating that there are no wedge-shaped bodies of non-resistant rock overlying the south-dipping resistant layers, as there should have been when the Dodgeville peneplain was undissected. He agrees, however, that these wedges could have been removed by the rejuvenated streams. Their absence, therefore, is no objection to the peneplain theory, but is in harmony with the cuesta, as well as with the peneplain theory.

As a matter of fact, but apparently unknown to Martin, there are just such wedges of St. Peter sandstone north of the Platteville-Galena cuesta in Wisconsin, and Maquoketa shale north of the Niagara cuesta in Iowa. Fig. 5 affords an illustration of the St. Peter wedges. Other illustrations are found in the south part of the Richland Center quadrangle, where ever-increasing thicknesses of St. Peter cap the north-south divides to the foot of the Platteville cuesta, where the full thickness of the St. Peter is represented. In Iowa the south rim of the valley of Turkey river, south of Osterdock, is underlain by a few feet of Maquoketa shale which dips south with the Galena dolomite below. Along a road which follows a flat-topped divide southward, the Maquoketa gradually thickens until its full thickness is found at the foot of the Niagara escarpment. Martin says: "They (the wedge-shaped bodies) would furnish excellent evidence of previous baselevelling, but no such remnants are known to exist." Now that such lenses of non-resistant material have been discovered, this point is transferred from the unfavorable to the favorable column for the peneplain theory.

In conclusion it may be said that the summit areas in

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[1] Salisbury, R. D., *Bull. Geol. Soc. Am.*, Vol. 3, pp. 183-186, *Jour. Geol.*, Vol. III, pp. 655-667.

the Driftless Area, after analysis, seem almost certainly to be remnants of a peneplain uplifted since its formation and now almost entirely destroyed by the rejuvenated streams. And yet demonstration of the multiple cycle theory does not rest on this evidence alone. It remains to be seen whether there are other indications of more than one cycle and whether there is a *combination* of evidence which actually proves the case.

Intermediate Plain (the Lancaster plain)

At many places in the Driftless Area there are isolated areas and more or less continuous surfaces, sharply set off from the remnants of the Dodgeville plain, but forming divides several hundred feet above drainage. Though similar in most respects to the summit surfaces, these flat-topped but lower divides occupy a position intermediate between the remnants of the Dodgeville plain and the valley bottoms. If the tops of these intermediate divides were projected across the valleys and across the areas where remnants of the Dodgeville plain exist, a plain similar to the Dodgeville plain would be formed, having a general altitude approximately 200 feet lower than the Dodgeville plain. This is the more conspicuous of the two upland plains, and is the one about which most has been written.

Various names have been applied to this plain by different writers. It is Hershey's[1] plain No. 1. Grant and Burchard[2] named it the Lancaster Plain. The writer[3] called it the Galena Plain in Jo Daviess County, Illinois. In Iowa it has been called the Lower Plain or Plain No. II[4]. Shipton[5] called it the Sparta Plain and Hughes[6] assigned to it the name Limeridge Plain. The surface is as well developed in the neighborhood of Lancaster, Wisconsin, as anywhere, and therefore the name assigned by Grant and Burchard is retained for this plain.

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[1] Hershey, O. H., *Am. Geol.*. Vol. 20, pp. 246-268.

[2] Grant, U. S. and Burchard, E. F., *Lancaster-Mineral Point Folio, U. S. Geol. Surv.*, p. 2.

[3] Trowbridge, A. C., *Jour. Geol.*, Vol. 21, pp. 739-741.

[4] Howell, J. V., *Iowa Geol. Surv.*, Vol. 25, pp. 59-60.

[5] Shipton, W. D., *Geology of the Sparta Quadrangle*, unpublished thesis in library of University of Iowa, p. 57.

[6] Hughes, U. B., *Geology of the Richland Center Quadrangle*, manuscript in preparation.

Portions of the Lancaster Plain are known in the northern part of the Sparta quadrangle at an average altitude of 1100 feet; in the Baraboo district at 1200 feet; in the northern and central portions of the Richland Center quadrangle on divides sloping southward from 1200 to 1100 feet; in the central and southern portions of the Lancaster and Mineral Point quadrangles at levels varying from 1100 to 1000 feet; in the northern and central portions of the Galena and Elizabeth quadrangles, Illinois, sloping southward from 1000 feet to 900 feet; in southeastern Minnesota at altitudes of about 1200 feet; and in northeastern Iowa from the Minnesota line at an altitude of 1100 feet to Dubuque, where it lies at and around 900 feet altitude. The best general view of the surface may be obtained from the Mississippi river between Bellevue, Iowa, and La Crosse. Along this whole extent of river the immediate rim of the Mississippi valley appears to be almost a horizontal line except where broken by tributary valleys. Nowhere does the Dodgeville plain come to the edge of the bluff, although, near Turkey river and Prairie du Chien, remnants of the higher plain are close enough to be visible from the river and appear as monadnocks standing above the plain which forms the rim of the valley.

On the whole, the Lancaster plain is represented by upland surfaces which are more numerous, larger, closer together, and more nearly continuous than the summit areas which constitute the remnants of the Dodgeville plain. In the Sparta quadrangle, the Lancaster plain is represented by a series of narrow divides above which stand conspicuous remnants of the Dodgeville plain such as Castle Rock and Balls Bluff. In the Baraboo district portions of the lower plain include the general flat crest of the North quartzite range at Ableman and at the Lower Narrows, broad, poorly drained divides between north flowing and south flowing, streams on the south range, and flat benches on the south range, such as the one at 1200 feet 2 miles northeast of Denzer. Just north of the Wisconsin river the plain is best shown on the crests of north-south divides, such as the divides between Pine, Bear, Narrows, and Honey Creeks, on which are located the main roads of the district, hundreds of prosperous farms, and the villages of Limeridge, Sandusky, and Loreto. Wide areas of the plain are found at or near Blake Prairie, Diamond Grove, Rockville, Hurricane, Lancaster, (Fig. 19), Liberty Ridge,

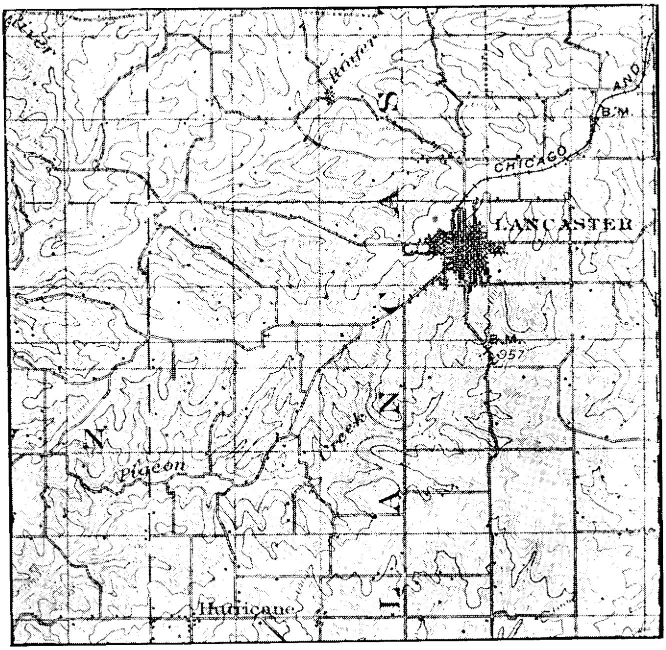

Fig. 19. A portion of the Lancaster topographic map showing the extent and distribution of the Lancaster plain in its type locality.

Jamestown, and Cornelia in the Lancaster quadrangle, and near Livingston, Rewey, Belmont, Cuba, and Fayette in the Mineral Point quadrangle. In these two quadrangles the surfaces representing the Lancaster plain are long and broad, and are utilized extensively for various sorts of human activity. Most of the surfaces are north-south divides or east-west projections of north-south divides. In the Elizabeth quadrangle in Illinois there are large areas of this intermediate plain, the most conspicuous of which are south of Apple River and northwest of Stockton, (Figs. 20 and 21), where there are surfaces 1x1½ miles

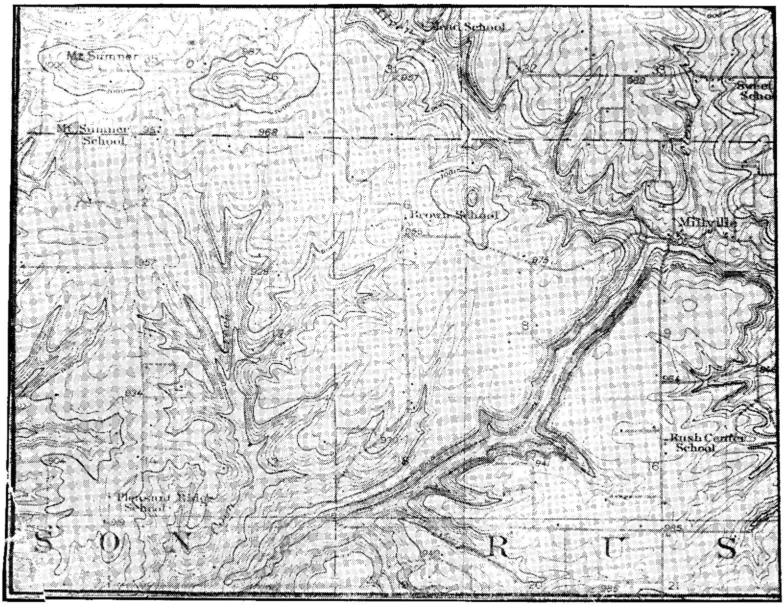

Fig. 20. A portion of the Elizabeth topographic map where the Lancaster plain is exceptionally well represented.

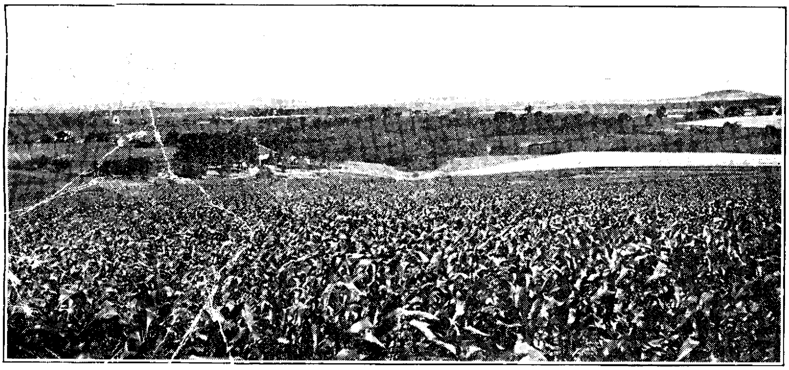

Fig. 21. View of the Lancaster plain in Jo Daviess County, north of Stockton, Illinois. The elevations in the distance are the "mounds" which are monadnocks on the plain. Below the general surface, there are valleys more than 200 feet deep.

in extent. These surfaces have maximum relief of less than 10 feet and are poorly drained. Above them stand conspicuous monadnocks, and below them are abrupt valleys more than 100 feet in depth. The Lancaster plain is represented in the Galena quadrangle by the divides between Sinsinawa and Galena rivers, used as the site of the Hazel Green Pike road, and the divide between Galena River and Smallpox Creek. The tops of these divides consist of flat surfaces or gentle slopes. They average 900 feet above sea, 300 feet above present drainage, and 150 feet below the tops of the mounds which stand conspicuously upon them. In Iowa most of the tops of the divides within eight or ten miles of the Mississippi River are to be correlated with the Lancaster plain; for instance, the divides between Upper Iowa River and the Minnesota line, between Clear Creek and Village Creek, Village Creek and Paint Creek, Paint Creek and Yellow River, Yellow River and Bloody Run, Bloody Run and Sny Magill Creek, the divides north and south of Yellow River, etc. (Figs. 22 and 26). The plain is also represented in the vicinity of Dubuque. The Lancaster plain in the Minnesota portion of the Driftless Area

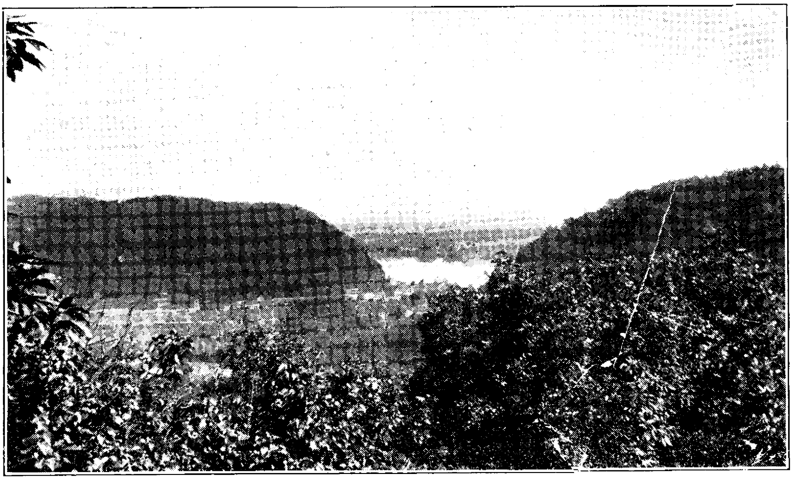

Fig. 22. View of the Lancaster plain and the gorges below it, as seen near Waukon Junction, Iowa.

forms gently rolling intermediate surfaces, so extensive and so nearly flat as to be known locally as "prairies." Areas representing the plain here are known south of Preston and in other portions of Fillmore county, in Houston county south of Root river near Caledonia, in nearly all parts of Winona county and in the southeastern portion of Wabasha county. Though the areas are most extensive away from the Mississippi river, representatives of it are known right to the edge of the river gorge.

As in the case of the Dodgeville plain, the Lancaster plain lies on different rock formations at different places. North of the Prairie du Chien cuesta in Wisconsin it lies on the Cambrian sandstone, in Minnesota on Platteville, St. Peter and Prairie du Chien, south of the Prairie du Chien cuesta on the Prairie du Chien and St. Peter formations, south of the Platteville-Galena cuesta on the Galena and Maquoketa formations. In general, the farther north a portion of the plain is the older the formation, and the lower the part of the formation on which it lies. Progressively younger rocks are bevelled by the plain toward the south.

The Lancaster plain slopes in a general southerly direction at an angle less than the angle of dip of the strata. The details in the relations of the plain and the structure south of the anticlinal axis are shown in the table on page 90.

The computations, the results of which appear in the table, show that there is a marked parallelism of plain and strata in several of the individual districts, such as the Richland Center, Sparta and Mineral Point quadrangles, but that in other districts and where greater distances are involved, this parallelism fails. It is notable that all the local estimates show the intermediate surface sloping in directions west of south, which is the direction of dip of the strata and that those estimates including more widely separated points on the plain show a general slope east of south. Considering only the local districts the plain appears to have an average slope of 10.9 feet per mile in the direction S 17°W and the strata dip S 28°W at an angle of 16.6 feet per mile. Over the larger areas the average direction

TABLE OF RESULTS OF COMPUTATION OF DIP AND STRIKE OF LANCASTER PLAIN AND ROCK STRATA

General Location	Location of Points	Direction of dip of plain	Amount of dip of plain; ft. per mi.	Direction of dip of strata	Amount of dip of strata; ft. per mi.
North part Richland Center Quadrangle	A-Limeridge B-3½ miles south Loreta C-2½ miles N.E. Richland Center	S 25°W	7.6	S 15°W	7.6
North part Sparta Quadrangle	A-1 mile south of Castle Rock B-Center Sec. 3 Burns Twp. C-W. C. Sec. 23 Burns Twp.	S 80°W	12.5	S 59°W	14.
Lancaster Quadrangle	A-Blake Prairie B-Lancaster C-Near Jamestown	S 26°W	8.9	S 29°W	34.
Mineral Point Quadrangle	A-Rewey B-Cuba C-Fayette	S 9°W	7.3	S 9°W	9.1
Galena Quadrangle	A-S. Sec. 24 Vinegar Hill Twp. B-Galena C-N. E. Sec. 23 Galena Twp.	S 46°W	27.2	S 13°W	13.9
Elizabeth Quadrangle	A-Foot of Hudson Mound B-Warren C-C Sec. 9 Rush Twp.	S 8°W	8.	S 20°W	9.8
Waukon Quadrangle in Iowa	A-4½ mi. W. of New Albin B-3 mi. S. E. of Lansing C-3 mi. S. E. of Watson	S 77°E	5.1	S 51°W	27.6
Iowa- Wisconsin	A-Near New Albin B-Near Watson C-Near Bloomington	S 42°E	2.1	S 22°W	15.
Wisconsin- Iowa- Illinois	A-Near Sparta B-Near New Albin C-Near Stockton	N 89°E	3.1	S 7°W	9.4
Wisconsin- Iowa	A-Near Sparta B-Near Bloomington C-Near New Albin	S 82°E	4.	S	9.4
Wisconsin- Iowa	A-Near Denzer B-Near Bloomington C-Near New Albin	S 16°W	2.8	S 11°W	11.
Wisconsin- Iowa- Illinois	A-Near Loreta B-Near Watson C-Near Stockton	S 1°E	3.	S 19°W	11.6

of slope of the plain is S 40°E and the average amount of slope 3 feet per mile, while the corresponding figures for the strata are S 12°W and 11.3 feet. Including the results of all the estimates, both local and general, the plain slopes S 11°E to an amount of 7.6 feet to the mile and the strata dip S. 20°W, 14.4 feet per mile. The plain and the strata fail of parallelism by 31° in direction and 6.8 feet per mile in dip.

In the literature of the subject the Lancaster plain and the Dodgeville plain have in some cases been confused; indeed there has been some doubt expressed that they are really distinct. In his criticisms of the peneplain theory to explain the accordant divides of the Driftless Area, Martin[1] assumes two cases: (1) that there are four upland plains, one for each cuesta, and (2) that there is but one upland plain. He does not consider the problem of two upland plains and appears to believe that all the upland surfaces form a single plain, if indeed they may be said to form plains at all. This confusion doubtless grows out of the fact that there are places where the summit plain only is found and places where only the intermediate plain occurs. In such latter places the Lancaster plain could easily be mistaken for a summit plain. There are also some localities within the Driftless Area in which both plains occur and where they appear to grade into each other.

And yet the summit plain and the intermediate plains are distinct. The evidences are as follows: (1) In most portions of the Driftless Area, as between Waukon and the Mississippi river (Fig. 23), and in the district south of Turkey river in Iowa, in the Galena and Elizabeth quadrangles in Illinois, in the northern and central portions of the Lancaster and Mineral Point quadrangles, in the Richland Center quadrangle, in the Baraboo district and in the Sparta quadrangle in Wisconsin, and in Minnesota both plains are found and in most of these places the lower plain is so sharply set off from the upper one that the two can be distinctly seen in any general view. (2) Even in districts where intermediate levels seem to grade into sum-

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[1] Martin, Lawrence, Bull. No. 36, *Wis. Geol. and Nat'l Hist. Surv.*, pp. 66-67.

mit levels, careful inspection brings out distinct differences in altitude between the two plains. For instance, the Lancaster plain around Lancaster, seems, on casual observation, to grade into the Dodgeville plain on the summit of Military Ridge. Grant and Burchard[1] included Military Ridge and the area around Dodgeville with the Lancaster plain. However, there are many views obtainable in which Military Ridge stands distinctly above the intermediate levels and carefully drawn profiles show the two plains to be distinct[2] (Fig. 24). (3) Where both plains are represented in the same locality, they lie at different stratigraphic horizons, either within the same formation or in different formations, although in practically all cases both lie on resistant rock. (4) If the Lancaster plain be projected from districts where the Dodgeville plain is missing into areas where the Dodgeville plain occurs it is found to lie distinctly below the Dodgeville plain. Similarly the Dodge-

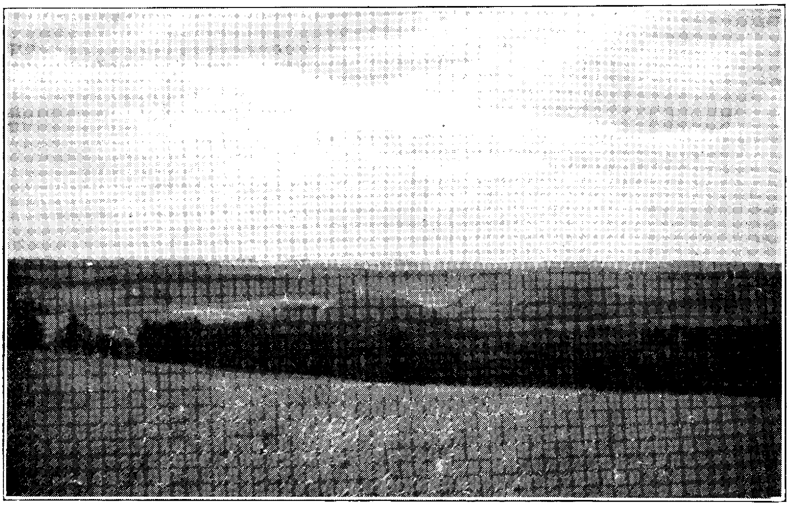

Fig. 23. View east of Waukon, Iowa, showing both the Dodgeville and Lancaster plains. The picture was taken from the Dodgeville plain which shows in the foreground and forms the skyline. The general topography which forms the rims of the valleys in the middle distance is the Lancaster plain.

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[1] Grant, U. S. and Burchard, E. F., *Lancaster-Mineral Point Folio, U. S. Geol. Surv.*, p. 2.

[2] Hughes, U. B., *Proc. Ia. Acad. Sci.*, Vol. 23, p. 131.

ville plain projected from cuesta to cuesta, lies on the average 200 feet higher than the Lancaster plain in the inter-cuesta areas. (See Figs. 14 and 23). (5) Where both plains are found together the change from one to the other takes place either along lines parallel with or oblique to the strike. (6) There are many places along the main south-flowing streams, for instance, along the Mississippi river, where upland surfaces representing the Lancaster plain can be traced continuously from an inter-cuesta area across a cuesta, on the summits of which the Dodgeville plain is represented, to connect definitely with the Lancaster plain in another inter-cuesta area (Fig. 25). There are lines along which the Lancaster plain is unbroken by remnants of the Dodgeville plain for the whole north-south extent of the Driftless Area. (7) If it be assumed that the Lancaster plain in an area south of a Dodgeville cuesta is merely the projection of the Dodgeville plain down the dip of the strata, so that the two plains together form the gentle southerly slopes of normal cuestas (Fig. 16), three points located so as to include both plains, should show a surficial slope parallel with stratigraphic dips. That this assumption is not true is shown by the table on page 95, in which both plains are represented in each computation. Nowhere do the slopes of the surface and the dips of the strata coincide.

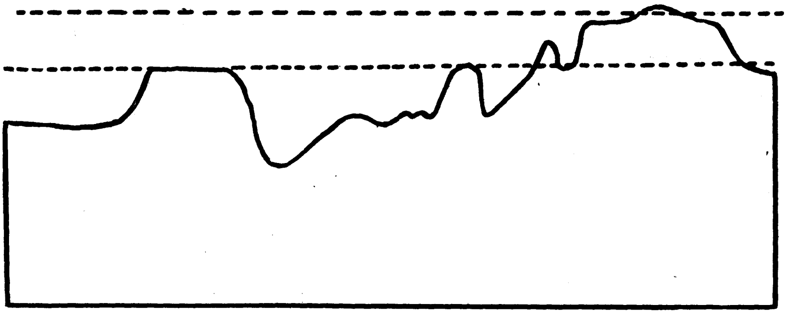

Fig. 24. A profile from Mt. Ida on the Dodgeville Prairie south across a portion of the Lancaster plain. The profile makes it clear that two plains are represented. (After U. B. Hughes).

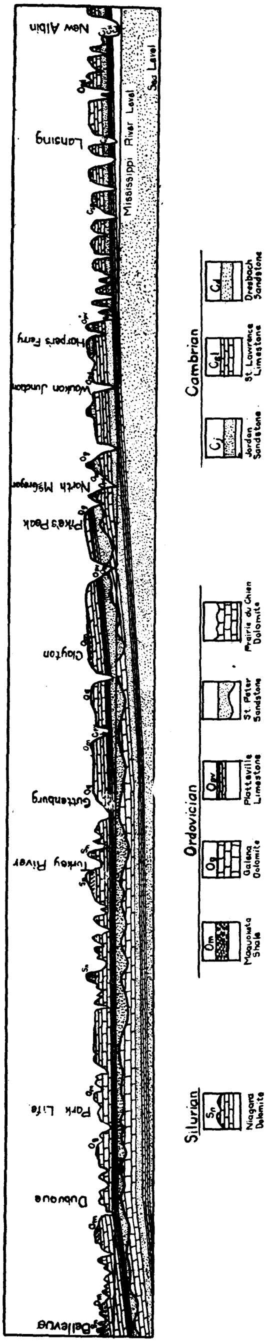

Fig. 25. A topographic profile and geologic structure section, drawn along the west rim of the Mississippi river from New Albin to Bellevue. The horizontal distance is 150 miles. The vertical scale is exaggerated.

Obviously the Lancaster plain is not an original marine plain of deposition, neither was it formed by marine denudation. Lying as it does here at one stratigraphic horizon and there at another, it cannot be a simple structural plain. Because the Lancaster plain is represented by many broad, flattish, intermediate surfaces close enough together to warrant correlation; because it is distinct from the Dodgeville plain; because it has a general southerly slope; because its slope is not parallel with the underlying strata; because the plain bevels the edges of the strata; because its surface has about the degree of irregularity and slope which a peneplain should have; because it is not confined to cuesta belts but has a wide distribution in the inter-cuesta areas the Lancaster plain seems even more surely to be a true peneplain than is the Dodgeville plain. It cannot be held to be a series of unrelated cuestas. The Lancaster plain, therefore, is believed to be a true peneplain, younger than the Dodgeville plain, uplifted since its formation, and now approaching thorough dissection in the present cycle of erosion. For an additional illustration of the features on which this belief is based, see Fig. 26. It should not be understood that this surface was

COMPUTATIONS SHOWING THE RELATION BETWEEN THE SLOPE OF A PLAIN MADE BY THE COMBINATION OF THE DODGEVILLE AND LANCASTER PLAINS AND THE DIP OF THE STRATA

General Location	Location of Points	Direction of slope of plain in ft. per mi.	Amount of slope of plain	Direction of dip of strata	Amount of dip of strata in ft. per mi.
Lancaster Quadrangle	A-Fennimore (Dodgeville plain) B-Blake Prairie (Lancaster plain) C-Rockville (Lancaster plain)	S 16°W	15.	S 27°W	22.8
Denzer-Sparta-Richland Center Quadrangles	A-Denzer (Dodgeville plain) B-Sparta (Dodgeville plain) C-Loreta (Lancaster plain)	S 41°W	40.	S 28°W	14.
Waukon Quadrangle in Iowa	A-Church (Dodgeville plain) B-3½ mi.S. E. of Lansing (Lancaster plain) C-3 mi. S. E. of Watson (Lancaster plain)	S 76°E	20.6	S 27°W	20.
Iowa-Wisconsin-Illinois	A-Near Graham, Iowa (Dodgeville plain) B-Lancaster, Wisconsin (Lancaster plain) C-Stockton, Illinois (Lancaster plain)	N 78°E	5.2	S 6°W	8.

flat before its uplift and dissection. Many remnants of the higher surfaces stood above it, and even its general lowland topography lacked much of being perfectly flat, as is true of all peneplains.

The Lancaster plain even considered alone, bears strong evidence in favor of the plural cycle theory. And there is corroborative evidence of other sorts which adds still further to the strength of the case thus far developed.

Antecedent Streams

The antecedency of streams and the nature and value of the evidence it bears on the erosional history of a region were discussed in Part I, pp. 21-24. Streams may become antecedent (1) by local warping of the strata and surface of a region after the course of the streams have been estab-

Fig. 26. A panoramic view looking up the Mississippi river toward Lansing, Iowa, and showing the flood plain and both valley walls. Note the even skyline on both sides extending into the distance. This is the Lancaster plain which definitely bevels formations of unequal resistance. (Photographed by Professor W. H. Norton).

lished, if the diastrophic warping takes place so slowly that the streams can degrade the up-warped areas as fast as they are uplifted, and thus hold their courses as conditions change, or (2) by the uniform uplift of a surface which has been reduced to grade and on which the streams have reached a final stage of adjustment, flowing by the most direct routes to the sea, provided again the streams hold their courses during and after uplift.

By study of the Driftless Area it becomes reasonably certain that the tilting and slight warping which the strata have undergone antedated the establishment of the courses of the present streams, for all the structures are bevelled by the Dodgeville and Lancaster plains. Either the streams of the Driftless Area are in harmony with conditions of slope, resistance, and structure and with the stage of early maturity, or they are antecedent and have courses now which they acquired in some late stage of a previous cycle. If the streams are merely consequent it would seem that the surface of the Driftless Area is in its first erosional cycle. If they are antecedent they furnish valuable evidences of more than one cycle in the erosional history of the region. In case there has been but one cycle of erosion all the streams should be consequent; if there has been more than one cycle the larger streams are likely to be antecedent, having developed their courses in the first cycle and held them into the second, and the many tributary streams should have been developed in the present cycle and be consequent. The problem then involves especially the major streams.

Mississippi River

Study of the present course of the Mississippi river shows certain anomolies in its relations to original topography and structure, which are significant. These anomolies can be made most clear by a study of the various stages of adjustment which major streams should have in the normal erosional cycle under conditions existing in the Driftless Area, and by comparison of the course of the Mississippi river with these various stages, considering the present mature condition of the region.

As has been stated in previous pages, the strata south from La Crosse and Sparta dip in an average direction S 26°W to an average amount of 14.6 feet to the mile. But north of Winona along the Mississippi a dip in the opposite direction is recorded by conformable stratigraphic contacts which decline appreciably from Winona to Minneapolis. The average dip of the strata north of the arch, which seems to run through Galesburgh, Winona, and St. Charles, determined by taking the averages of four computations by means of the three point method is found to be N 35° W 9.3 feet per mile. The highest portion of the original surface, therefore, must have been near Winona and the surface must have sloped down to the north and to the south from the divide. In the knowledge that the formation of this arch antedated the establishment of the present course of the Mississippi river and that the various rock formations do not thin out appreciably in approaching the crest of the arch, it is possible to reconstruct the original surface for a line following the present course of the Mississippi river. This surface is found to lie at 960 feet at Bellevue, 1030 feet at Dubuque, 1520 feet at Prairie du Chien, 1850 feet at Lansing, 2000 feet at La Crosse, 1870 feet at Winona, and 1410 feet at Minneapolis. A section showing this original surface and the attitude of the strata beneath it for the whole length of the Mississippi river from Minneapolis to Bellevue is shown in Fig. 27.

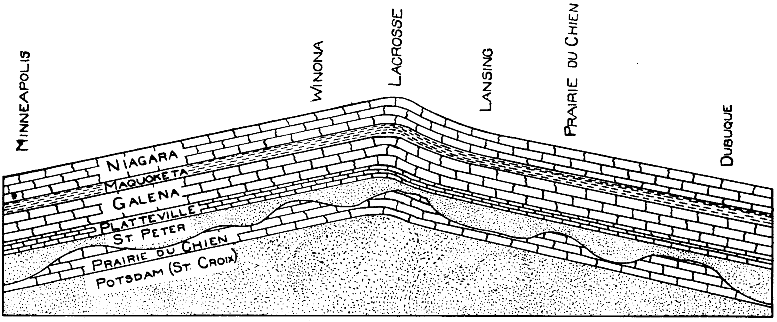

Fig. 27. A section showing the original surface of the Driftless Area and the structure of the strata along a line now followed by the Mississippi river. The total horizontal distance is approximately 250 miles. Vertical scale: 1 inch equals 360 feet.

Such a surface would be eroded by streams which would exhibit different stages of adjustment in different stages of the erosion cycle.

In the first stage of adjustment streams would form, flowing south and north from the crest of the arch. From the main streams, tributaries would develop which would curve headward up the slope of the plain toward the divide from either side. As all the streams in this first stage were flowing on the Niagara dolomite there were only slight differences in resistance, and the courses of the streams would be determined primarily by the topographic slopes which were in turn determined by the structure. The general northerly and southerly slopes from the axis of the arch were not steep, but are believed to have been steep enough to control the general courses of the streams. The details of the courses might be influenced by the minor structures such as anticlines, synclines, accentuations of the monocline, faults, joints, etc., by local irregularities in the surface, or by slight differences in resistance. The conditions during this first stage of adjustment are illustrated in Fig. 28.

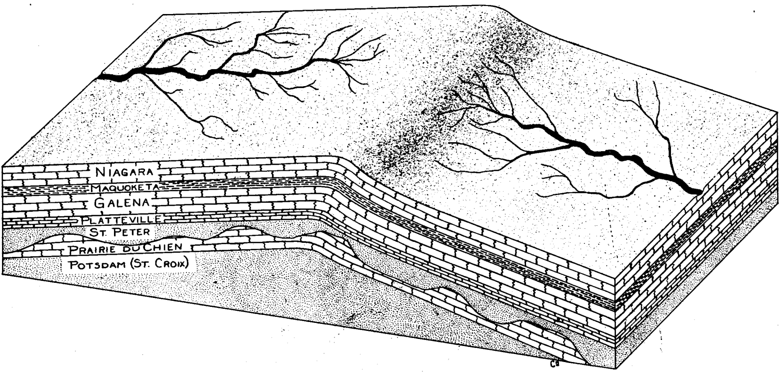

Fig. 28. Block diagram illustrating the drainage conditions in the Driftless Area, as they should have been in the initial stage of stream adjustment.

As the main streams on the two limbs of the arch cut downward they would, somewhere in their courses, penetrate the resistant Niagara dolomite and reach the relatively non-resistant Maquoketa shale. On this soft formation the main streams would develop broad valleys and would send out tributaries (Fig. 29).

When maturity of the erosion cycle was reached and the inter-valley divides had been made narrow, the south-flowing main stream, having greater volume, or a higher gradient, or flowing on less resistant material than the stream on the opposite side of the arch, might work headward through the main divide and steal water by reversion of the main stream flowing in the opposite direction. (Fig. 30). In this case it seems that the pirate stream would work headward down the course already established by the reversed stream, that is, in a line roughly parallel with the dip of the strata and with the original slope of the surface.

Finally when old age has been reached and the main streams have been reduced to grade throughout their courses, *and not before* that stream which has the shortest route to the sea would capture all the drainage and would adopt a course, which for the first time would be independent of structure and original slope and dependent upon the slopes of the graded plain. Some of the tributary streams, of which there would be few, might still be dependent upon structure (Fig. 31).

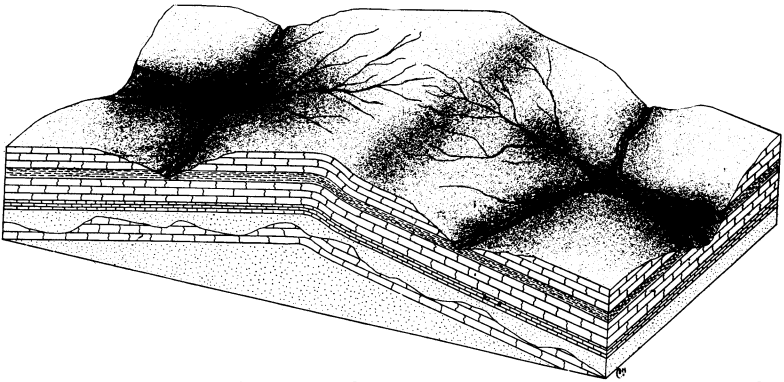

Fig. 29. Block diagram showing the drainage conditions in Stage II of stream adjustment.

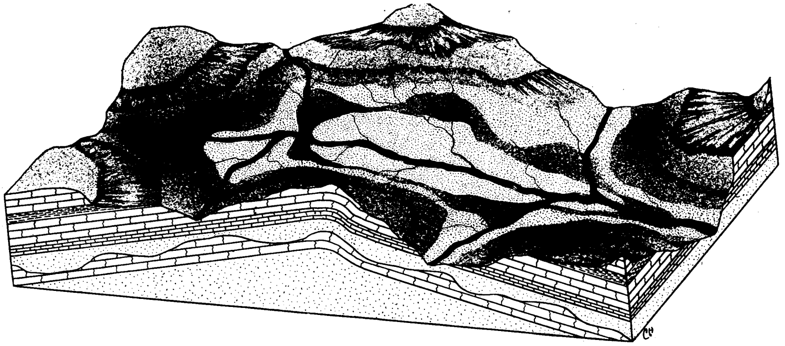

Fig. 30. Block diagram illustrating Stage III of stream adjustment, in case the south-flowing stream has the advantage of the north-flowing one.

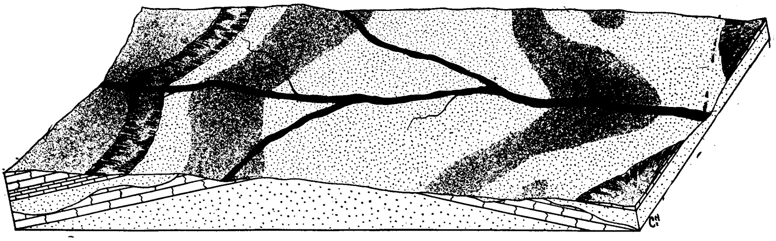

Fig. 31. Block diagram showing the courses of the streams in a final stage of stream adjustment in a first cycle of erosion.

Now the present course of the Mississippi river in early maturity of the present cycle of valley development is almost exactly what would be expected if it were determined by two streams flowing in opposite directions from the crest of the arch, the south-flowing stream having captured the north-flowing one, as outlined above (Fig. 32). North of the axis of the arch, between Minneapolis and La Crosse, the river flows in the general direction, S 51°E, which is an angle of 164° with the average direction of dip of the strata. The river not only does not flow in the direction of the dip but it does not flow parallel with the strike. Its average direction lacks but 16° of being opposite to the dip and to

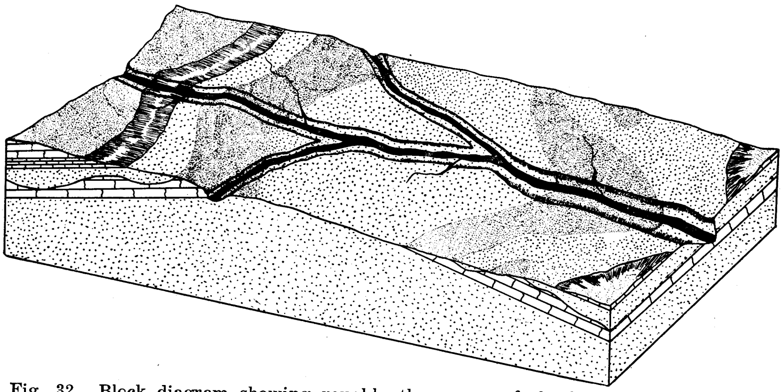

Fig. 32. Block diagram showing roughly the course of the Mississippi river in its relations to structure. The river is antecedent in the same sense that the Susquehanna river in the Appalachians is antecedent.

the slope of the original surface. The original surface had the theoretical altitude of 1410 feet at Minneapolis, 1870 feet at Winona and 2000 feet at La Crosse, and the present river flows from Minneapolis, past Winona, to La Crosse. South of the axis of the arch and the main divide on the original surface, where the strata have an average dip in the direction S 26°W, which also must have been the average direction of slope of the original surface, the river follows a curved course from La Crosse to Bellevue in the general direction S 18°E, forming an angle of 44° with the dip of the strata and the slope of the original surface. On neither side of the arch is there any evidence that the minor curves of the river really are controlled by minor structural features such as anticlines and synclines.

It should also be borne in mind that the Mississippi river, by taking a course more nearly directly south at some point south of St. Paul, would have flowed around the southwest end of the plunging anticline, avoiding the crest of the arch and the high portion of the original surface entirely. Such a course also would have been little if any longer to Dubuque than the course which was actually established.

There is a further indication that the Mississippi river has had such a history as outlined above in the fact that certain of the larger streams north of the axis of the anticline, for instance, Whitewater river, join the master stream with an acute angle down-stream. This suggests that the Mississippi river was flowing in the opposite direction while Whitewater river was being developed, and that its direction of flow was later reversed.

This lack of harmony between rock structures and original slopes on the one hand and the present course of the Mississippi river on the other, cannot be explained on the basis of the ordinary superimposition. Such an interpretation could be correct only in case some post-Paleozoic formation on which the stream could have established its present course, had been deposited over the strata of the district, after they were deformed, so as to let the stream down on the stratigraphic structures and topographies as the covering formation was penetrated. No such covering formation is known to have existed in the Driftless Area; and it seems extremely unlikely that a deposit so thick did exist and has been so thoroughly removed that no remnants of it are left. There are a few patches of stream gravel on the uplands, which some have considered to be Cretaceous and others Tertiary in age, but these deposits are local in their distribution and are believed by no one to have covered the entire Driftless Area. Certainly they did not cover it to such depths as to mask the present structures. Neither is the glacial drift competent to cause such superposition, for there are considerable areas on both sides of the Mississippi which are driftless. Furthermore, the drift must have had a thickness of more than 600 feet at Minneapolis to have carried the river over the crest of the arch at La Crosse.

Because the Mississippi river is generally independent of structure, because it flows for 135 miles in a direction which is up the slope of the original surface, because it cuts across the axis of a fold whose dips are considerable, because the surface of the Driftless Area is in maturity and shows no signs of old age, and because the river has not been superimposed, the Mississippi river is believed to be antecedent and to record more than one cycle in the erosional history of the surface.

The relations between the course of the Mississippi river and the Dodgeville and Lancaster plains north of La Crosse are not definitely ascertainable. On the south limb of the anticline, however, the general course of the river comes within 5° of being parallel in direction with the Dodgeville plain and within 6° of parallelism with the Lancaster plain. It seems likely therefore, that the river established its present course in old age of the cycle of erosion in which the Dodgeville peneplain was formed and held that course without great change during the dissection of the Dodgeville plain and the formation of the Lancaster plain and while the Lancaster plain was being uplifted and eroded.

It is not known that this holds in detail for that part of the river north of La Crosse.

Other Streams

All the smaller tributary streams of the Driftless Area appear to have been formed in the present cycle of erosion, be it the first, second or third cycle which the Area has experienced. It would seem likely, however, that if the Mississippi river existed in a previous cycle, some of its larger tributaries, such as the Wisconsin, La Crosse, Upper Iowa, Turkey, Root and Whitewater rivers might have established their courses at the same time and have held their courses to the present.

Within the Driftless Area, Wisconsin river flows from Prairue du Sac to the Mississippi in a general direction S 73°W, which is at an angle of 47° with the general dip of the strata and what must have been the slope of the original surface. The whole course of the river in this distance is on Potsdam sandstone, but before it had cut quite so deeply it must have flowed from the soft sandstone, across the resistant Prairie du Chien dolomite, instead of remaining on the soft sandstone as it could have done by developing a course more nearly parallel with the strike of the strata. As Wisconsin river is not adjusted to the structure the conclusion seems reasonable that it probably developed a course in harmony with conditions which existed in old age of a previous cycle and held that course during rejuvenation. In the sense in which Willis, Davis, and Hayes and Campbell used the term in connection with certain rivers of the Appalachians, Wisconsin river is, then, probably antecedent and an evidence of more than one cycle of erosion.

The direction of dip of the strata in the neighborhood of La Crosse river near the crest of the arch is not known accurately, and it is not known whether the river, which flows S 56°W is parallel with or oblique to the axis of the anticline. It may, therefore, be antecedent or consequent.

The courses of the streams in Iowa doubtless have been influenced by glacial drift which extends eastward almost or quite to their points of junction with the Mississippi;

and the problem of their antecedency is therefore obscured. Upper Iowa river has a course N 46°E from Decorah to its mouth, which fails of parallelism with the dip by 142°. Indeed the river flows for 35 miles in a direction which must have been up an original slope of 10 or 15 feet per mile. If glaciation had nothing to do with the establishment of this course Upper Iowa river is probably antecedent. Turkey river below Elkader flows in the general direction S 66°E. As this makes an angle of only 2° with the strike of the strata, Turkey river may be considered to be adjusted in harmony with its development within a single cycle. In Minnesota, Root river has a course out of harmony with the structure and the slopes of the theoretic original surface. It flows in a general direction which is up a stratigraphic dip of 4 feet per mile, although by taking a more southerly course it could have flowed around the end of the plunging anticline. Although Whitewater river north of the axis of the arch, as stated on p. 102, flows in a direction which is in harmony with structure and original slope, it joins the Mississippi with an acute angle downstream, suggesting the possibility that its course was established according to original slope and maintained after reversal of the master stream. Thus, while there is little suggestion of antecedency for the Whitewater river itself, its course taken in connection with the course of its main, adds strength to the belief that the establishment of the present course of the upper Mississippi involved a case of piracy of a magnitude which could hardly have taken place all within the present cycle of erosion.

In Illinois, Sinsinawa Creek, Galena River, Smallpox Creek, Apple River and Plum River are so nearly parallel with the dip that their histories probably do not date back of the present erosional cycle.

Intrenched Meanders

If the erosional history of the Driftless Area has involved more than one cycle of erosion it seems that some of the streams at least should have developed meanders in old age of a cycle and intrenched their meanders in the later cycle following uplift. The difficulty in distinguishing intrenched meanders from curves made in other ways not involving more than one cycle of erosion is brought out in Part I, as are also other limitations and possibilities in the application of intrenched meanders to interpretations of the erosional histories of regions.

The two major streams of the Driftless Area, the Mississippi and Wisconsin rivers, show no intrenched meanders, in spite of the fact that they seem to have had a history which would have developed such features. Both streams have flood plains several times the widths of the rivers and the details of their present courses are what would be expected under these conditions; but their curves are not intrenched. Except for their details, the general courses of these rivers are quite remarkably straight. If the streams were at grade on the Dodgeville plain and developed meanders there they must have straightened their courses as they cut down toward the Lancaster plain. Either the Lancaster peneplain was not sufficiently flattened for the development of conspicuous meanders or meanders were formed in this second cycle and cut off again after uplift of the Lancaster plain. It is not unreasonable to suppose that such streams would straighten themselves after rejuvenation; indeed, it is not clear that a stream could maintain the meanders developed in one cycle much past maturity of the following cycle. Therefore, the absence of intrenched meanders in these major streams is not thought to argue strongly against the idea that the Driftless Area has suffered more than one cycle of erosion. On the other hand the curves of these streams have nothing to offer in favor of this idea.

Conditions are somewhat different in the cases of smaller streams. Upper Iowa, Yellow, Turkey, and little Maquoketa rivers in Iowa are quite crooked and spurs from the valley walls project into the curves. But a large part of the courses of these streams lie in an area which has been glaciated, and the curves may have been developed on the surface of the drift and superimposed on the bedrock. But on the east side of the Mississippi river in Wisconsin and Illinois, where the area has never been glaciated and where there is no other known cause for exceptionally crooked streams, Trempeleau, Black, Kickapoo, Grant, Platte, Little Platte, Pecatonica, Galena, and Apple rivers all have distinctly crooked courses where the area has never been glaciated and where there is no other known cause for exceptionally crooked streams (Fig. 33). Kummel[1] studied the Galena, Platte, Grant, and Pecatonica rivers, described their meandering courses and their mature valleys, and concluded that they could not have been developed in a single cycle, either by superposition or by inequalities in resistance of rock. He concluded that they are true intrenched meanders significant of more than one cycle of erosion. His argument is convincing but hardly conclusive. There are so many ways in which curves might be developed and so difficult is it to distinguish curves made in differ-

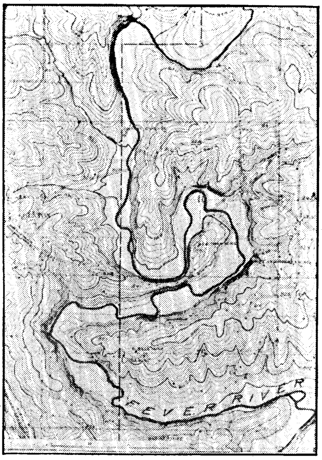

Fig. 33. A map showing a portion of the course of Galena river near Benton, Wisconsin. The curves may constitute intrenched meanders. (After Martin).

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[1] Kummel, H. B., "Some meandering rivers of Wisconsin," *Science*, New Series, Vol. I (1895), pp. 714-716.

ent ways, that the writer believes that these intrenched curving streams, considered alone without reference to relations between mains and tributaries, might have acquired these curves without having experienced more than one cycle. On the other hand it is believed that these intrenched curves bear as much evidence in favor of the plural cycle theory as intrenched meanders ever afford.

Associated Sets of Crooked and Straight Streams

But if the crooked courses of these streams within the Driftless Area have been developed in a single cycle their tributaries must have had the same histories as the mains and should have courses as crooked as the courses of the mains. Neither in the case of the above-mentioned streams in the Driftless Area of Wisconsin and Illinois nor of those in the slightly glaciated portion of Iowa do the mains and the tributaries have comparable natures and degrees of crookedness.

The fact that the tributaries are less crooked than their mains in Iowa is not significant, for it is possible that the main streams developed their course in the drift and that the tributaries were developed under different conditions after superimposition had been accomplished.

In the cases of those streams in areas which were not even slightly glaciated, however, and in which the tributaries are straight and the mains are notably curved, a suggestion is offered that the histories of the main streams and of the tributaries have not all been worked out in a single cycle. It would seem likely that the mains developed meanders when they were at grade in maturity or old age of a previous cycle of valley development and that either the tributaries had not reached grade and therebore did not meander before the first cycle was interrupted, or the tributaries did not exist at the close of the first cycle and have developed their straight courses entirely under conditions of higher gradient in the present cycle.

There is a marked difference in degree of crookedness between tributaries and mains in practically all of the drainage systems intermediate in size between the largest and the smallest, as illustrated in Fig. 34. This fact is of some value as evidence in favor of the idea that more than one cycle was involved in the erosional history of the Driftless Area. This evidence is chiefly corroborative, however, and is not conclusive considered alone.

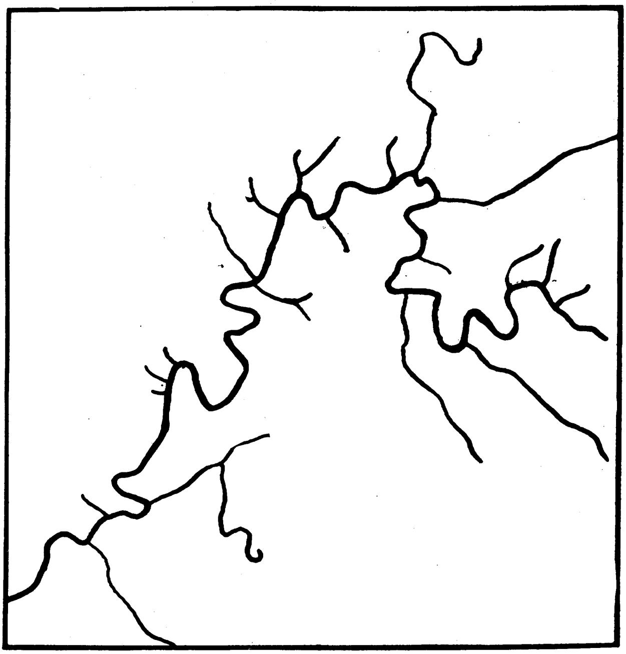

Fig. 34. A plat of part of the course of Grant river and its tributaries. The fact that the tributaries are not nearly so crooked as the main stream suggests that the curves of the river were developed in the last stages of a previous cycle and that the tributaries were mainly or wholly developed in the present cycle.

Stream Terraces

The Driftless Area abounds in stream terraces of various sorts, but none of them is significant as an evidence of more than one cycle of erosion.

At many points throughout the area there are projections or benches along the valley walls, whose tops are more or less flat, whose outer faces are steep, and to which the term terraces might be applied. These features are well known in Jo Daviess County, Illinois[1], in the Sparta district[2] and along the Wisconsin river[3] in Wisconsin, and in many of the valleys of Iowa, notably in the valley of Village Creek. These terraces are formed by resistant layers of rock at various stratigraphic horizons, as for instance, certain resistant sandstone layers in the Potsdam formation, the Mendota limestone member, the cherty member of the Galena formation, and the calcareous beds in the upper Maquoketa. They are purely structural, occur at different levels, cannot be correlated with either the Dodgeville or the Lancaster plain, and cannot be used as evidence of more than one cycle of erosion in the Driftless Area.

In several of the main tributaries of the Wisconsin river, notably in the valley of the Kickapoo river and the valley of Pine creek, there are distinct and almost continuous terraces which slope gently downstream. They consist of nonresistant rock, and bevel the layers of the Potsdam sandstone. The valleys have a double appearance, there being a narrow, rock-bound valley within a much wider, older one. These terraces are also due indirectly to structure. The Wisconsin river flows west and south with a gradient considerably less than the slope of the strata in that direction, so that its bed is on progressively younger strata towards its mouth. Although it has now penetrated the resistant Prairie du Chien formation where it joins the Mississippi, there was a time when its lower course was in this resistant formation and its upper course and its tributaries were on the Cambrian sandstone. Under these conditions the degradation was so much slower on the Prairie du Chien formation than was possible upstream on the sandstone that a temporary grade was established and maintained on the sandstone. There the main and tributary streams developed broad, open valleys with flat bottoms. When the resistant dolomite at the mouth of the river was finally cut through the sandstone beneath it was excavated rapidly and the streams above the resistant rock were allowed to intrench

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1. Trowbridge. A. C. and Shaw, E. W., Bull. No. 26, *Ill. Geol. Surv.*, pp. 144-5.
2. Martin, Lawrence, *Bull. Geol. Soc. Am.*, Vol. 28, pp. 148-149.
3. MacClintock, Paul, *The Wisconsin River between Prairie du Sac and Prairie du Chien*, manuscript so far unpublished.

themselves. The renewed activity was felt last in the tributary valleys and the terraces have therefore been eroded least there, so that they are now most conspicuous in valleys tributary to the main streams rather than in the main valley itself. There are coarse stream-laid gravels on some of these terraces, as for instance in the valley of Pine Creek southwest of Richland Center, and in the valley of Honey Creek near Plain. It is clear that these terraces also are not significant in connection with the erosional history of the general surface of the Driftless Area.

Flat-topped terraces, consisting of alluvial and lacustrine materials are found abundantly in nearly all the larger tributary valleys to the Mississippi and Wisconsin rivers. The origin of these terraces has been worked out[1] and found to be due to a partial filling of the Mississippi and Wisconsin river valleys by fluvio-glacial material at the time of the Wisconsin ice invasion, the consequent ponding of the tributaries, and the re-excavation of the fill in the mains and the tributaries after the retreat of the Wisconsin glacier. The origin of these terraces too has little to do with the general erosional history of the Driftless Area as a whole.

Although there are many terraces in the Driftless Area, it is concluded that none of them bears evidence of more than one cycle of erosion in the region.

Upland Fluvial Deposits (high level gravels)

One of the best evidences that there have been more than one cycle of erosion in the Driftless Area is found in the fact that stream deposits exist on some of the summit surfaces of the Area. These deposits have been known for a long time and have usually been referred to as "high-level gravels."[2] As the term implies, these deposits occupy the highest portion of the topography and consist almost entirely of gravel.

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[1] Trowbridge, A. C. and Shaw, E. W., Bull. No. 26, *Ill. Geol. Surv.*, pp. 145-152.

[2] Strong, Moses, *Geol. Wis.*, Vol. IV, 1875-79, p. 88.
Winchell, N. H., *Geol. and Nat'l Hist. Surv. Minn.*. Vol. I, 1884, pp. 305-310; 353-356.
Chamberlin. T. C. and Salisbury, R. D., *Sixth Ann. Rept. U. S. Geol. Surv.*, 1884-85, p. 273.
Salisbury, R. D., *Bull. Geol. Soc. Am.*, Vol. 3, 1892, pp. 183-186; *Jour. Geol.*, Vol. III, 1895, pp. 655-667.

So far they have been found at Seneca, Wisconsin, on the flat summit of the south quartzite range near Devil's Lake, Wisconsin, on the summit plain in the south portion of the Sparta quadrangle north of Cashton in Wisconsin, in the Tomah quadrangle, Wisconsin, at Iron Hill near Waukon, near Church, and near Elon in Iowa, and in various portions of the Driftless Area in Minnesota. In all these places the gravel is thick enough to form a measurable deposit and at Senaca and Waukon the thickness is as great as 35 feet. The deposit occupies summit positions in the topography, which position represents the Dodgeville plain in each case. In addition to these localities where the gravel is in place, there are many places in Iowa and Illinois and probably in Wisconsin and Minnesota, where scattered pebbles which have been derived from the deposit are found at all levels. However, there is no place known where the gravel lies in its original position at levels below the Dodgeville plain. At Devil's Lake they are associated with potholes in the summit surface. It is not believed that these patches of gravel are remnants of a formation which once covered the entire Driftless Area, but that the gravels were deposited only along stream courses.

There can be no doubt that these gravels are of fluvial origin. The pebbles range in size from a small fraction of one inch to three or four inches in diameter. The smaller ones are rounded and highly polished and seem to have been carried far, or at least to have undergone transportation for a long time. The large ones are more irregular and some of them seem hardly to have been transported at all. At Seneca, Waukon and Elon, the gravel deposits are distributed in crescent shaped areas resembling the curves of streams.

The writer has broken hundreds of the pebbles and has yet to find one composed of anything but silica. Most of them are chert, but some are white quartz, some are almost black, and some have the color and appearance of jasper and chalcedony. They are known to include nothing which could not have been derived from the pre-Cambrian and Paleozoic formations which originally covered the Driftless

Area. At Waukon, Elon, Seneca, and at some points in Minnesota, the gravel is firmly cemented with iron, so that a conglomerate exceedingly resistant to erosion is formed.

Some of the pebbles contain fossils which are of Ordovician and Niagaran age. Some of the pebbles and fossils collected from the Sparta quadrangle are shown in Fig. 35.

The conclusion seems unavoidable that streams were once nearly at grade on the Dodgeville plain; that they deposited extensively in their beds, and that deposition ceased as the dissection of the summit plain was inaugurated by uplift. The coarse texture of the fluvial deposit, their apparently local origin, and their association at Devil's Lake with potholes all suggest that they were not deposited by the largest and oldest streams of the time, but rather by secondary streams whose gradients were still appreciable and whose sources were not far distant, and yet by streams which have long since ceased to exist. Presumably the larger streams deposited also, but the material probably consisted of sand and silt rather than of gravel, and these non-resistant deposits have been entirely removed or mingled with the upland soils so thoroughly as to be indistinguishable. The gravel was probably deposited on those portions of the Dodgeville plain which were somewhat above the lower valley bottoms, and by subsequent erosion they have come to stand as the very highest points because of their superior resistance.

Whatever may have been their detailed origin and distribution these fluvial gravels, occurring at widely separated points on the Dodgeville plain, hundreds of feet above present drainage, go far to prove that the surface of the Driftless Area has not been formed by erosion in a single cycle. Certainly there is no provision in the cuesta single cycle theory for the occurrence of these deposits on the Dodgeville plain.

Conclusion

As was brought out in Part I, the most satisfactory proof of more than one cycle of erosion is to be found in certain *combinations* of evidences. A combination amounting to

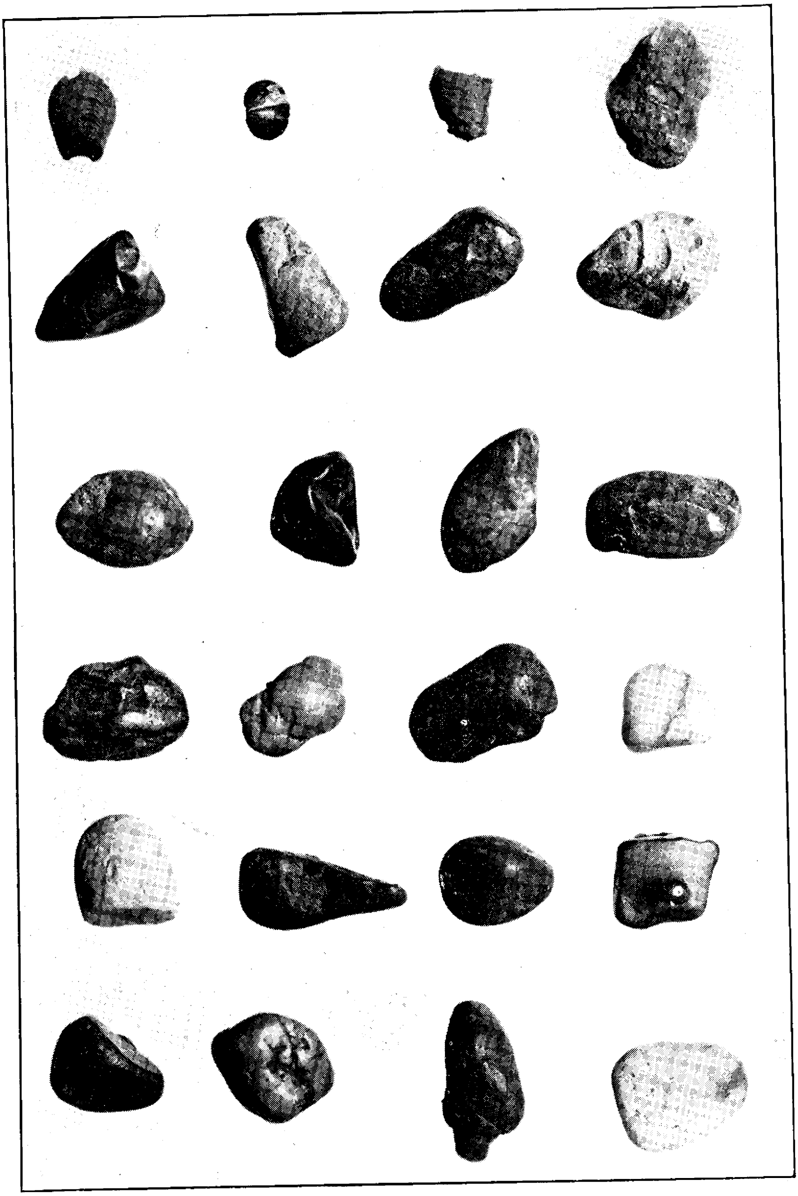

Fig. 35. Pebbles and fossils from the summit fluvial deposits in the south portion of the Sparta Quadrangle. (After Shipton).

proof exists in the Driftless Area. It is impossible that a surface could have been developed in a single cycle of erosion, which has (1) even-crested summit areas which, after analysis, represent a peneplain, (2) an intermediate plain which can be interpreted only as a partial peneplain, (3) antecedent streams which could have developed their present courses only in old age of an erosion cycle, (4) intrenched meanders for which no other explanation than that they record more than one cycle have been worked out, (5) associated sets of crooked and straight streams which are valuable corroborative evidence of plural cycles, and (6) undoubted fluvial deposits widely distributed on flat surfaces far above present drainage.

THE NUMBER OF EROSIONAL CYCLES

The next question which confronts the interpreter of the erosional history of the Driftless Area has to do with the number of cycles of erosion which have been involved in the formation of the surface. The question can be answered when it has been determined how many distinct *sets* of evidences of more than one cycle are included among the five evidences outlined above.

In the first place, there is no way to ascertain how many cycles, if any, intervened between the time of withdrawal of the last Paleozoic sea and the cycle in which the Dodgeville plain was formed. There may have been time for several cycles of erosion between these dates. But of any such cycles all evidence was obliterated in the making of the Dodgeville plain. If it be assumed that the cycle which was inaugurated by the final withdrawal of the sea was the same cycle as that in old age of which the Dodgeville plain resulted, there would be no way to prove the assumption to be incorrect.

Considering the evidences of more than one cycle of erosion it is clear that the Dodgeville plain and the Lancaster plain could not have been formed in the same cycle. From foregoing discussions it is clear that the antecedent streams and upland fluvial deposits go with the Dodgeville plain, and the intrenched meanders and associated sets of crooked and straight streams with the Lancaster plain. Even-crested summit areas, antecedent streams and fluvial deposits on divides constitute evidence of one ancient cycle, and an intermediate plain which is a partial peneplain, intrenched meanders and associated sets of crooked and straight streams afford evidence of another one. Below the intermediate plain the streams in their deeply excavated valleys show that a third cycle is involved.

It is believed that the surface of the Driftless Area has been eroded in at least three cycles, the first known one being represented to-day by the Dodgeville plain, the second one by the Lancaster plain, and the third one by the present valleys below the Lancaster plain. These cycles are called the Dodgeville cycle, the Lancaster cycle and the present cycle respectively.

THE HISTORY OF DIASTROPHISM

The first recorded diastrophic event involved in the erosional history of the Driftless Area caused the warping of the strata to form the anticline with its axis crossing the Mississippi river at or near La Crosse, and with its south and north dipping limbs, together with the gentle and local anticlines and synclines on the limbs of the larger fold. This movement may or may not have accompanied or caused the final withdrawal of the Paleozoic seas. It was an uplift of the surface with warping.

After the initial movement and the establishment of the land surface, after the streams had reached grade and developed the Dodgeville plain, an uplift occurred which interrupted the Dodgeville cycle and inaugurated the Lancaster cycle. Although the Dodgeville plain is not perfectly parallel with the Lancaster plain nor with the present flood plain of the Mississippi river, this uplift was not accompanied by marked warping or tilting. The local irregularities of the Dodgeville and Lancaster plains are clearly due to erosion rather than to diastrophism and are neglected in the following estimates. The relative directions and amounts of slope of the Dodgeville plain, the Lancaster plain, and the graded plain of the Mississippi river, south of La Crosse, are shown in the accompanying table.

TABLE SHOWING THE RELATIVE DIRECTIONS AND AMOUNTS OF SLOPE OF THE DODGEVILLE PLAIN, THE LANCASTER PLAIN, AND THE MISSISSIPPI FLOOD PLAIN

Plain	Average direction of slope	Average amount of slope
Dodgeville Plain	S 23°E	3.3 feet per mile
Lancaster Plain	S 40°E	3 feet per mile
Mississippi Flood Plain	S 18°E	4 inches per mile

The difference in direction of slope of the Dodgeville and Lancaster surfaces is not great, considering the possibilities of error in estimating averages, and could be due to differences in direction of drainage during the respective cycles. Consequently, they cannot be said to record warping or tilting of the Dodgeville surface during uplift. The amounts of slope of the Dodgeville and Lancaster plains are almost identical, which seems to prove that there was no notable tilting of the Dodgeville surface before the formation of the Lancaster plain. The second diastrophic movement recorded in the features of the surface was then one of nearly uniform uplift.

The amount of this uplift can be ascertained at least roughly by the average difference in altitude between the Dodgeville plain and the Lancaster plain. On the average these two plains are 235 feet apart vertically in the Baraboo district, 265 feet in the Sparta quadrangle, 148 feet in the Richland Center quadrangle, 175 feet in the Lancaster and Mineral Point quadrangles, 218 feet in Jo Daviess County, Illinois, 117 feet in the Waukon quadrangle, 190 feet in the Elkader quadrangle, 125 feet in southeastern Minnesota. As the average of these figures is 184 feet, the second recorded diastrophic movement was an uplift of about that amount.

The Lancaster cycle was interrupted by a third uplift which was the greatest of all the movements which affected the Driftless Area. Streams which had developed graded flats on the Lancaster plain during the Lancaster cycle were able in the following cycle to cut to the levels of the bottoms of the rock valleys below the later fluvio-glacial fills. The average depth of the valleys cut during this cycle is approximately the amount of the uplift which closed the Lancaster cycle. The following table gives details of the depths of valleys cut during this cycle.

TABLE SHOWING DEPTHS OF VALLEYS WHICH MEASURE THE AMOUNT OF THE UPLIFT WHICH INTERRUPTED THE LANCASTER CYCLE

Valley	Altitude of Lancaster plain (feet)	Altitude of rock bottom of valley (feet)	Depths of Valley below the Lancaster plain and amount of uplift (feet)
La Crosse River near Sparta	1100	600	500
Devils Lake Gap	1200	570	630
Galena River near its mouth	860	490	370
Upper Iowa River near its mouth	1150	530	620
Mississippi River at La Crosse	1100	470	630
Mississippi River at Prairie du Chien	1100	473	627
Mississippi River at Dubuque	880	279	601

Considering the fact that not all the wells, the records of which were used for the altitudes of the bedrock beneath the surfaces of the fills, are in the middles of the valleys and the probability that not all the streams had reached grade when the filling began, the depths of these valleys are quite remarkably uniform. This average depth, approximately 600 feet, seems to be a fair estimate of the amount of uplift. If the streams were not at grade when degradation ceased and aggradation began the amount of uplift may be considered to have been more than this. Of the two uplifts which have occurred since the land surface of the Driftless Area was established the second one was three times as great as the first.

From the table showing the relations between the two upland plains and the bottoms of the present Mississippi Valley, (p. 117), the inference might be drawn that the uplift which interrupted the Lancaster cycle was accompanied by tilting, for the Lancaster plain and the present Mississippi flood plain are not parallel. However, the nature of this uplift is to be obtained by comparison of the Lancaster plain not with the present flood plain, but with the rock bottom of the valley beneath the present river level. The streams rejuvenated by the uplift of the Lancaster plain continued to cut downward until the rock bottoms of the present valley were reached. The present flood plains of the streams were established later, under different conditions. Although it is impossible to determine the exact slope of the surface represented by the buried bock bottoms of the valleys, it is shown in the last table that the depths of the valleys cut during the post-Lancaster cycle and consequently the amount of uplift which inaugurated that cycle are notably uniform. This suggests that the peneplain which would have been developed if this cycle had gone to a late stage would have been roughly parallel with the Lancaster plain. This being the case the uplift of the Lancaster plain is more likely to have been uniform than accompanied by tilting.

The rather low altitudes of the parallel Dodgeville and Lancaster plains in Minnesota suggests the possibility that the movement which interrupted the Lancaster cycle was accompanied by warping in that state. On the other hand, a slightly decreased slope in old age of each of the two cycles or a slight change in the direction of slope of the two plains would explain the slight discrepancy equally well.

There seems to be no escape from the conclusion that there has been still another period of diastrophism in the Driftless Area, this time a subsidence rather than an elevation of the surface. The evidence of subsidence is found in the fact that the Mississippi river and its main tributaries are now at grade at levels on the average 180 feet above levels to which they were formerly able to reduce their beds. It is not believed that this fact is to be explained on the supposition that the present grade is merely temporary and controlled by some obstruction such as the rock ledge at Rock Island or the rapids at Keokuk. These obstructions are far from sufficient to explain the difference in grade levels now and as they were, for the Mississippi river today has a gradient of less than 6 inches per mile from La Crosse to the Gulf, including the rapids. It is believed, therefore, that the last diastrophic movement in the history of the Driftless Area was a subsidence of about 150 to 200 feet and that it took place sometime before, during, or just after the partial filling of the valleys by fluvio-glacial debris.

If it be assumed that this subsidence was accompanied by tilting, so that the south portion of the Driftless Area subsided more than the north portion, the apparent parallelism of the Dodgeville plain, the Lancaster plain, and the rock-bottomed valleys, and the more gentle slope of the present Mississippi flood plain would be explained. This assumption is rendered unnecessary, however, if it be considered that the present Mississippi has a sufficiently greater volume and lighter load than all previously existing streams, to allow it to develop and maintain a gradient one-tenth as steep as any preceding gradient.

The conclusion is reached, therefore, that at least four different diastrophic movements affected the Driftless Area, namely, (1) uplift with warping and tilting which initiated the land surface; (2) a nearly uniform uplift of about 180 feet interrupting the Dodgeville cycle; (3) a nearly uniform uplift of 600 feet or more which started the excavation of the deep valleys; and (4) a subsidence, perhaps accompanied by tilting, which raised the level of grade to that of the present Mississippi river.

THE DATES OF EVENTS

The whole history presented in this paper is limited in time between the Niagaran epoch on the one side and the Wisconsin epoch on the other. The sequence of events has already been worked out. The accuracy with which the dates of these events can be stated depends upon the accuracy with which the ages of the upland plains can be determined. There has been disagreement concerning the ages of these plains and perhaps the final conclusion will have to await further work, but strong evidence now at hand leads to the conclusions here presented.

The Age of the Dodgeville Plain

There is no known way to determine the age of the Dodgeville plain by a study confined to the Driftless Area. The most promising method lies in the attempt to determine the age of the high level gravels which are contemporaneous with the plain. In 1882 Winchell[1] discovered silts and sands and clays of undoubted Chetaceous age in southeastern Minnesota, and in the same district he found a gravel deposit later found to be similar in some respects to the hige-level gravel of the Driftless Area. Because the gravels were associated with the Cretaceous deposits Winchell tentatively assigned a Cretaceous age to them. In 1895, after study of the Tertiary gravels of the Gulf Coast and of Arkansas and southern Illinois, and after seeing the gravel deposits of the Driftless Area at Seneca and Devil's Lake, Salisbury[2] concluded that the gravels were not older than Cretaceous nor younger than Lafayette, and was inclined to believe that they are late Tertiary in age. For unstated reasons most recent writers have followed Winchell and tentatively assigned a Cretaceous age to the high-level gravels and the plain on which they lie. Perhaps the reason is that marine Cretaceous rocks in western Iowa and Minnesota lie on a base of slight relief and bevel the same southwest dipping formations as occur in the Driftless Area.

After having spent part of a field season in southeastern Minnesota, assisted by Professor Leroy Patton, the writer is strongly inclined to favor the Tertiary age of the plain, for the following reasons: (1) The gravels of the Driftless Area are dissimilar from the rocks which carry Cretaceous fossils in Minnesota and from certain deposits of stratified gravels in Minnesota believed to be related to or derived from the Cretaceous rocks. Near New Ulm, Brown County, there is an exposure of stratified high-level gravels interbedded with sand and clay. The surface rock at this place is regarded as Cretaceous. The stratified deposit itself may be Cretaceous but might easily have been locally derived

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[1] Winchell, N. H., *Geol. and Nat'l Hist. Surv. Minn.*, Vol. I, pp. 309-310; 353-356.

[2] Salisbury. R. D., *Jour. Geol., Vol. III*, pp. 655-667.

from the Cretaceous. The latter seems quite probable for the reason that the Cretaceous deposits in this district contain pieces of gravel similar to the high-level gravel and also chalky particles which appear in the stratified deposits. The latter particles, however, could not have stood much transportation and are of themselves a strong argument for the local derivation of the high-level gravels. Other material derived from the Cretaceous in the earlier stages of the dissection of the Cretaceous surface might have become widespread as stream gravels on the old surface of the peneplain. (2) It should be noted that although Winchell may have been correct in his conjecture that certain gravels described by him were locally derived from Cretaceous deposits, it does not follow as a corollary that the *time* of derivation was Cretaceous and that therefore any surface upon which these gravels lie is Cretaceous. In Winchell's report[1] he distinctly states his belief that the gravels which he here describes were placed in position "by drift forces." Whether he meant that they were Cretaceous deposits reworked during the Pleistocene period by a glacier is not clear. Certainly they are not glacial, but undoubtedly they were derived from the Cretaceous deposits revealed by post-Cretaceous streams. Winchell seems to have believed that at least some of the gravel deposits in Minnesota were of post-Cretaceous age. The writer believes that the high-level gravels of the Driftless Area, nowhere associated with sands, silts, or clays, are post-Cretaceous, though perhaps derived partly from Cretaceous formations containing gravel layers or levels. (3) Winchell's conclusions were with regard to local and isolated cases only and had no reference to gravel deposits of similar nature found in localities not suggesting a local derivation. (4) The Dodgeville plain constituting a stratigraphic base for the gravel has never been traced and found to underlie Cretaceous rocks but on the contrary its altitude in Minnesota is such as to cause it to bevel the Cretaceous. (5) The gravels extend far beyond any known Cretaceous and occur extensively where there is not the slightest indication of Cretaceous age.

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[1] Winchell, N. H., *Geol. and Nat'l Hist. Surv. Minn.*, Vol. I, p. 309.

(6) The gravels of the Driftless Area are strikingly similar to the Tertiary gravels of the Gulf region. (7) There are numerous patches of similar deposits south of the glaciated area and beneath the drift which seem to connect the gravel formation of the Driftless Area with the Tertiary deposits of the Gulf Coast. (8) The Dodgeville plain on which the gravels lie slopes south toward the Tertiary deposits rather than west toward the Cretaceous. (9) Salisbury's interpretation has been in print for a quarter of a century and all new discoveries seem to corroborate his tentative conclusions. (10) All patches of gravel between the Driftless Area and known Tertiary deposits occupy summit areas in the topography. (11) If the base of the Tertiary deposits were projected north it would coincide roughly with the Dodgeville plain. (12) The base of the Tertiary deposits is in itself a peneplain. (13) The Tertiary gravels are known to lie on a raised peneplain in the southern Appalachians and elsewhere. These facts seem to the writer almost conclusive of the Tertiary age of the Dodgeville plain. Whether the plain is Eocene, Oligocene, Miocene, or Pliocene in age cannot be determined, for the precise age of the Tertiary gravels on the Gulf Coast is in doubt. It is believed, however, to be *late* rather than *early* or middle Tertiary.

The Age of the Lancaster Plain

The Lancaster plain is clearly younger than the Dodgeville plain and is probably therefore late Tertiary or Pleistocene in age. It has been generally understood that the great uplift in the interior of the United States came at the close of the Tertiary, in the epoch known by some as the Ozarkian. Because the greatest movement which affected the Driftless Area uplifted and started the dissection of the Lancaster plain this plain has been most generally referred to the late Tertiary.

The writer is not certain that the Lancaster plain is not Tertiary in age, but he wishes to present some evidences that it was not completed and uplifted before the first ice invasion. The work of the writer during several years, and the work of A. J. Williams[1] has shown that there is old

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[1] Williams, A. J., Manuscript so far unpublished.

drift extending eastward beyond the mapped border of Kansan drift on the west side of the Driftless Area in Iowa, almost and in many places quite to the Mississippi river. There is also at least one area of this upland drift in Illinois[1]. Whereas the Kansan drift within the mapped area lies at all levels of the bedrock topography from the tops of the highest hills to the bottoms of the deepest valleys, this drift beyond the Kansan border, with the exception of a tongue of supposedly Kansan drift near McGregor, is found most abundantly on the Lancaster plain, sparingly on the slopes above the Lancaster plain, and still more sparingly on the Dodgeville plain. Of the several hundred isolated remnants of this drift which are now known, not a single patch is in place in the valleys below the Lancaster plain. If this drift were Kansan and deposited after the deep valleys were cut, it would seem difficult to explain why it would all have been removed from the valleys and valley benches so that the drift now extends farther east on the narrow divides than in the broad, open, terraced valleys. Still more difficult would it be to explain, if the deposition of this drift took place after the valleys were cut, how a glacier thick enough to fill valleys 600 feet and more deep so as to spread over the divides could have advanced, deposited this drift and retreated without so having changed the profiles of the valleys or so having modified the divides or so having marked the rock surfaces as to have left some trace on the surface below the Lancaster plain. When it is recalled that almost wherever known this oldest Pleistocene drift lies on high divides or benches above valleys believed to have been cut after the deposition of the drift, as in New Jersey[2], Montana[3], and the San Juan mountains of Colorado[4], there is nothing new nor radical in the supposition that in the Driftless Area also, it antedated in its deposition the formation of the deep valleys. This upland drift has the appearance of great age but perhaps not of greater age than

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[1] Trowbridge, A. C. and Shaw, E. W., *Bull. Ill. Geol. Surv.*. No. 26, p. 87.
[2] Salisbury, R. D., *Ann. Rept. State Geologist of New Jersey for 1893*, pp. 73-123, especially p. 87.
[3] Alden, W. C. and Stebinger, Eugene, *Bull. Geol. Soc. Am.*, Vol. 24, pp. 529-572.
[4] Atwood, W. W. and Mather, K. F., *Jour. Geol.*, Vol. 20, pp. 385-409.

the Kansan drift, where it is thin. Where either drift is thin, it has been brought to its limits of weathering.

There is then some evidence, which seems to the writer to be strongly indicative, if not conclusive, that this drift, in a district which has been called driftless, is pre-Kansan in age, and that it was deposited while the Lancaster plain was still intact and before the deep valleys were formed. Otherwise, why should there be no patches of the drift in the valleys? And why should the valleys show not the slightest indication of having been glacially worn? The Kansan drift seems clearly enough to have been deposited after the valleys were formed.

The above evidence seems to justify the interpretation, at least as a working hypothesis, that the Lancaster plain was intact at the time of the pre-Kansan ice invasion, but that it was uplifted and partly dissected before the Kansan epoch. Leverett[1] objects to this interpretation and cites the presence of pre-Kansan drift in the bottoms of deep rock-bound valleys in Wisconsin and southeastern Iowa. So far as the writer has been able to investigate the evidence, he finds it inconclusive. The writer's interpretation is strengthened by E. W. Shaw[2], whose recent work in the Ozark district seems to show that the main uplift and the main development of the Mississippi valley there took place during the early Pleistocene, rather than at the close of the Tertiary as was previously supposed.

Accepting the above interpretations of the ages of the Dodgeville and Lancaster plains, at least as probabilities, the probable dates of diastrophic events and erosion cycles are easily determined and are stated in the following summary of events.

SUMMARY OF EVENTS

The first step in the history of the surface of the Driftless Area was the final emergence of the surface from the sea and the formation of an anticline with its axis running through La Crosse and its south limb forming a great

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[1] Personal communications and oral discussions in the field.
[2] Personal communications to the writer.

monoclinorium which extends far beyond the boundaries of the Driftless Area to the south and southwest. This movement left the surface high above the level of grade, with a stream divide on the axis of the fold. This event took place after the Niagaran epoch of the Silurian period and probably after the Pennsylvanian period, but before the Cretaceous. The date may be set roughly at the close of the Paleozoic era.

Following its initiation, the surface was eroded in one or more cycles and was brought to the condition of a plain with a relief of less than 200 feet, the Dodgeville plain. The cycle was not complete, but a stage at least as late as early old age was reached. The divide at La Crosse was probably obliterated before the close of this cycle. The stage in the history of the region was probably brought to an end at some time during or at the close of the Tertiary period.

Probably in late Tertiary time the gravel-strewn Dodgeville plain was uplifted almost uniformly to the amount of approximately 180 feet.

The uplift mentioned in the last paragraph inaugurated a new cycle of erosion known as the Lancaster cycle, which continued probably until the advance of the pre-Kansan glacier in the earliest part of Pleistocene period, by which time a second peneplain, the Lancaster plain, had been formed. Neither was this cycle of erosion complete. However, the surface at this time was much more nearly flat than the present surface. The surface doubtless lacked something of having gone so far in its stage of reduction as was the case during the Dodgeville cycle.

The Lancaster erosion cycle was interrupted most likely at some time soon after the retreat of the pre-Kansan glacier in the early Pleistocene, by a diastrophic uplift without tilting or warping, amounting to 600 feet or more. This movement raised the Lancaster plain to levels high above grade and inaugurated a third cycle of erosion.

The details of the post-Nebraskan, pre-Wisconsin history of the Driftless Area are not known, but the history seems to have been one of erosion interrupted locally and temporarily by the deposition of at least two bodies of glacial drift on the borders of the area. Deep valleys appear to have been cut before the advance of the Kansan glacier and the deposition of a thin body of Kansan drift on the west border. The valleys of Pecatonica and Apple[1] rivers had been cut to depths below their present bottoms by the time of the Illinoian (?) ice invasion from the east.

Some time before or during or immediately after the Wisconsin glacial epoch, when the valley trains were deposited in the Mississippi and Wisconsin valleys, there appears to have occurred a subsidence of the surface amounting to about 180 feet and perhaps accompanied by a tilting of all older graded surfaces slightly to the south. The subsidence rendered it impossible for the Mississippi and its tributaries to cut back to their original levels. If tilting occurred the gentler slope of the present flood plain as compared with all previous gradients is explained.

After the withdrawal of the Wisconsin glacier the Mississippi river and its tributaries began to excavate their valleys by the removal of the fluvio-glacial debris but they reached grade 30 or 40 feet below the original top of the deposit and 180 feet on the average above its bottom. Having reached grade, the streams have all developed valley flats in the soft material deposited by waters during the Wisconsin epoch.

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[1] Trowbridge, A. C. and Shaw, E. W., Bull. Ill. Geol. Surv. No. 26, pp. 95-99.

FIRST SERIES NO. 43 FEBRUARY 15, 1921

UNIVERSITY OF IOWA STUDIES

STUDIES IN NATURAL HISTORY

VOLUME IX NUMBER 2

THE HESPERIOIDEA OF AMERICA NORTH OF MEXICO

by

ARTHUR WARD LINDSEY

PUBLISHED BY THE UNIVERSITY, IOWA CITY

Issued monthly throughout the year. Entered at the post office at Iowa City, Iowa, as second class matter. Acceptance for mailing at special rates of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

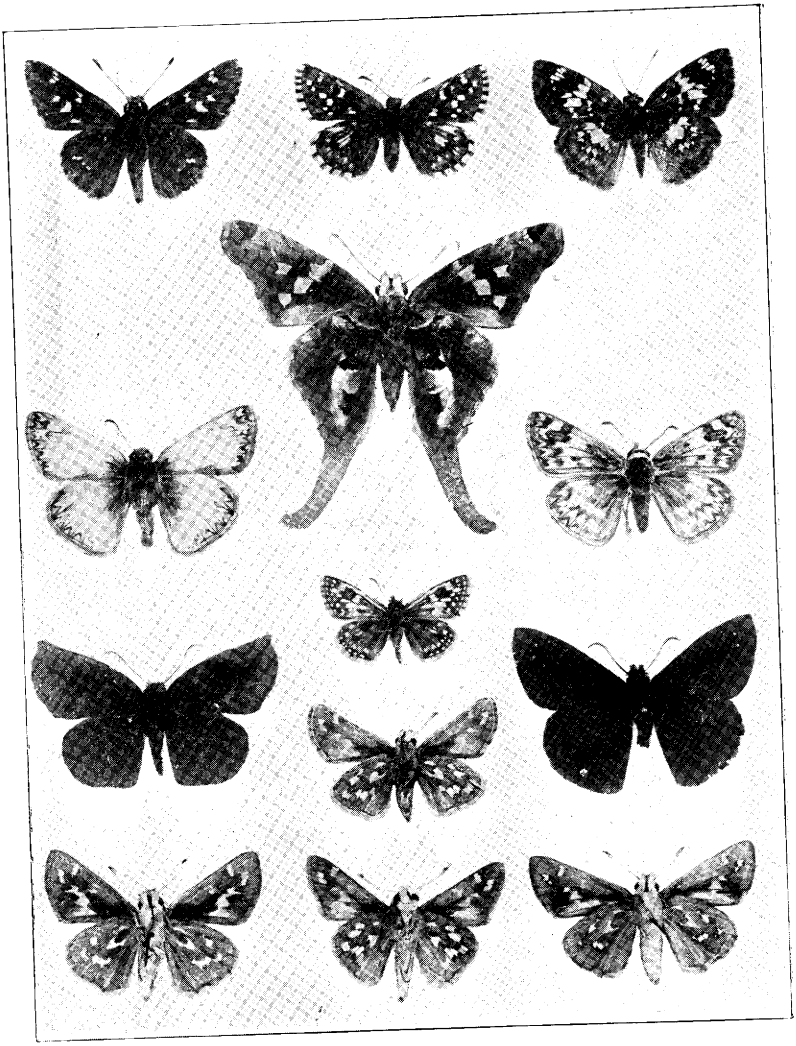

PLATE I

1. Atrytonopsis python Edw., ♂
2. Hesperia centaureae Ramb., ♀
3. Xenophanes tryxus Cr., ♂
4. Hesperia ericetorum Boisd., ♂
5. Chioides zilpa Butl, ♂, under surface
6. Hesperia ericetorum Boisd., ♀
7. Hesperia philetas Edw., ♂
8. Eantis thraso Hbn., ♀
9. Pamphila nevada Scud, ♀, under surface
10. Melanthes brunnea H.-S., ♂
11. Pamphila comma, race colorado Scud., ♀, under surface
12 Pamphila viridis Edw., ♂, under surface
13. Pamphila comma, race oregonia Edw., ♀, under surface

UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

PROFESSOR CHARLES CLEVELAND NUTTING, M.A., Editor

CONTINUATION OF BULLETIN FROM THE LABORATORIES OF NATURAL HISTORY
OF THE STATE UNIVERSITY OF IOWA

VOLUME IX NUMBER ~~2~~ 4

THE HESPERIOIDEA OF AMERICA NORTH OF MEXICO

A GENERIC REVISION AND SYNOPSIS OF THE SPECIES

by

ARTHUR WARD LINDSEY, PH.D.

PUBLISHED BY THE UNIVERSITY, IOWA CITY

THE HESPERIOIDEA OF AMERICA NORTH OF MEXICO

Since the time of the early writers who were satisfied to place their skippers in the two genera, *Pamphila* and *Hesperia*, the classification of these insects has been in a more or less chaotic state. The two old genera can readily be subdivided, but the structures of the skippers which are useful in their classification are of a peculiarly unstable character and have therefore proven a stumbling block to those who have attempted such subdivision. This is due to the fact that very few of our species are structurally identical, as a result of which one division has led to another until we have reached the deplorable state where, to be consistent, we must either lump extensively or split still more finely, with most lepidopterists in favor of the former. In the following pages I have attempted to rearrange our species and reorganize our genera to eliminate the confusion which has attended the group in North America, while bearing in mind both the convenience of the classification and the opinions of the learned authors of many genera for which I have been unable to see any necessity. Undoubtedly I have erred in some points, especially in the case of the numerous species found in the southwest which belong to genera more typical of the Central American fauna, but I believe that the examination of a more complete collection of exotic species will clear up many obscure points for which I have been able to offer only a tentative solution.

In the course of my work I have had occasion to ask information of Prof. H. F. Wickham, Dr. J. McDunnough, and Dr. Henry Skinner. Dr. Skinner has also supplied me with a number of specimens which I could not otherwise obtain, and Prof. Wickham has lent a number of books from his private library. Dr. Barnes of Decatur, Ill., has very generously allowed me the freedom of his fine collection and library, and also supplied me with many specimens for study. Mr. R. A. Leussler of Omaha has given me specimens of several species which I had been unable to secure, and Mr. Nathan Banks has kindly examined the collection at Cambridge for certain material and furnished transcripts of several necessary descriptions not in my possession. Mr. Gerhard of the Field Museum made it possible for me to spend several profitable hours in the examination of the Strecker collection in that institution. To all of these men I wish to express my gratitude for their valuable assistance.

The first step toward a rational classification of the skippers was made by Scudder in 1874 [1] when he proposed the division of the family, as he regarded it, into two tribes, the *Hesperides* and *Astyci.* These represented approximately the genera *Thymele* and *Pamphila* of Fabricius' classification in Illiger's Magazine in 1807. Scudder based his tribes on the secondary sexual characters of the males and characters found in the early stages.

This paper was followed in 1878 by Mabille's work on the Hesperiidae in the Brussels museum.[2] Mabille adopted the tribes proposed by Scudder but subdivided them into several minor groups each. Scudder later expressed his approval of these divisions for the *Hesperidi* but reserved his judgment of the *Astyci.*[3] Many of Mabille's groups are not represented in our fauna; the others have been the subject of very little dispute.

In the same year there appeared a paper by Burmeister [4] in which the family is divided into four tribes. I am familiar with this paper only through the remarks of Scudder in the Butterfles of New England, but these are quite sufficient to show that none but historic interest attaches to the rather remarkable arrangement proposed.

A year after this Speyer produced a brief work [5] in Germany wherein we find the first suggestion of the systematic importance of the position of vein five of the primaries. This suggestion furnished the necessary complement to Scudder's foundation for the major subdivisions of the skippers, which are still in use.

Nothing further of importance was done in the systematic

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[1] Bull. Buff. Soc. Nat. Hist. I, 195, 1874.

[2] Ann. Soc. Ent. Belg. XXI, 12, 1878.

[3] Butt. New Eng. II, 1372, 18.

[4] Desc. Phys. Rep. Arg., Lep. 245, 1878.

[5] Stett. ent. Zeit. XL, 477, 1879.

study of these insects until 1893, when Watson published[6] his "Proposed Classification of the Hesperiidae," which is practically the classification now in use. Watson divided the family into three subfamilies, the *Pyrrhopyginae, Hesperiinae* and *Pamphilinae*, equivalent to the *Pyrrhopygini* of Mabille and the two tribes of Scudder. He further subdivided the Hesperiinae into two groups and the Pamphilinae into three. Group C of the Pamphilinae is wholly oriental and African. The others correspond to the similar divisions of Scudder in part. As Watson was working on the collection in the British Museum where *Megathymus* was placed in the Heterocera, he merely mentioned the genus to indicate that if placed in the Hesperiidae it would form an additional subfamily.

At this time Godman and Salvin had been publishing for six years parts of the three volumes on Rhopalocera of the Biologia Centrali-Americana. The first signature on the skippers appeared a few months before Watson's revision, but the work was not completed until 1901. The subfamilies are those of Watson and the Hesperiinae are divided as in his classification, but the Pamphilinae, worked up by Godman after Salvin's death, are divided into eight groups. These are not wholly acceptable, but they suggest an improvement over the two groups of other writers. The chief systematic interest of the Biologia lies in the number of genera described, the excellent plates, and the great value of the work for specific identifications.

But one other paper, Mabille's monumental "Famille Hesperidae,"[7] has been written on the Hesperioid fauna of the world since the earliest times. In this work Mabille uses the same arrangement as that of Watson, excepting the establishment of the subfamily *Ismeninae* to take the place of Watson's Group C of the Pamphilinae, and the definite placing of *Megathymus* in the subfamily *Megathyminae*.

There remains to be mentioned Dyar's "Review of the Hesperiidae of the United States."[8] This brief paper is the only one ever published on the skippers of this country, and in spite of omissions and commissions of an unusual nature it has filled a

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[6] Proc. Zool. Soc. London, 1893, 3-132, pl. I-III.

[7] Genera Insectorum XVII, 1903-4.

[8] Journ. N. Y. Ent. Soc. XIII, 111-141, 1905.

great need of systematic lepidopterists. It was intended, as the name implies, merely as a synopsis of the genera and species and follows the "Famille Hesperidae" with comparatively few changes.

These works are the foundation of our present system of classification. Many others with a wider range have contributed to our knowledge of the skippers but in none of these is any work of importance on the gross classification attempted.

It will be noted in the preceding sketch of the history of the skippers that they have been treated as the family Hesperiidae, equivalent to the several families of butterflies with which they have been associated. This position is the only one to which they have been widely assigned, though a number of writers have given them superfamily rank. E. Reuter carries this a step further and proposes a distinct suborder under the name Grypocera,[9] equivalent to the Rhopalocera and Heterocera, while Spuler does likewise, but applies the name Netrocera.[10] This reopens the question of suborders, for if we accept Comstock's Frenatae and Jugatae the two older groups can no longer occupy this rank and must be either reduced or discarded. I regard them as natural groups though I am inclined to agree with Comstock's subdivision. The Rhopalocera and Heterocera may conveniently be designated as series. In this arrangement I cannot accept Reuter's Grypocera as indicative of the true relations of the skippers, but the name is still given some use in Europe. There are many points, however, in which the skippers show more primitive development or peculiar uniform specialization which distinguish them from the true butterflies, and the most natural arrangement appears to be that of Comstock [11] in which they are made a superfamily equivalent to the butterflies proper, According to our present nomenclature this superfamily should be known as the Hesperioidea. The following synopsis indicates the foundation of this classification for the suborder Frenatae.

Frenatae

Series HETEROCERA. Antennae rarely clavate. When clavate usually more or less pectinate or ciliate. Hind tibiae usual-

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[9] Act. Soc. Faun. Flor. Fenn. XXII.

[10] Spuler, Die Schmetterlinge Europas I, 70, 1908.

[11] Manual 364, 1895.

ly with two pairs of spurs; front legs normal. Frenulum present in many families. Venation of primaries generalized or characteristically specialized. Pupa loose in cocoon, earthen cell or plant tissues. Superfamilies Sphingoidea, Saturnioidea, Bombycoidea and Tineoidea.

Series RHOPALOCERA. Antennae usually strongly clavate; never pectinate or ciliate.

Superfamily HESPERIOIDEA: Pupa suspended in a slight cocoon. Hind tibiae rarely with less than two pairs of spurs; front legs normal. Frenulum absent. Primaries with twelve veins, all free. (All five branches of radius present and from cell according to Comstock's system.)

Superfamily PAPILIONOIDEA: Pupa naked, usually suspended from silken attachments and specialized for concealment. Hind tibiae with only the terminal pair of spurs; front legs in higher families greatly reduced. Frenulum absent. Primaries with less than twelve veins or with some stalked.

In the Hesperioidea we have two families, the Hesperiidae and Megathymidae. The second includes only the genera Megathymus and Aegiale, and is equivalent to the subfamily of other writers. The first includes all other skippers. The Megathymidae are very closely related to the Pamphilinae, and some students regard them as a highly specialized branch from the same parent stock. The fact that the boring habit of the larvae is apparently acquired lends color to this opinion, but I cannot regard the small head as a necessary accompaniment of the boring habit. Rather than assume an elaborate process of evolution for the reduction of such a specialization as the large head, I regard the Megathymidae as a line separated from the parent stock of the Pamphilinae before the increase in size of the head, and proceeding by parallel development to a point of higher specialization of similar structures.

The three subfamilies of Hesperiidae are easily distinguished, apparently natural groups. The only question regarding them is that of relative position, and the present arrangement of the Hesperiinae between the Pamphilinae and Papilionoidea is favored by most of the evidence, though in the structure of the imago they are more primitive than the Pamphilinae. The close relationship of the Pyrrhopyginae with the Hesperiinae and of the Megathymidae with the Pamphilinae leads to their being placed at the beginning and end of the superfamily respectively. The result is a linear series which is not entirely satisfactory, but since no linear series can represent true phylogenetic relations this must be accepted as the best possible, and it does, at least, correctly indicate the general relations of the several major divisions.

The separation of genera has been the most troublesome phase of the study of skippers since Hübner's classification was first amplified. I have come to the conclusion that the intermediate position of the group, together with the apparently transitional state of many of the structures, is accompanied by a greater blending of forms than has been recognized in the past, and that the normal genus may present a wide variation of structure, *provided that a transition between the extremes be present in the included species.* This is nicely illustrated by *Thanaos, Hesperia* and *Poanes* (*sensu* B. & McD., Check List). In *Thanaos* we have a group of insects of very similar habitus which no one has ever divided, but within the genus are to be found differences in structure which have been made to separate three genera in other cases. The neuration, shape of the wings, palpi and secondary sexual characters very nearly run the gamut of variation found in Group B of the Hesperiinae. *Hesperia* is similar but shows an even greater range of variation in the antennal club, shape of the wings, and in the palpi. In fact this variation is so great as to occasion some doubt of its unity, but it is impossible to divide the genus without separating some species whose relationship is apparent.

The matter of secondary sexual characters as a basis for the separation of genera is the greatest bugbear of systematists in this family. Godman and Salvin and Mabille have contributed abundantly to the confusion of genera so based, and in many cases these genera cannot be separated by other means. As far as I am aware the only definite stand taken upon the question is that expressed by Watson in his revision.* He says: "With

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* Since writing this I have found a quotation from Dr. P. L. Sclater by Col. C. Swinhoe in defense of genera based on secondary sexual characters (Ann. & Mag. Nat. Hist. (VII), III, 108, 1899).

regard to the vexed question of the generic importance of male secondary sexual characters, the conclusion which has been forced upon me is that, in any particular genus in which male secondary sexual characters are found, the particular male character (be it costal fold, discal stigma, or tuft of hairs) may be either present or absent in different species of that same genus, but is never replaced by a character of different structure."

This seems by far the most satisfactory attitude to adopt, though it is necessary to understand that in cases such as *Thanaos* and *Hesperia* two or three such characters may be present or absent in various combinations in the several species. In my work, rather than carry the splitting of genera further, I have unhesitatingly followed Watson's conclusion. This has resulted in the dropping of a number of familiar genera, but I think that once we are accustomed to the change it will render our classification more convenient and more useful, as well as more natural. Some change is demanded for the sake of consistency, and since our genera have already been carried beyond the point of usefulness, "lumping" is the only desirable change.

The structures of systematic value in the Hesperioidea are found in all parts of the body. The size of the head serves to distinguish the two families, and its appendages, the palpi and antennae, offer a means of separating many genera. The palpi vary in length and position and the relative size of the second and third joints is useful, but it is necessary to look at all of these things in a general way. For example, in *Pholisora* as here treated we find great variation in the vestiture of the palpi and in the relative length of the third joint, but throughout the genus long palpi with smooth deep scaly vestiture, an oblique second joint and a porrect third joint with long scales are present. *Thanaos* has palpi of a similar form but with shaggy vestiture. The third joint in some genera is long, slender and vertical.

The antennae have a characteristic slender tip which has been aptly termed the apiculus. This varies from the tiny point found in *Pamphila* to the long one of *Goniurus*, and has been entirely lost in some genera. This modification has apparently taken place by two distinct lines of evolution, first the loss of the apiculus by gradual reduction and second by the thickening and fusion of the structure with the club. The first has apparently taken place in the Pamphilinae and the second in the Hesperiinae. The relation of the length of the apiculus to the thickness of the club has been used extensively to separate certain genera of the Pamphilinae but I find that its value is limited. It is variable in most species, and only where extremely short or extremely long is this variation negligible. In such species as *verna* the apiculus is sometimes longer and sometimes shorter than the thickness of the club and is always difficult to measure with satisfactory accuracy. The length of the entire antennae measured in proportion to some other part of the insect is useful to distinguish a few genera of our fauna.

The legs offer three important characters, viz., the presence or absence of the epiphysis on the front tibiae, the presence or absence of spines on the mid tibiae and to a certain extent their form, and the number of pairs of spurs on the hind tibiae. The epiphysis does not concern us in a study of the North American fauna and the spurs on the hind tibiae characterize only one genus, but the spinulation of the mid tibiae is useful in several cases and in spite of some evidence to the contrary, I believe that it is a good character, at least to the extent used in this paper.

The wings vary greatly in shape, sometimes in a striking way, as in *Eantis*, *Systasea* and *Goniurus*. In certain others, as *Atrytonopsis*, they have a distinctive form which is less useful because less pronounced in the female and difficult to characterize. The neuration is of comparatively little use beyond a few conspicuous features, for it is impossible to pick a reasonably long series of related species without finding some transition in all of the salient features. In spite of this I have made use of the position of vein 11 of the primaries to separate *Chiomara* from *Thanaos*, but in this case there seem to be other grounds, and the one vein furnishes a convenient and apparently reliable corollary. The distance between the bases of veins 6 and 7 of the primaries of *Pholisora* is greater than in most other genera. The relation of vein 5 to 4 and 6 in the primaries distinguishes the Megathymidae and most Pamphilinae from the other skippers, and helps to separate some genera. The position of veins 2 and 3 of the primaries is another character which must be used with caution, for these veins vary in closely related species and can be depend-ed upon only in extreme cases. The neuration of the secondaries is scarcely worthy of notice, though some exotic genera are characterized by the presence of vein 5, which is usually absent or very weak.

The abdomen is of little service, though it aids in distinguishing the genera of group A of the Pamphilinae from certan Hesperiinae in that it projects beyond the secondaries in the former and scarcely reaches their anal angle in the latter.

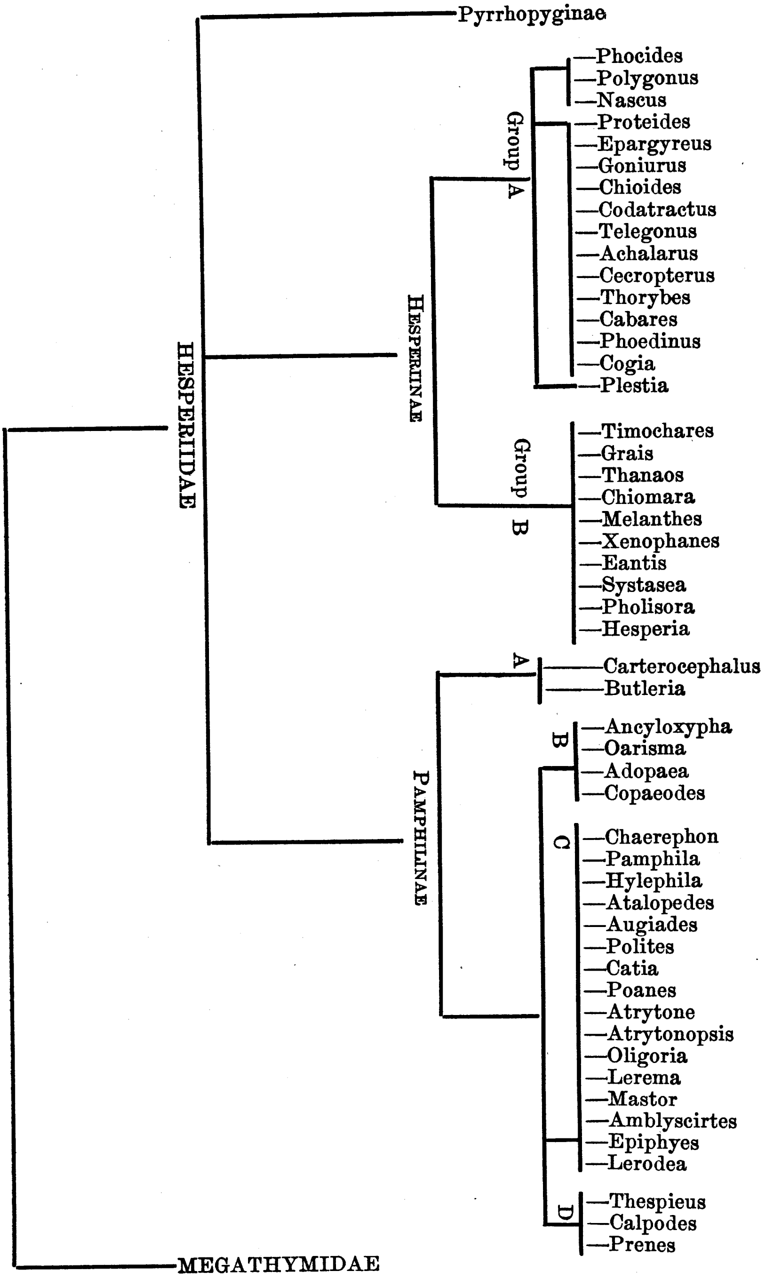
The male secondary sexual characters in the Hesperiinae consist of the costal fold on the primaries, tuft (always proximal in our species) on the hind tibiae, tuft on the upper surface of the secondaries and the two lobes found at the base of the abdomen on its ventral surface in *Hesperia.* In the Pamphilinae the only form found in the North American fauna is the brand or stigma on the disk of the primaries. While I agree with Watson's treatment of these characters I believe that the great difference in form between some of the stigmata indicates sufficiently different development of the species possessing them to warrant their generic separation. Fortunately in our fauna this character can be supplemented by others. It is necessary to guard agains splitting on this basis, for many stigmata which are superficially different may easily be seen to follow in their fundamental structure a single type.

The genitalia, especially of the males, are of great value in making specific determinations, and similarity of genitalia often affords an index of generic relationship. I have found several apparent contradictions to the latter statement, and am therefore inclined to use it very cautiously until more is known about the skippers, but still I hesitate to include in the same genus species whose genitalia are of widely different forms.

In attempting to work out the phylogeny of our existing speces I have come to the conclusion that the subfamily Ismeninae, made up entirely of old world species, represents the most primitive existing form. The entire subfamily is characterized by the upturned, appressed second joint of the palpi, very similar to that of the Hesperiinae of group A, and the long, porrect third joint which is unique. The antennae have a short shaft and a long, moderately thick club with a long apiculus which is never sharply recurved. The hind tibiae of the males are provided with a tuft attached at the proximal end and lying along the upper edge of the joint in a groove formed of strong scales. Vein five of the primaries is intermediate between veins four and six. From these structures we may assume that the immediate ancestors of the skippers had antennae enlarged at some distance proximad of the distal end, leaving the terminal portion slender, and that vein five of the primaries in these insects had not yet formed a definite connection with either of the adjacent veins. From such forms evolution has proceeded with the permanent reflection of the apiculus by either a curve or a sharp bend. (I can construe the reflexed club of the Pyrrhopyginae only as a further development of the Hesperiid antenna, though this does not seem a satisfactory explanation). In addition the apiculus has been reduced as already mentioned and various slight specializations have taken place. The wings of the Hesperiinae have changed only in the variably complete loss of vein five of the secondaries and the lengthening of the cell in group A, while in the Pamphilinae vein five of the primaries, has formed a definite connection with the median stem (English system; cubitus of Comstock and Needham), as also is the case with the Megathymidae. Following these lines I have drawn up the following diagram which I believe will indicate better than a written discussion the relations and phylogeny of the genera used in this work. The arrangement undoubtedly has its faults, but I believe that it corrects a number of features of former arrangements which were more or less unnatural. In the main it adheres to the order of genera which has been in common use.

Superfamily HESPERIOIDEA

Antennae clavate, in a few genera with the club very slender. Club usually with a slender tip called the apiculus. Palpi variable, usually relatively large and thick, upturned to porrect. Head wide, eyes large and far apart, lashed. Insertion of antennae near eyes. Body stout, slender in a few genera. Wings relatively smaller than in the Papilionoidea and with very strong venation in most genera. Primaries with twelve veins, all free; cell open or weakly closed. One anal. Secondaries with eight


Pyrrhopyginae
HESPERIIDAE
HESPERIINAE
Group A
Phocides
Polygonus
Nascus
Proteides
Epargyreus
Goniurus
Chioides
Codatractus
Telegonus
Achalarus
Cecropterus
Thorybes
Cabares
Phoedinus
Cogia
Plestia
Group B
Timochares
Grais
Thanaos
Chiomara
Melanthes
Xenophanes
Eantis
Systasea
Pholisora
Hesperia
PAMPHILINAE
A
Carterocephalus
Butleria
B
Ancyloxypha
Oarisma
Adopaea
Copaeodes
C
Chaerephon
Pamphila
Hylephila
Atalopedes
Augiades
Polites
Catia
Poanes
Atrytone
Atrytonopsis
Oligoria
Lerema
Mastor
Amblyscirtes
Epiphyes
Lerodea
D
Thespieus
Calpodes
Prenes
MEGATHYMIDAE

or nine veins, five usually absent; cell open. Two anals. Front legs normal, tibiae usually with the epiphysis present (in all North American genera). Middle legs with one pair of spurs on the tibiae and with or without spines. Hind legs with two pairs of spurs, or with only the distal pair in some genera.

The two families are based on the following characters:

Family HESPERIIDAE: Head nearly as wide to wider than thorax. Hind tibiae usually with two pairs of spurs. Palpi moderate to large. Larvae external plant feeders.

Family MEGATHYMIDAE: Head narrower than thorax. Hind tibiae with one pair of spurs. Palpi rather small. Larvae borers in plant stems. Imagines larger than most Hesperiidae, heavy bodied and strong of flight.

Family HESPERIIDAE

Characters of the superfamily, distinguished from the *Megathymidae* as shown in the preceding synopsis. The North American species fall into three subfamilies which may be separated by the following key, which also deals with the groups into which the subfamilies are divided.

Key to subfamilies and groups

1. Club of antennae large, entirely reflexed....PYRRHOPYGINAE
   Club variable, never entirely reflexed..................2

2. Vein 5 of primaries not curved at base, usually about intermediate between 4 and 6. Mid tibiae without spines ....HESPERIINAE 3
   Vein 5 curved at base, arising nearer to 4, or with the mid tibiae spined..........................PAMPHILINAE 4

3. Cell of primaries more than two-thirds as long as wing or antennae with a slender reflexed or recurved apiclus ....Group A
   Cell two-thirds or less. Club curved, blunt or fusiform, but never with a slender apiculus...................Group B

4. Vein 5 intermediate, straight. Club blunt. Palpi porrect ....Group A
   Vein 5 curved at base, nearer to 4. Palpi not porrect. Group B of authors................................5

5. Third joint of palpi long slender and vertical. Antennae short with the club blunt........................Group B
Third joint small or antennae with a slender apiculus
....Group C
Cell of primaries two-thirds as long as wing, usually with a recurrent vein or a vestige of it..................Group D

Subfamily PYRRHOPYGINAE

This subfamily includes a large number of South and Central American species of which only one, *araxes*, occurs within our territory. The large antennal club, bent back along the shaft or recurved, is typical of all the species. In other respects their structure agrees to a great extent with that found in group A of the Hesperiinae. The cell of the primaries is apically produced with the discocellulars outwardly concave, and is about two-thirds as long as the wing. The discocellulars are weak, but clearly traceable. Vein 5 is approximately intermediate in the primaries, and absent in the secondaries, though found in a few exotic genera.

Araxes has been included in the genus *Pyrrhopyge* by all writers with whose works I am familiar, but the difference in habitus and the form of the secondaries have led me to remove it. Watson's diagnosis of his genus *Microceris* (P. Z. S. 1893, 15) differs in only a few points from the structures of *araxes*, but the type, *variicolor*, judging by the original description and figure, is not at all closely related. I am therefore basing a new genus on the points of difference between *araxes* and Watson's description of *Microceris*.

Genus APYRROTHRIX gen. nov.

Similar to *Pyrrhopyge*. Differs from that genus in the more gently curved costa and more prominent apex of the primaries and the form of the secondaries. In *Pyrrhopyge* these appear to be longer through the cell than along the inner margin, and the outer margin is even or slightly concave between veins 2 and 7. The abdomen usually equals or surpasses the anal angle of the secondaries. In *araxes* the secondaries are broad and full, and surpass the abdomen. The outer margin is deeply crenulate, produced between veins 2 and 4 in the male and conspicuously so in the female. According to Watson veins 7 and 8 of the primaries of *variicolor* are short stalked, while in *araxes* they are free. Watson's figure of the neuration of his genus differs in a few points in the secondaries also, and on the whole the relationship seems to be rather with the typical species of *Pyrrhopyge* than with *araxes*. Fig.1.

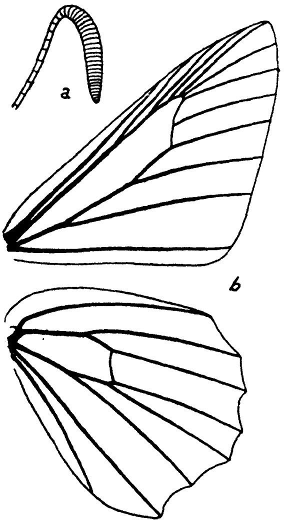


Fig. 1. *Apyrrothrix araxes* Hew. a. Club of antenna. b. Neuration

Type: *Erycides araxes* Hew.

1. *APYRROTHRIX ARAXES*

Erycides araxes Hewitson, Desc. Hesp. 2, 1867.

Pyrrhopyga cyrillus Plötz, Stett. ent. Zeit, XL, 529, 1879.

Biologia Cent.-Am., Rhop. II, 252, pl. 73, ff 14, 15, 16, 1893.

Holland, Butterfly Book 319, pl. XLV, f. 9, 1898.

Mexico. I have two bred specimens from southern Arizona which are very close to *araxes* but the typical form is not known to occur north of the boundary.

1a. race *ARIZONAE*

Pyrrhopyge araxes, form *arizonae* G. & S., Biol. Cent.-Am., Rhop. II, 253, 1893.

Skinner, Trans. Am. Ent. Soc. XXXVII, 201, pl. X, 1911.

Dark marks on under surface of secondaries not well defined, suffused with ochreous. Outer margin of ochreous area diffuse.

Arizonae occurs in Arizona in August and September.

Subfamily HESPERIINAE

Structure very diverse but always showing the characters mentioned in the key. Antennae varying in length, club flattened oval to extremely long and slender, with the distal half or less reflexed or recurved. Palpi with the second joint closely appressed and the third minute to long, large and porrect. Neuration fairly constant. Branches of radius variable in position. Vein 5 straight and about intermediate between 4 and 6, 2 variable. Secondaries with position of 7 variable and vein 5 absent to weakly tubular at its outer end (*Thanaos*, some specimens), usually marked by a fold. Mid tibiae without spines. Two pairs of spurs present on the hind tibiae in our genera. Secondary sexual characters of the males: costal fold, tibial tuft, tuft on secondaries, and basal lobes on under surface of abdomen.

GROUP A

Group A is more widely represented in South and Central America, and a number of our species are merely strays from more southern localities. The genera have been very inconsistently treated in the past, and I am lumping a few of them which show a complete lack of constant structural differences with the exception of the costal fold. Several such as *Cecropterus* and *Thorybes* are very closely related but because of the very distinct form of the male genitalia I am retaining them, based on such characters as will serve for their separation. The group is distinguished by the length of the cell and the form of the antennal club.

Key to the genera

1. L. D. C. of primaries very long and curved........*Phocides*
   L. D. C. normal.................................2

2. Apiculus of antennae longer than rest of club, straight and sharply bent at base............................*Nascus*
   Apiculus otherwise..............................3

3. Primaries with a tubular, or at least well marked, recurrent vein in cell...4
   Recurrent vein scarcely traceable or absent..............9

4. Antennae with a distinct, slender, reflexed apiculus......5
   Antennal club fusiform, more or less elongate; arcuate or with a well rounded bend at middle.....................7

5. Secondaries tailed............................*Goniurus*
   Secondaries not tailed..............................6

6. Apiculus sharply bent; primaries apically produced
   ....*Proteides*
   Apiculus recurved; apex of primaries moderate..*Epargyreus*

7. Recurrent vein nearer vein 4 than vein 3...............8
   Recurrent vein nearer 3......................*Chioides*

8. Outer margin of secondaries slightly crenulate. . *Codatractus*
   Outer margin even. . . . . *Telegonus*

9. Club of antennae large, fusiform. . . . . *Plestia*
   Club more slender, with a distinct apiculus. 10

10. Apiculus much shorter than rest of club, bent at about a right angle. 11
    Apiculus about as long as rest of club, usually sharply reflexed or recurved. 13

11. Secondaries lobed. . . . . *Polygonus*
    Secondaries broadly rounded or merely produced at anal angle 12

12. ♂ with a tuft of scales on upper surface of hind wings; palpi moderate. . . . . *Cogia*
    No tuft. Palpi exceeding front by about length of head . . . . *Phoedinus*

13. Vein 1a of secondaries about two-thirds as long as 1b. Primaries with a broad yellow band. . . . . *Cecropterus*
    Vein 1a longer. Primaries with spots or a broken yellow band 14

14. Outer margin of secondaries broadly rounded; of primaries slightly and almost evenly convex. . . . . *Thorybes*
    Outer margin of secondaries more or less produced and angled at 1b; of primaries slightly sinuate. . . . . . . *Achalarus*
    Outer margin of secondaries with a slight truncate lobe between veins 3 and 4. . . . . *Cabares*

Genus PHOCIDES Hübner

Phocides Hbn., Verz. bek. Schmett. 103, 1820. Type *Papilio palemon* Cr.

Erycides Hbn., Verz. bek. Schmett. 110, 1820. Type *Papilio pygmalion* Cr.

Dysenius Scudder, Syst. Rev. 46 (67), 1872. Type *Erycides albicilla* H. S.

Palpi oblique, vestiture smooth, deep and scaly; third joint small. Antennae with club rather long, moderately thick; apiculus not more than one-half as long as rest of club, very slender and abruptly bent. Primaries shaped as in *Goniurus*, with a costal fold in the male. Cell over two-thirds as long as wing. Vein 5 nearer to 6 than to 4; L. D. C. long and strongly curved. Vein 3 near end of cell and 2 well toward base of wing. Recurrent vein faint, at base of vein 4. Secondaries produced toward anal angle with outer margin sharply bent at 1b but not lobed. Outer margin only slightly irregular. *Phocides* is easily recognized by the general habitus of the species when once seen. Fig. 2.

The action of former writers in combining these three genera was undoubtedly correct, though some slight differences of structure exist between the species occurring in our country.

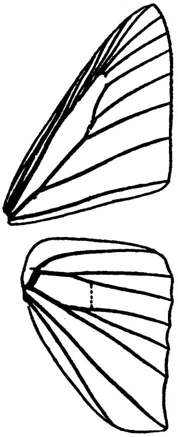


Fig. 2. *Phocides batabano* Lucas. Neuration

Key to the species

Primaries immaculate, black	*batabano*
Primaries with a red spot above	*lilea*
Primaries with hyaline white spots	*urania*

1. *PHOCIDES BATABANO*

Eudamus batabano Lucas, Sagra, Hist. Cuba, vii, 624, 1857.
Erycides mancinus H.-S., Corr.-Blatt Regensb. xvi, 143, 1862.
Erycides okeechobee Worthington, Papilio i, 133, 1881.
Skinner, Trans. Am. Ent. Soc. xxxvii, 199, pl. x, 1911.

Florida, March and April.

2. *PHOCIDES LILEA*

Erycides lilea Reakirt, Proc. Acad. Nat. Sci. Phil. 1866, 339.
Erycides albicilla H. S., Corr-Blatt Regensb. xxiii, 169, 1869.
Erycides socius Butl. & Druce, Cist. Ent. i, 112, 1872.
Dysenius cruentus Scud., Syst. Rev. 46(67), 1872.
Erycides sanguinea Scud., Syst. Rev. 47(68), 1872.
Erycides decolor Mab., Bull. Soc. Ent. France 1880, xlvi.
Biol. Cent.-Am., Rhop. ii, 296, pl. 76, ff. 23, 24, 1893.
Skinner, Trans. Am. Ent. Soc. xxxvii, 199, 1911.

The only specimen which I have seen bears the label "Colima, Mex." Skinner lists a Texas record by Capt. Pope in the Mexican Boundary Survey.

3. *PHOCIDES URANIA*

Erycides urania Westw. & Hew., Gen. Diurn. Lep. 510, pl. 79, f. 1, 1852.
Erycides texana Scud., Syst. Rev. 47(68), 1872.

Skinner, Ent. News I, 23, 1890, and II, 101, pl. 1, 1891.
Skinner, Trans. Am. Ent. Soc. XXXVII, 198, 1911.
Texas, Arizona and southward.

Genus NASCUS Watson

Nascus Watson, Proc. Zool. Soc. London, 1893, 28, Type *Papilio phocus* Cr.

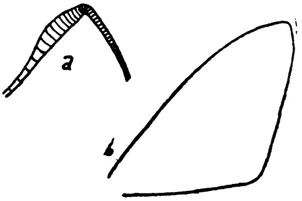


Fig. 3. *Nascus hesus* Westw. a. Club of antenna. b. Outline of primary

Watson characterized this genus as follows: "Antennae: club rather robust, bent into a hook, terminal portion very slender and rather longer than rest of club. Palpi upturned, third joint almost concealed. Fore wing: outer margin very much longer than inner margin, the apex being very conspicuously produced; cell more than two-thirds the length of costa; male with a costal fold; discocellulars very oblique, the lower one slightly the longer; vein 3 shortly before end of cell; vein 2 close to base of wing. Hind wing anally produced, and with an inconspicuous tooth at vein 1b; vein 7 close to end of cell; discocellulars and vein 5 barely traceable; vein 3 immediately before the end of the cell; vein 2 considerably nearer to end of cell than to base of wing. Hind tibiae with a long fringe of coarse hairs and with two pairs of spurs." In our fauna the very long apiculus separates this genus from all others. Fig. 3.

1. *NASCUS HESUS*

Telegonus hesus Westw. & Hew., Gen. Diurn. Lep. II, pl. 78, f. 5, 1852.
? *Papilio nicias* Fab., Mant. Ins. II, 86, 1787.
? *Eudamus etias* Hew., Desc. Hesp. 13, 1867.
Aaron, Ent. News I, 25, 1890 and II, 101, pl. 1, 1891.
Eudamus euribates Skinner (not Cramer) Trans. Am. Ent. Soc. XXXVII, 191, pl. X, 1911.
Mexico to Brazil; Skinner includes Texas, following Aaron, presumably.

I have compared Cramer's, Westwood and Hewitson's and Skinner's figures, and find that the two latter agree very well, but that, even allowing for the poor quality of Cramer's figure, they can hardly be *euribates* Cramer. I have no data on the occurrence of the species in this country.

Genus POLYGONUS Hübner

Polygonus Hbn., Samml. exot. Schmett. II, t. 144, 1822-6. Type *Polygonus lividus* Hbn.

Acolastus Scud., Syst. Rev. 50, 1872. Type *Hesperia savigny* Latr.

Nennius Kirby, Wytsman's Hübner 105, 1902. New name for *Polygonus* and *Acolastus*.

Second joint of palpi appressed, densely scaled; third porrect, small. Reflexed apiculus abruptly constricted, about one-half as long as rest of club. Head slightly wider than thorax. Primaries narrow, costa evenly curved, inner margin nearly straight and outer sharply curved opposite cell; no fold in male. Cell three-quarters as long as wing; vein 5 about equidistant between 4 and 6; spur vein scarcely traceable, nearer to 3. Secondaries broadly rounded, lobed at anal angle. Fig. 4.

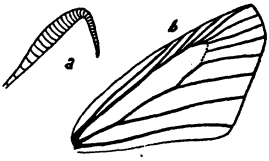


Fig. 4. *Polygonus amyntas* Fab. a. Club of antenna. b. Neuration of primary

According to Scudder (Hist. Sk. 253) *Polygonus* was preoccupied by *Polygona* in the Mollusca. *Acolastus* was preoccupied in the Coleoptera, a fact which was overlooked for many years, and Kirby offered *Nennius* to replace it. According to the current international rules of zoological nomenclature a difference of one letter is sufficient to validate a generic name, so *Polygonus* cannot be regarded as preoccupied, and therefore must be retained for *amyntas*.

1. POLYGONUS AMYNTAS

Papilio amyntas Fab., Syst. Ent. 533, 1775.

Polygonus lividus Hbn., Samml. exot. Schmett. II, t. 144, 1822-26.

Hesperia savigny, Latr., Enc. Meth. IX, 741, 1823.

Skinner, Trans. Am. Ent. Soc. XXXVII, 200, pl. X, 1911.

The typical form is very dark. It occurs in Florida in Aug. and Sept.

1a. race *ARIZONENSIS*

Erycides amyntas arizonensis Skinner, Trans. Am. Ent. Soc. XXXVII, 209, pl. X, 1911.

The western race of *amyntas* is paler than the typical form, both above and below, and the pale transverse bands of the secondaries are faintly visible on the upper surface. Texas and Arizona, September.

Genus PROTEIDES Hübner

Proteides Hbn., Verz. bek. Schmett. 104, 1820. Type *Papilio idas* Cr.

Dicranaspes Mab., Ann. Soc. Ent. Belg. XXI, 24, 1878. Type *Papilio idas* Cramer.

Proteides is very close to *Epargyreus,* and I think that with a large series of the tropical species the two genera will be found to be scarcely worthy of separation. In our fauna, however, the sharply constricted and reflexed apiculus and the narrow, apically produced primaries of *Proteides* are very distinctive. The male has no costal fold. Fig. 5.

1. *PROTEIDES IDAS*

Papilio idas Cramer, Pap. Exot. III, 118, p. CCLIX, A, B, 1779-80.
Papilio mercurius Fab., Mant. Ins. II, 86, 1787.
Biol. Cent.-Am., Rhop. II, 301, pl. 77, f. 5, gen., 1893.
Skinner, Trans. Am. Ent. Soc. XXXVII, 194, 1911.

Occurs in Texas, New Mexico and Arizona. I have no further data.

Genus EPARGYREUS Hübner

Epargyreus Hübner, Verz. bek. Schmett. 105, 1820. Type *Papilio tityrus* Fab.

Second joint of palpi closely appressed, densely clothed with scales in which the small third joint is almost concealed. Antennae about one-half as long as the primaries, club more or less sharply curved at the middle. Head not quite as wide as thorax. Primaries elongate, rather narrow; outer and inner margins about equal in length, outer slightly more oblique but otherwise similar to *Goniurus.* Costal fold present. Cell three-quarters as long as wing; vein 5 slightly nearer to 4 than to 6. Recurrent vein nearer to vein 3. Vein 1 strongly sinuate. Secondaries rounded, lobed at anal angle. Fig. 5.

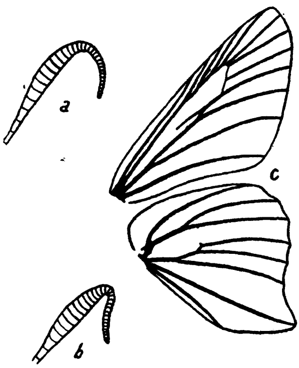


Fig. 5. a. Club of antenna of *E. zestos* Geyer. b. Club of antenna of *P. idas* Cramer. c. Neuration of *E. tityrus* Fab.

The primaries are longer and narrower in *exadeus* than in *zestos* and *tityrus,* and the apiculus of the antennae shows a tendency to be more slender and more sharply bent. This has led me to the conclusion stated under *Proteides* that the two genera are possibly not distinct.

Key to the species

1. Under surface of secondaries with a silky white patch..............2
   No silky white on secondaires.................................*zestos*
2. Spots of primaries deep yellow and usually broadly contiguous.*tityrus*
   Spots small and widely separated, or if larger, very pale yellow.*exadeus*

1. *EPARGYREUS ZESTOS*

Proteides zestos Geyer, Zutr. exot. Schmett. IV, 9, t. 106, ff. 615, 616, 1832.
Eudamus oberon Worthington, Papilio I, 132, 1881.
Skinner, Trans. Am. Ent. Soc. XXXVII, 193, 1911.

Florida, August and September.

2. *EPARGYREUS TITYRUS*

Papilio tityrus Fab., Syst. Ent. 532, 1775.
Papilio clarus Cramer, Pap. Exot. I, 66, pl. XLI, E, F, 1775.
Holland, Butterfly Book 323, pl. XLIII, f. 5, 1898.
Smyth, Ent. News XIX, 191, pl. X, 1908.
Skinner, Trans. Am. Ent. Soc. XXXVII, 192, 1911.

Ranges throughout the United States and into southern Canada and South America. June to August.

ab. *OBLITERATUS*

Epargyreus tityrus obliteratus Scudder, Butt. New Eng. II, 1402, 1889.

Only three small, rounded spots in place of the discal band, and only one small preapical spot. Silver on under surface of secondaries more extensive than usual.

3. *EPARGYREUS EXADEUS*

Papilio exadeus Cramer, Pap. Exot. III, 118, pl. CCLX, C, 1779-80.
Biol. Cent.-Am., Rhop. II, 299, pl. 77, f. 1, gen., 1893.
Skinner, Trans. Am. Ent. Soc. XXXVII, 194, pl. X, 1911.

Southern California, Arizona, New Mexico, March.

Genus GONIURUS Hübner

Goniurus Hübner, Verz. bek. Schmett. 104, 1820. Type *Papilio simplicius* Stoll.

Eudamus Swainson, Zool. Ill. (2), II, 48, 1831-2. Type *Papilio proteus* Linn.

? *Polythrix* Watson, Proc. Zool. Soc. London, 1893, 19. Type *Eudamus metallescens* Mabille.

Second joint of palpi closely appressed, third porrect, small. Antennae a little over one-half as long as primaries, club slender, apiculus shorter and distinctly more slender than remainder. Primaries broad and short; outer margin evenly rounded to slightly sinuate, about as long as inner; costa evenly rounded, relatively short, without fold in one species. Cell two-thirds as long as wing; vein 5 slightly nearer to 4 than to 6. Secondaries with anal angle produced into a long tail; outer margin slightly excavated opposite cell and before tail, sometimes slightly crenulate. Fig. 6.

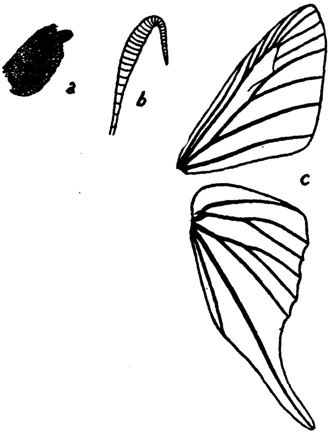


Fig. 6. *Goniurus*. a. Palpus of *simplicius* Stoll. b. Club of antennae of *simplicius* Stoll. c. Neuration of *proteus Linn*

The above description is taken from *simplicius* and *eurycles*. *Proteus* has a longer cell as shown in the figure and both *proteus* and *dorantes* have relatively shorter antennae. It may prove desirable to use *Eudamus* for these two species, but without knowing more of the related Central American fauna I cannot make a satisfactory decision on this point. Of the other three North American species which I here remove from *Goniurus* I feel that *albofasciatus* and *zilpa* warrant the establishment of a new genus, and that the relationship of *alceus* to *melon*, in spite of its tailed secondaries, is too close to be disregarded.

Key to the species

1. Upper surface with shining green hairs.................... *proteus*
   Without green hairs.. 2
2. Fringes checkered; spots not united to form a straight band.. *dorantes*
   Fringes not checkered; band usually present...................... 3
3. Band always present; no costal fold in male; outer margin of primaries slightly sinuate.................................... *eurycles*
   Band sometimes broken or even absent; male with fold; outer margin slightly convex.. *simplicius*

1. *GONIURUS PROTEUS*

Papilio proteus Linn., Syst. Nat. I, 484, 1758.
Scudder, Butt . New Eng., II, 1386, 1889.
Biol. Cent.-Am., Rhop. II, 277, pl. 75, f. 5, gen., 1893.

Holland, Butterfly Book 321, pl. XLV, f. 6, 1898.
Skinner, Trans. Am. Ent. Soc. XXXVII, 194, 1911.

Florida and Georgia, August to October. Arizona and Texas, June and July. Dr. Skinner gives the range as New York to the Gulf and southward through Mexico and Central America.

2. *GONIURUS DORANTES*

Papilio dorantes Stoll, Pap. Exot., Supp., 172, pl. XXXIX, f. 9, 1790.
Eudamus amisus Hew., Desc. Hesp. 5, 1867.
Eudamus protillus H.-S., Corr.-Blatt Regensb. XXIII, 171, 1869.
Biol. Cent.-Am., Rhop. II, 278, pl. 75, f. 7, ♂ gen., 1893.
Skinner, Trans. Am. Ent. Soc. XXXVII, 197, 1911.

Southern California, Mexico.

2a. *race RAUTERBERGI*

Eudamus protillus var. *rauterbergi* Skinner, Ent. News VI, 113, 1895.
Skinner, Trans. Am. Ent. Soc. XXXVII, 197, 1911.

Skinner says that this form is "smaller and very much darker than *protillus*; the fringes are far less marked, and the tails lack the admixture of light hairs."

Texas, Arizona and southward; July and September.

3. *GONIURUS SIMPLICIUS*

Papilio simplicius Stoll, Pap. Exot., Supp., 171, pl. XXXIX, f. 6, 1790.
Biol. Cent.-Am. Rhop. II, 270, pl. 75, f. 1, ♂ gen., 1893.
Skinner, Trans. Am. Ent. Soc. XXXVII, 196, 1911.

Some females can scarcely be told from *eurycles*, but usually the obsolescence of the hyaline marks of the primaries and the slightly different shape of the wings enable one to recognize the species. The males are readily identified by the costal fold.

Texas, March and October.

4. *GONIURUS EURYCLES*

Hesperia eurycles Latr., Enc. Meth. IX, 730, 1823.
Skinner, Ent. News XII, 171, 1901.
Skinner, Trans. Am. Ent. Soc. XXXVII, 197, pl. X, 1911.

I have *eurycles* from Guatemala, taken in April, and from Colombia taken in November, but aside from Dr. Skinner's note in the Entomological News I have seen no records of its occurrence north of Mexico.

Genus CHIOIDES gen. nov.

Palpi large, porrect; second joint deeply scaled, third strong, conspicuous. Antennae less than one-half as long as primaries, club relatively smaller and thicker than in *Goniurus*, and more broadly curved, with the apiculus less distinct. Primaries with the apex subtruncate, outer margin concave below apex. Cell about three-fourths as long as wing; recurrent vein nearer to vein 3 than to vein 4; bases of 3 and 4 much farther apart than M. D. C. and L. D. C. combined. Costal fold present in our species. Fig. 7.

Type: *Eudamus albofasciatus* Hewitson.

Catillus, a Central American species, and *albofasciatus* are very closely related, and agree in the form of the male genitalia. *Zilpa* differs somewhat in the form of the wings and the male genitalia, but on the whole it is apparently related to the other species, and with them distinct from *Goniurus*. The difference is scarcely greater than between *proteus* and *simplicius*.

1. *CHIOIDES ALBOFASCIATUS*

Eudamus albofasciatus Hew., Desc. Hesp. 3, 1867.
Biol. Cent.-Am., Rhop. II, 280, pl. 75, f. 11, ♂ gen., 1893.
Skinner, Trans. Am. Ent. Soc. XXXVII, 197, 1911.

Texas, March. Arizona, July and September. Distinguished from *zilpa* by the long narrow white band on the under surface of the secondaries.

2. *CHIOIDES ZILPA* (Plate I, Fig. 5)

Goniurus zilpa Butler, Lep. Exot. 109, t. XL, f. 2, 1872.
Biol. Cent.-Am., Rhop. II, 279, pl. 75, f 8, ♂ gen., 1893.

Patagonia Mts., Arizona, May. Kerrville, Tex., September.

Genus CODATRACTUS nom. nov.

Heteropia Mabille, Le Nat. 1889, 68. Type *Heteropia imitatrix* Mab. Preoccupied in sponges by *Heteropia* Carter, Ann. &Mag. Nat. Hist. (5), XVIII, 47, 1886.

Structure in general similar to *Chioides* but with veins 3 and 4 of the primaries not so far apart at their bases as the combined length of the two discocellulars and the recurrent vein nearer to 4 than to 3. The antennal club is fusiform, more or less sharply bent near the middle but with the distal portion not differentiated.

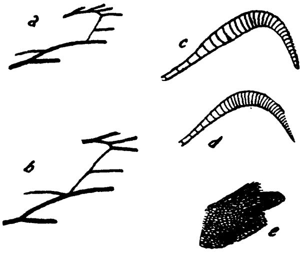


Fig. 7. *Chioides zilpa* Butler. a. Detail of neuration end of cell of primaries. c. Club of antenna. e. Palpus. *Codatractus alceus* Hew. b. Detail of neuration, end of cell of primary. d. Club of antenna.

Outer margin of primaries slightly sinuate; no costal fold in male of *melon;* I have not seen a male of *alcaeus.* Fig. 7.

To place such a strongly tailed species as *alcaeus* with a species in which the secondaries are merely angled is radical, but a study of related Central American species has led me to believe that in this case, at least, it is justified. *Alcaeus* agrees with *melon* very closely in structure, and the male genitalia of the two species are very similar.

1. *CODATRACTUS ALCAEUS*

Eudamus alcaeus Hew., Desc. Hesp. 3, 1867.
Skinner, Ent. News XII, 171, 1901.

My only specimen is a female from Mexico, and I have seen no others. The reference to the Entomological News is the only record of its occurrence in the United States with which I am familiar.

2. *CODATRACTUS MELON*

Heteropia melon Godman & Salvin, Biol. Cent.-Am., Rhop. II, 297, pl. LXXVI, g. 26, 27, 1893.

The typical form of *melon* is not known to occur north of Mexico.

2a. *race ARIZONENSIS*

Heteropia melon var. *arizonensis* Skinner, Ent. News XVI, 232, 1905.
Skinner, Trans. Am. Ent. Soc. XXXVII, 186, pl. X, 1911.

Baboquivari Mts., Ariz., July.

Differs from true *melon* in the whiter marginal area of the secondaries below.

Genus *TELEGONUS* Hübner

Telegonus Hübner, Verz. bek. Schmett. 104, 1820, Type *Papilio anaphus* Cramer.

Palpi oblique, third joint distinct. Antennae with a long slender tapering club, not sharply bent but curved at the middle. Primaries broad, outer margin equal to inner; costa slightly curved, without a fold in the male; outer margin very slightly sinuate. Secondaries produced and angled at 1b; outer margin straight from vein 7 to the anal angle. Cell of primaries about two-thirds as long as wing, discocellulars very oblique; vein 5 slightly nearer to vein 4 than to vein 6; recurrent vein near 4; vein 2 over one-half as far from base of wing as from 3.

1. *TELEGONUS HAHNELI*

Aethilla hahneli Staud., Exot. Tagf. I, 291, II, pl. 98, 1888.
Biol. Cent.-Am., Rhop. II, 306, pl. 77, ff. 13, 14, 1893.
Skinner, Ent. News XII, 171, 1901.

Staudinger's figure does not agree at all with that of Godman and Salvin, which represents the species recorded from North America. Since the latter authors state, however, that they had specimens from Dr. Staudinger himself, the best thing that we can do is retain the name in its present usage until the types can be examined.

Arizona (Skinner).

I have a specimen from Dr. Skinner labelled "Jamaica." Beyond his record in the Entomological News I have no knowledge of the occurrence of the species within our country.

Genus *PLESTIA* Mabille

Plestia Mab., Le Nat. (2), II, 146, 1888. Type *Plestia staudingeri Mab.*

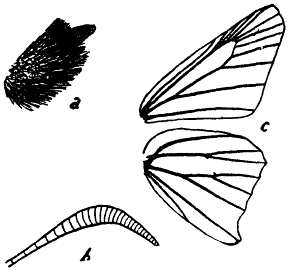


Fig. 8. *Plestia dorus* Edw. a. Club of antenna. c. Neuration of wings

Palpi porrect, exceeding front by length of head; second joint with shaggy vestiture of scales and hair, third conical, moderately large. Antennae with the club fusiform and pointed, almost as long as the shaft. Primaries trigonate, outer margin bent opposite cell; costal fold present in male. Cell over two-thirds as long as wing, recurrent vein absent. Vein 5 nearer 6 than 4. Secondaries trigonate, prominently lobed at anal angle. Legs and under surface of thorax very hairy. Fig. 8.

1. *PLESTIA DORUS*

Eudamus dorus Edwards, Papilio II, 140, 1882.
Biol. Cent.-Am., Rhop. II, 290, pl. 76, ff. 8, 9, 1893.
Holland, Butterfly Book, 322, pl. XLV, f. 11, 1898.
Skinner, Trans. Am. Ent. Soc. XXXVII, 187, 1911.

Arizona, May, June and July. New Mexico, May.

Genus *ACHALARUS* Scudder

Achalarus Scudder, Syst. Rev. 50 (71), 1872. Type *Papilio lycidas*, Abbot and Smith.

Murgaria Watson, Proc. Zool. Soc. London, 1893, 37. Type *Telegonus albociliatus* Mabille.

Palpi porrect; second joint closely and roughly scaled; third small, almost concealed in vestiture of second. Antennae about one-half as long as primaries; club slender, tapering gradually into the reflexed tip, which is not quite as long as the rest of the club. Primaries moderately broad; costa slightly rounded, with or without the fold in the male; outer margin slightly sinuate in the male, more evenly rounded in the female; cell slightly over two-thirds as long as wing; spur vein very faintly indicated, near vein 4; 5 slightly nearer to 4. Secondaries angled at 1b in the male, more rounded in the female. In *epigona* this character is very variable, some specimens having the angle acute and others obtuse. Vein 5 is not present, as stated by Watson (P. Z. S. 1893, 34) but is indicated by a slight fold.

Although it seems very radical to combine these genera, a careful consideration of their structures has failed to disclose any basis for their separation. *Epigona*, formerly placed in *Phoedinus*, is obviously congeneric with *albociliatus*, and hence under the old arrangement would fall into *Murgaria*, while both dffer from *lycidas* only in the absence of the costal fold in the males. Some specimens of the white fringed species have the anal angles of the secondaries much more acute than in *lycidas*, and therefore look much different, but as I have stated, this character is very variable. The male genitalia are similar and of a peculiar form.

Key to the species

1. Primaries with yellow spots.................................*lycidas*
   Primaries with or without white spots..........................2
2. Primaries with well defined whitish hyaline spots............*epigona*
   Primaries with an obscure dark band, rarely with a few white spots ....*albociliatus*

1. *ACHALARUS LYCIDAS*

Papilio lycidas Abbot and Smith, Lep. Ins. Ga. I, 39, pl. 20, 1797.
Proteides lyciades Geyer, Zutr. ex. Schmett. IV, 10, ff. 621, 622, 1832.
Skinner, Trans. Am. Ent. Soc. XXXVII, 188, 1911.

New York and Pennsylvania, August, and south to the gulf, where it is taken in May and June.

2. *ACHALARUS EPIGONA*

Myscelus epigona H.-S., Corr.-Blatt Regensb. xxiii, 167, 1869.
Eudamus epigena Butler, Trans. Ent. Soc. Lond., 1870, 493.
Eudamus orestes Edw., (Lintner Ms.), Cat. Diurn. Lep. N. A. 58, 1877.
Biol. Cent. Am., Rhop. ii, 332, pl. 80, ff. 9-11, 1893.

Arizona, June and August.

3. *ACHALARUS ALBOCILIATUS*

Telegonus albociliatus Mab., Pet. Nouv. Ent. ii, 162, 1877.
Eudamus coyote Skinner, Can. Ent. xxiv, 164, 1892.

Texas and Arizona. We have been confusing two species under this name, but at present I am unable to correct the error with certainty.

Genus CECROPTERUS Herrich-Schäffer

Cecrops Hbn., Zutr. Exot. Schmett. t. 32, ff. 183, 184, 1818. Type *Cecrops zarex* Hbn. Preoccupied in Crustacea.

Cecropterus H.-S., Corr.-Blatt Regensb. xxiii, 131, 1869. For *Cecrops* Hbn.

Rhabdoides Scud., Butt. New Eng. iii, p. 1854, 1889. Type *Eudamus cellus* Boisd. & Lec.

Fig. 9. *Cecropterus cellus* Bd. and Lec. a. Club of antenna. b. Detail of neuration; anal area of secondary

Palpi larger than in *Achalarus;* second joint oblique, roughly scaled; third porrect, moderate, not concealed by vestiture of second. Antennae about one-half as long as primaries; club slender, tapering, bent near middle, with the apiculus scarcely more slender than the basal portion. Primaries similar to *Achalarus* ♀ and *Thorybes*; cell slightly over two-thirds as long as wing; recurrent vein faint but indicated at base of vein 4; 5 slightly nearer to 4 than to 6; discocellulars less oblique than in *Achalarus,* more as in*Thorybes;* costal fold not present in male. Outer margin of secondaries rounded, apex broadly rounded; Vein 1a about two-thirds as long as 1b. Fig. 9.

Cellus resembles *Thorybes* very closely in most of its structures, but I hardly think that the species belongs there. I do not see anything to separate it from the genus *Cecropterus,* however, and so am placing it for the present with the other species whose banded primaries give them a close superficial resemblance. *Pseudocellus* appears to be closer to *Achalarus* but I have not had material for dissection and so prefer to leave it with *cellus.*

1. *CECROPTERUS CELLUS*

Eudamus cellus Bd. & Lec., Lep. Am. Sept. t. 73, 1833.
Cecrops festus Geyer, Zutr. exot. Schmett. v, 21, ff. 907, 908, 1837
Biol. Cent.-Am., Rhop. ii, 331, pl. 80, f. 8, ♂ gen., 1894.
Holland, Butterfly Book 326, pl. xlv, f. 12, 1898.
Skinner, Trans. Am. Ent. Soc. xxxvii, 189, 1911.

Pennsylvania, July. Virginia and West Virginia, May and June. Texas and Arizona, April and August.

2. *CECROPTERUS PSEUDOCELLUS*

Achalarus pseudocellus Coolidge and Clemence, Ent. News xxii, 3, 1911.
Skinner, Trans. Am. Ent. Soc. xxxvii, 190, 1911.

Arizona, June to September inclusive. This species is smaller and darker than *cellus*, lacks the terminal pale area on the under surface of the secondaries and has a pale ring at the base of the antennal club. I have examined a long series in the Barnes collection without finding any specimen in which the pale ring could not be seen.

Genus THORYBES Scudder

Thorybes Scud., Syst. Rev. 50 (71), 1872. Type *Papilio bathyllus* A. & S.

Lintneria Butler, Trans. Ent. Soc. London, 1877, 57. Type *Papilio daunus* Cramer.

Cocceius G. & S., Biol. Cent.-Am., Rhop. ii, 336, 1900. Type *Eudamus pylades* Scud.

Palpi with the second joint appressed, densely scaled; third small, porrect, partly concealed by scales of second. Club of antennae moderate, tapering into a slender apiculus which is slightly shorter than the rest of the club. In specimens the apiculus varies from sharply reflexed to slightly recurved. Primaries rather short and broad with the costa and outer margin convex; cell slightly over two-thirds as long as wing; recurrent vein barely indicated near vein 4; 5 equidistant between 4 and 6; 2 nearer base of wing than to 3. Secondaries broadly rounded, length along vein 6 about equal to or greater than along 1b;

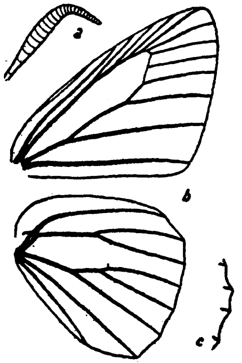


Fig. 10. a. Club of antenna of *Cogia hippalus* Edw. b. Neuration of *Thorybes pylades* Scud. c. Truncate lobe on outer margin of secondary of *Cabares potrillo* Lucas

anal angle sometimes very slightly prominent. Costal fold present in *pylades* and *drusius* but not in the other species. Fig. 10.

In establishing *Cocceius* Godman and Salvin state that it differs from *Thorybes* in the presence of the costal fold and that this indicates that its relationship is rather with *Achalarus*. It is related in many more points, however, to *Thorybes*, and the costal fold does not seem adequate to separate the two groups as genera. The male gentalia of the species are similar.

Key to the species

1. Fringes of secondaries white, at least in middle of outer margin. *drusius*
   Fringes not white 2
2. Under surface of secondaries transversely strigate 3
   Under surface not strigate 4
3. Hyaline spots moderate to small, without dark outlines; ground color dark .... *mexicanus*
   Hyaline spots large with dark outlines; ground color pale ....
   .... *mexicanus, race nevada*
4. Spots usually large, extending from vein to vein; palpi usually pale below .... *bathyllus*
   Spots usually small; palpi usually concolorous with body below. . *pylades*
   Spots absent .... *pylades, ab. immaculata*

1. *THORYBES DRUSIUS*

Eudamus drusius Edw., Can. Ent. xv, 211, 1883.
Biol. Cent.-Am., Rhop. ii, 336, 1894.
Skinner, Trans. Am. Ent. Soc. xxxvii, 185, pl. x, 1911.

Arizona, June, July and August. Western Nebraska, Leussler.

2. *THORYBES PYLADES*

Eudamus bathyllus Harris (not A. & S.), Ins. Inj. Veg. 3rd ed., 312, 1862.
Eudamus pylades Scud., Proc. Bost. Soc. Nat. Hist. xiii, 207, 1870.
Biol. Cent.-Am., Rhop. ii, 336, pl. 80, f. 23, 1894.
Holland, Butterfly Book 324, pl. xlviii, f. 6, 1898.
Skinner, Trans. Am. Ent. Soc. xxxvii, 176, 1911.

Occurs throughout the United States and most of Canada. In Florida and Texas it has been taken as early as April and as late as October; farther north it flies from May to August.

ab. *IMMACULATA*

Eudamus pylades immaculata Skinner, Trans. Am. Ent. Soc. xxxvii, 177, 1911.

This is a rather uncommon form in which the hyaline spots of the primaries are entirely absent.

3. *THORYBES DAUNUS*

Papilio daunus Cramer, Pap. Exot. II, 44, pl. CXXVI, F, 1777.
Papilio bathyllus Abbot & Smith, Lep. Ins. Ga. I, 43, pl. XXII, 1797.
Holland, Butterfly Book 325, pl. XLVIII, f. 5, 1898.
Skinner, Trans. Am. Ent. Soc. XXXVII, 178, 1911.

Some females of *pylades and bathyllus* are difficult to separate but as a rule the size of the spots and color of the palpi in this species are characteristic. The males of this and the following species are easily separated from the others by the absence of the costal fold.

Florida north and west to Pennsylvania, Iowa, Nebraska and Texas. I have seen southern specimens dated May and August, while farther north the species occurs from June to September.

4. *THORYBES MEXICANA*

Eudamus mexicana H.-S., Corr.-Blatt Regensb. XXIII, 198, 1869.
Eudamus ananius Plötz, Stett. ent. Zeit. XLIII, 99, 1882.
Biologia Cent.-Am., Rhop. II, 334, pl. 80, ff. 15, 16, 17, 1894.
Skinner, Trans. Am. Ent. Soc. XXXVII, 180, 1911.

Specimens in the Barnes collection which agree with those in the British museum are similar to *pylades* above but faintly strigate below, and rather darker than normal specimens of *pylades*.

Arizona, June and July. Colorado, July.

4a. *race NEVADA*

Thorybes nevada Scud., Syst. Rev. 50 (71), 1872.
Eudamus aemilea Skinner, Ent. News IV, 64, 1893.
Holland, Butterfly Book 325, pl. XLVI, f. 39, 1898 (type).
Wright, Butt. W. Coast 254, pl. XXXII, f. 478, 1905.
Skinner, Trans. Am. Ent. Soc. XXXVII, 182, 1911.

Ground color rather pale, with a fine terminal line and margins of spots darker. Spots large. Strigation of under surface usually heavy.

California and Oregon, June and July. 8000 ft.

Genus CABARES Godman & Salvin

Cabares G. & S., Biol. Cent.-Am., Rhop. II, 337, 1894. Type *Thanaos potrillo* Lucas.

"Antennae with a gradually tapering club, curved in the middle into a crook. Palpi porrect, the third joint rather prominent. Primaries with the cell more than two-thirds the length of the costa, the second, third, and fourth subcostal segments subequal; lower discocellular rather shorter than the middle, the two forming an oblique line at a large acute angle to the axis of the wing; third median segment less than half the second, and rather shorter than the first; a curved recurrent nervule starts from the end of the cell. Secondaries with the discocellulars very slender; third median segment very short; second subcostal segment also short. Primaries short, slightly truncate at the tip; no costal fold in the male; secondaries with a projection in the middle of the outer margin from the end of the median nervure. Hind tibiae with two pairs of spurs."

"Type *Thanaos potrillo* Lucas." (Original description).

This appears to be a good genus, and the one species which occurs in our fauna can easily be placed by the peculiar lobe on the outer margin of the secondaries. Fig. 10.

1. *CABARES POTRILLO*

Thanaos potrillo Lucas, Sagra's Hist. Cuba VII, 641, 1857.
Biol. Cent.-Am., Rhop. II, 337, pl. 80, ff. 24, 25, 26, 1894.

The species is occasionally taken in Texas.

Genus COGIA Butler

Cogia Butler, Trans. Ent. Soc. London 1870, 508. Type *Cogia hassan* Butler.

Palpi porrect; second joint heavily clothed with scales; third small but not concealed. Antennae about one-half as long as primaries; club moderately thick, tapering into the short, reflexed apiculus. This is about half as long as the rest of the club and is usually bent at about a right angle. Shape of wings similar to *Thorybes* but costa of primaries less strongly curved and secondaries a little more produced anally. Cell of primaries about two-thirds as long as wing; vein 5 intermediate between 4 and 6; recurrent vein faintly indicated, nearer to 4 than to 3. Primaries of male without costal fold but secondaries with a short tuft of scales lying in the fold along vein 1b near the base of the wing. Fig. 10.

Key to the species

1. Fringes fuscous..2
   Fringes white..*hippalus*
2. Subapical spots indistinct; those between veins 2 and 4 usually lacking; color dark..*calchas*
   Subapical spots clear; those between 2 and 4 usually present; color pale fuscous..*outis*

1. *COGIA CALCHAS*

Eudamus calchas H.-S., Corr.-Blatt Regensb XXIII, 188, 1869.
Spathilepia terranea Butler, Lep. Exot. 111, t. XL, f. 8, 1872.
Biol. Cent.-Am., Rhop. II, 340, pl. 81, f. 6, ♂ gen., 1894.

Texas, October. Most specimens can be distinguished from *outis* by the dark color and limited maculation.

2. *COGIA OUTIS*

Eudamus outis Skinner, Ent. News V, 332, 1894.
Skinner, Trans. Am. Ent. Soc. XXXVII, 184, pl. X, 1911.

Texas, August. Ground color pale fuscous, as in *hippalus*. The primaries usually have the two hyaline spots between veins 2 and 4 but I have seen specimens in which these were lacking or greatly reduced.

3. *COGIA HIPPALUS*

Eudamus hippalus Edw., Papilio II, 27, 1882.
Hesperia gila Plötz, Stett. ent. Zeit. XLVII, 91, 1886.
Biol. Cent.-Am., Rhop. II, 340, pl. 80, ff. 29-31, 1894.
Skinner, Trans. Am. Ent. Soc. XXXVII, 184, 1911.

Southern Arizona and New Mexico, June, July and August.

Genus PHOEDINUS Godman & Salvin

Phoedinus G. & S., Biol. Cent.-Am., Rhop. II, 335, 1894. Type *Eudamus caicus* H.-S.

I was inclined for a time to unite this genus with *Cogia*, disregarding the tufted secondaries, but the large palpi with their conspicuous third joint serve to distinguish it so easily that it seems better to retain it. The spur vein is very faintly indicated near vein 4. There are no secondary sexual structures in the male.

1. *PHOEDINUS MYSIE*

Thorybes mysie Dyar, Jn. N. Y. Ent. Soc. XII, 40, 1904.
Skinner, Trans. Am. Ent. Soc. XXXVII, 181, 1911.

This species is not represented in the Barnes or Strecker collections, and I have seen nothing which answers the description. Apparently it is a *Phoedinus* with fuscous fringes and more spots on the primaries than *caicus*. It was described from the Patagonia Mts., Arizona.

2. *PHOEDINUS CAICUS*

Eudamus caicus H.-S., Corr.-Blatt Regensb. XXIII, 188, 1869.
Eudamus schaefferi Plötz, Stett. ent. Zeit. XLIII, 99, 1882.
Eudamus moschus Edw., Papilio II, 141, 1882.
Biol. Cent.-Am., Rhop. II, 335, pl. 80, ff. 18-20, 1894.
Skinner, Trans. Am. Ent. Soc. XXXVII, 183, 1911.

The fringes of the secondaries of this species are pure white, save at the apex and anal angle.

Arizona, July and August.

GROUP B

The second group of the subfamily Hesperiinae is distinguished from group A by the short cell of the primaries, the form of the antennal club, and the palpi. The cell is never over two-thirds as long as the wing, and is usually a little less; the antennal club is ovate or fusiform, usually somewhat flattened and more or less curved, but never bent as in most of the genera of group A and never with a distinct apiculus; the palpi are porrect or oblique, either large or with hairy vestiture or both. The only similar palpi in group A are found in the genus Plestia.

The genera of this group appear to be very poorly defined, owing to the structural variation of the species. If we split to the extent reached by some lepidopterists we can make a genus for practically every species, so the opposite course seems advisable, and I have therefore lumped a number of familiar genera to group species which appear to be related. This has resulted, especially in *Pholisora,* in the association of species which can easily be separated by structural differences, but in all cases these characters show a transition through the several species which causes me to regard them as unreliable for the separation of genera.

Key to the genera

1. Secondaries irregular, excavated opposite end of cell and before anal angle; not trigonate. Vein 2 of primaries nearer base of cell than to vein 3....................*Systasea*
   Not such insects....................................2
2. Club of antennae long, slender, not distinctly flattened, and scarcely exceeding twice the diameter of the shaft.........3
   Club thicker in at least one direction..................4
3. Primaries slightly excavated below apex; humeral angle prominent, rounded............................*Eantis*
   Apex rectangular; humeral angle normal......*Xenophanes*
4. Palpi large; third joint conspicuous; vestiture not roughly hairy ....*Pholisora*
   Palpi moderate to large; third joint not conspicuous or vestiture hairy...5

5. Club of antennae elongate-ovate, flattened, blunt; species largely white or checkered......................*Hesperia*
   Club more or less fusiform and pointed.................6
6. Outer margin of primaries evenly rounded or nearly so...7
   Apex of primaries subtruncate or rectangular...........8
7. Vein 11 of primaries arising just beyond middle of cell and reaching costa before end of cell................*Chiomara*
   Vein 11 arising at or beyond outer third of cell and ending in costa beyond end of cell.......................*Thanaos*
8. Anal angle of primaries broadly rounded; outer and inner margins about equal..........................*Melanthes*
   Anal angle sharply rounded; outer margin distinctly shorter than inner...9
9. Cell narrow, about equal to distance between cell and costa ....*Grais*
   Cell normal, much wider than this distance.....*Timochares*

Genus HESPERIA Fabricius

Hesperia Fab., Ent. Syst. III, (I), 258, 1793. Type *Papilio malvae* Linn.

Pyrgus Hbn., Verz. bek. Schmett. 109, 1820. Type *Papilio syrichtus* Fab.

Heliopetes Billberg, Enum. Ins. 81, 1820. Type *Papilio arsalte* Linn.

Syrichtus Boisd., Icones 230, 1833. Type *Papilio proto* Esp.

Scelothrix Ramb. Cat. Lep. Andal. I, 63, 1858. Type *Papilio carthami* Hbn.

Leucoscirtes Scud., Syst. Rev. 52 (73), 1872. Type *Syrichtus ericetorum* Boisd.

Muschampia Tutt, Brit. Butterflies, I, 218, 1906. Type *Papilio proto* Esp.

Sloperia Tutt, Brit. Butterflies I, 218, 1906. Type *Hesperia poggei* Led.

Powellia Tutt, Brit. Butterflies I, 218, 1906. Type *Papilio sao* Berg.

Favria Tutt, Brit. Butterflies I, 218, 1906. Type, *Hesperia cribrellum* Eversman.

Bremeria Tutt, Brit. Butterflies I, 296, 1906. Type *Syrichtus bieti* Obth.

Palpi porrect; second joint with shaggy vestiture in some species, smooth in others, and of mixed scales and hair. Antennae slightly less than one-half as long as primaries; club elongate oval, flattened, blunt. Costa of primaries more or less flattened; outer margin rounded, sometimes evenly and sometimes more strongly toward the apex. Cell less than two-thirds as long as wing; vein 5 slightly nearer to 6 than to 4; position of 2 and 3 very variable. Secondaries broadly rounded with a slight indication of an anal lobe, to sub-trigonate with the outer margin slightly wavy. Secondary sexual characters of males the costal fold, tibial tuft, and abdominal lobes; one or more of these characters may be absent. Fig. 11.

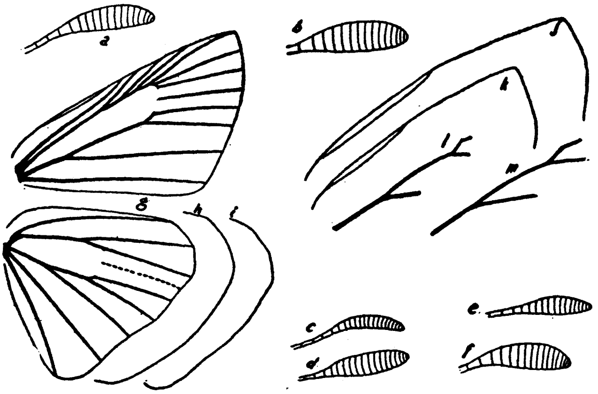


Fig. 11. *Hesperia.* Antennal clubs: a. *nivella,* b. *ericetorum,* c. and d. *tessellata,* two views, e. *syrichtus,* f. *macaira,* g. Neuration of *tessellata,* h. Outer margin of secondary of *syrichtus,* i. Outer margin of secondary of *nivella,* j. Costal margin and apex of primary of *nivella,* k. same of *syrichtus,* l. Detail of neuration, posterior margin of cell of *centaureae,* m. Same of *nivella*

The North American species have hitherto been placed in three genera, based chiefly on secondary sexual characters. Barnes and McDunnough made a step in advance by avoiding these characters in their Contributions III, pp. 121-2, where they remark: "A better means of separation of *Pyrgus* [including *syrichtus, montivaga* and *philetas*] from *Hesperia* (*Scelothrix*) than that given by Dyar, and one that would include both sexes appears to be found in the palpi; in *Pyrgus* they are only slightly upturned and the clothing under a strong lens is seen to be rather even and composed largely of scales with a few hairs of equal length intermingled; in *Hesperia* the palpi are strongly upturned and very heavily and roughly clothed underneath with long hairs, the scales being confined to the lateral basal portion."

It is quite true that this furnishes a good basis for the separation of our species, and the general habitus of each group is also distinctive, but I have unidentified species of the genus from South America which have the habitus of *Hesperia* (sensu B. & McD.) and the palpi of *Pyrgus*. It seems that the only conclusion which will give a well founded classification is to adopt the genus *Hesperia* of many European writers.

I cannot expect unanimous approval of the sinking of *Heliopetes*, but after examining all of the species carefully and comparing them with those of *Hesperia* I am unable to point out any structure which does not find either its counterpart or a similar tendency in the latter genus. The pattern of *Hesperia* is easily traceable in *ericetorum* and *domicella*, both above and below; in *nivella, laviana* and *macaira* the under surface is puzzling, but the brown pattern may easily be a modification of a superficial vestiture such as that found in *syrichtus*, while the black marks are so scanty as to afford no comparison.

Key to the species

1. Upper surface of primaries with a broad white discal band or mostly white 8
   Band narrow and macular or not evident 2
2. Spots of primaries subquadrate, well separated 3
   Spots crowded, slender; with an additional row of spots beyond cell .. 6
3. Primaries with a triangular white spot in the angle of vein 2 and the cell 4
   This spot absent .... *centaureae*
4. Male with fold; subterminal spots on under surface of secondaries deeply crescentic in most specimens, even when reduced in size .. *ruralis*
   Male without fold; subterminal spots never deeply crescentic, usually poorly defined 5
5. Under surface of secondaries without distinct contrasts, whitish; markings of upper surface usually reduced; a pale, glossy species .. *scriptura*
   Under surface with contrasting markings; upper surface with maculation rarely reduced; darker species .... *xanthus, macdunnoughi*
6. Under surface of secondaries with two small submarginal lunules between veins 4 and 6 7
   These vague, fused with a marginal white patch or with each other .... *tessellata*

7. Under surface of secondaries very pale, without sharp contrasts.*philetas*
Maculation of under surface contrasting; under surface often powdered with brown scales..................................*syrichtus*
8. Basal third of wings dark..9
This area not more than slightly dark shaded..................10
9. Secondaries with a subterminal esries of large white crescents
....*ericeteorum* ♀
These crescents much reduced...........................*domicella*
10. Cell of secondaries below clear white.......................*nivella*
Cell more or less brown...11
11. Secondaries with broad smooth brown shades below..............12
With a definite yellowish brown pattern, no broad shades..*ericetorum* ♂
12. Inside of outer shade oblique, almost straight...............*laviana*
Inside of outer shade curved with outer margin of wing......*macaira*

1. *HESPERIA CENTAUREAE* (Plate I, Figure 2)

Hesperia centaureae Rambur, Faun. Ent. Andal. II, 315, pl. 8, f. 10, 1840.
Hesperia wyandot Edw., Proc. Ent. Soc. Phil. II, 21, pl. 5, f. 4, 1863.
Scudder, Butt. New Eng. II, 1542, 1889.
Holland, Butterfly Book 327, pl. XLVII, f. 13, 1898.

N. Europe; Labrador, June and July. Ontario, Canada, May, July. New Jersey and Virginia, April and May. North Carolina, April. Colorado, August, 13000 ft. Male with costal fold and tibial tuft.

2. *HESPERIA RURALIS*

Syrichtus ruralis Boisd., Ann. Soc. Ent. France (2), X, 311, 1852.
Syrichtus caespitalis Boisd., op. cit., p. 312.
Hesperia ricara Edw., Proc. Ent. Soc. Phil. IV, 203, pl. I, f. 2, 1865.
Syrichtus petreius Edw., Trans. Am. Ent. Soc. III, 215, 1871.
Holland, Butterfly Book 328, pl. XLVII, f. 14, 1898.
Wright, Butterflies of the West Coast No. 458, pl. XXXI, 1905.
Oberthür, Etudesde Lep. Comp. VI, 339, pl. CXXXVII, ff. 1204, 1205, 1212, 1912 (types of *caespitalis* and *ruralis*).

Western North America from Texas to Alberta, April to July.

A smaller, darker species than the preceding. Male with fold and tuft.

3. *HESPERIA XANTHUS*

Pyrgus xanthus Edw., Field and Forest III, 142, 1878.
Holland, Butterfly Book 328, pl. XLVII, 15, 1898.

Colorado, July. *Xanthus* very closely resembles *ruralis* but most specimens have the subterminal maculation of the secondaries poorly defined and reduced as noted in the key, and the males lack the costal fold.

4. *HESPERIA MACDUNNOUGHI*

Syrichtus macdunnoughi Oberthür, Etudes IX, (2), 86, pl. CCLXIV, f. 2205, 1913.
B. & McD., Contributions III, (2), 122, pl. X, f. 14, 1916.

There are five specimens from Arizona in the Barnes collection under this name. Four I am unable to distinguish from *xanthus*; the remaining one has the secondaries pale below, as in *scriptura.*

5. *HESPERIA SCRIPTURA*

Syrichtus scriptura Boisd. Ann. Soc. Ent. France, (2), x, 312, 1852.
Holland, Butterfly Book 328, pl. XLVII, f. 12, 1898.
Wright, Butt. W. Coast 251, pl. XXXI, 459, 1905.
Oberthür, Etudes de Lep. Comp. VI, 339, pl. CXXXVII, p. 1206, 1207, 1912 (type f. 1206).

New Mexico, California, Colorado, April to June. This species is readily distinguished by the color of the under surface, its glossy appearance, and as a rule by the reduction of the maculation of the secondaries. As in the two preceding, the male has the tibial tuft but no costal fold.

6. *HESPERIA SYRICHTUS*

Papilio syrichtus Fab., Syst. Ent. 534, 1775.
Pyrgus montivagus Reakirt, Proc. Acad. Nat. Sci. Phil. 1866, 334.
Skinner, Ent. News XVII, 277, pl. XII, 1906.

Texas and Florida, June and July.

I have seen the type of *montivagus* in the Strecker collection and it is *syrichtus*, not *tessellata* as treated by many writers. I have a long series from Florida in which the under surface of the secondaries has a heavy superficial vestiture of brown scales in both sexes. Male with both costal fold and tibial tuft.

7. *HESPERIA PHILETAS* (Plate I, Fig. 7)

Pyrgus philetas Edw., Papilio I, 46, 1881.

Arizona and Texas, June to October.

8. *HESPERIA TESSELLATA*

Hesperia tessellata Scud., Syst. Rev. 52, (73), 1872.
Syricthus communis Grote, Can. Ent. IV, 69, 1872.
H. montivaga Scud., (not Reakirt) Butt. New Eng. II, 1536, 1889.
Holland, Butterfly Book 327, pl. XLVII, f. 18, 1898.
Wright, Butt. W. Coast 250, pl. XXXI, 457, 1905.

Occurs from coast to coast and from the Gulf to northern Canada, April to October.

8a. *Race OCCIDENTALIS*

Pyrgus occidentalis Skinner, Ent. News XVII, 96, 1906.
Skinner, Ent. News XVII, 277, pl. XII, 1906.

California, Arizona and Texas. This form is scarcely worthy of a name. but may be regarded as a pale southwestern geographical race. I have not looked for differences in the genitalia.

9. *HESPERIA DOMICELLA*

Syrichtus domicella Erichson, Schomb., Reise. n. Guiana III, 604, 1848.
Pyrgus nearchus Edw., Papilio II, 26, 1882.
Holland, Butterfly Book 327, pl. XLVII, f. 19, 1898.

Arizona, August and September.

This and the four following species, formerly placed in *Heliopetes*, have both the costal fold and tibial tuft in the males.

10. *HESPERIA ERICETORUM* (Plate I, Fig. 4♂, 6♀)

Syrichtus ericetorum Boisd., Ann. Soc. Ent. France (2) x, 313, 1852.
Syrichtus alba Edw., Proc. Ent. Soc. Phil. VI, 206, 1866.
Wright, Butt. W. Coast 250 pl. XXXI, f. 456, 1905.
Oberthür, Etudes de Lep. Comp. VI, 339, pl. CXXXVII, f. 1210, 1912 (type).

California, April to August. Arizona, July.

11. *HESPERIA MACAIRA*

Pyrgus macaira Reakirt, Proc. Acad. Nat. Sci. Phil. 1866, 334.
Syrichtus oceanus Edw., Trans. Am. Ent. Soc. III, 213, 1871.
Leucochitonea locutia Hew., Exot. Butt., Leuch. t. 2, ff. 19, 20, 1875.

Brownsville, Texas; June.

12. *HESPERIA LAVIANA*

Leucochitonea laviana Hew., Desc. Hesp. 48, 1868.
Leucochitonea pastor Felder, Verh. z.-b. Ges. Wien XIX, 476, 1869.
Pyrgus leca Butler, Trans. Ent. Soc. London 1870, 510.

Texas, June and July.

13. *HESPERIA NIVELLA*

Leucoscirtes nivea Scud. (not *niveus* Cr.), Syst. Rev. 52 (73), 1872.
Leucoscirtes nivella Mab., Bull. Soc. Ent. Belg. XXVII, LV, 1883.
Leucochitonea orbigera Mab., Le Nat. x, 242, 1888.
Biol. Cent.-Am., Rhop. II, 446, pl. 90, ff. 22-24, 1897.

Brownsville, Texas; June.

Genus SYSTASEA Butler

Systasea Butler, Edw., Can. Ent. IX, 120, 1877. Type, *Leucochitonea pulverulenta* Folder.

Celotes G. & S., Biol. Cent.-Am., Rhop. II, 452, 1899. Type *Pholisora nessus* Edw.

Palpi porrect, moderate; second joint slightly hairy; third slightly drooping in dried specimens. Antennae about one-half as long as primaries; club moderate, curved, fusiform, rather blunt. Primaries with a costal fold in the male; costa slightly curved; outer margin curved, with a shallow excavation before anal angle; inner margin slightly concave, scarcely longer than outer; U. D. C. short, M. D. C. and L. D. C. about equal. Vein 2 twice as far from 3 as from base of cell. Secondaries very irregular with emarginations opposite cell and before anal angle. As a rule the antennal club of *nessus* is slightly larger in proportion to the shaft than that of *pulverulenta* but it varies in each species. In spite of the difference in appearance of the two species I can find nothing to warrant placing them in different genera. It may be that tropical species exist which will fill in the gap between them. Fig. 12.

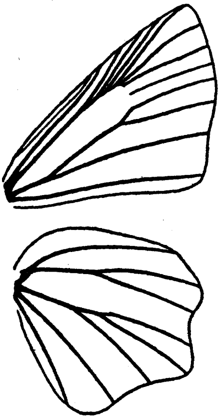


Fig. 12. Neuration of *Systasea pulverulenta* Feld

Key to the species

Terminal portion of wings with brown dashes..*nessus*
This area without dashes.............*pulverulenta*

1. *SYSTASEA NESSUS*

Pholisora nessus Edw., Can. Ent. IX, 192, 1877.
Spilothyrus notabilis Strecker, Lep. Rhop. 131, 1878.
Biol. Cent.-Am., Rhop. II, 452, pl. 91, ff. 27, 28, 29, 1899.
Holland, Butterfly Book 329, pl. XLVII, f. 17, 1898.
Texas and Arizona, April to August.

2. *SYSTASEA PULVERULENTA*

Leucochitonea pulverulenta Feld., Verh. z.-b. Ges. Wien XIX, 478, 1869.
Hesperia zampa Edw., Trans. Am. Ent. Soc. V, 207, 1876.
Biol. Cent.-Am., Rhop. II, 413, pl. 87, ff. 24, 25, 1895.
Holland, Butterfly Book 329, pl. XLVI, f. 1, 1898.
Arizona, July and August. Texas, April and October.

Genus PHOLISORA Scudder

Pholisora Scud., Syst. Rev. 51, (72), 1872. Type *Papilio catullus* Fab.
Staphylus G. & S., Biol. Cent.-Am., Rhop, II, 429, 1896. Type *Helias ascalaphus* Staud.
Bolla Mabille, Gen. Ins. XVII, 72, 1903. Type — *pullata* Mab.
Hesperopsis Dyar, Jn. N. Y. Ent. Soc. XIII, 118, 1905. Type *Thanaos alpheus* Edw.

The species grouped in this genus offer a troublesome problem in generic distinctions. *Bolla* was separated from *Pholisora* by Mabille on the basis of the more pointed club of the antennae. Dyar associates *Hesperopsis* in his description with *Hesperia* instead of *Pholisora* and calls attention to the long palpi, especially the long third joint, and the absence of the costal fold. I have bleached and mounted structures of *alpheus, libya, catullus, ceos* and *hayhurstii* and have found the following things to be true: In *alpheus* the third joint of the palpi is about three-fifths as long as the second and both are slender; the vestiture of the third joint makes it appear about twice as long as it really is. *Libya*, associated with *alpheus*, has the third joint relatively shorter, both second and third thicker, the vestiture of the third similar and that of the second deeper. The entire appendage looks more like the palpus of *catullus* than *alpheus*. The eleventh vein of the primaries of *alpheus* arises well before the middle of the cell, while in all of the other species it arises near the middle, usually slightly beyond. *Ceos* differs from *catullus* in the relatively longer third palpal point and thicker second, and in the short vestiture of the third. In the shape of the wings it is intermediate between *catullus* and *hayhurstii* and farthest removed from *alpheus*. The antennal club is thickest in *alpheus* and most slender in *ceos*, but if the same aspect be compared the species are seen to differ but slightly. From this it

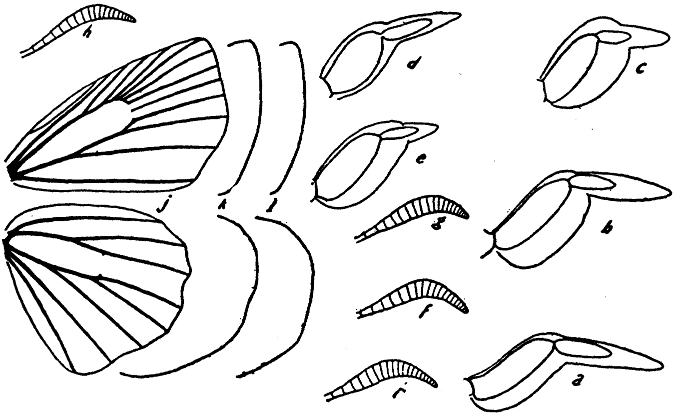


Fig. 13. *Pholisora*. Palpi: a. *alpheus*, b. *libya*, c. *catullus*, d. *ceos*, e. *hayhurstii*. Antennal clubs: f. *libya*, g. *catullus*, h. *ceos*, i. *hayhurstii*, j. Neuration of *hayhurstii*, k. and l. Outer margins of wings of *ceos* and *catullus*

appears that there is no closer bond between *alpheus* and *libya* than between *libya* and *catullus*, while *ceos* varies in the opposite direction from *catullus* but in the structure of the palpi shows some affinity with the first two species. For these reasons I prefer to regard the group as one genus with a wide range of structural variation. In this sense *Pholisora* may be characterized as follows:

Palpi exceeding the front by the length of the head or more; second joint oblique, rather long, with moderate scaly vestiture; third porrect, slender, long. Antennae about one-half as long as primaries; club more or less tapered and blunt. Wings rounded; secondaries with or without a slight indention in the outer margin at the end of the cell and sometimes with a slight lobe at the anal angle. Neuration variable; vein 11 of primaries never much beyond middle of cell and vein 2 about the same distance from base of cell and vein 3; U. D. C. long, over half the length of M. D. C. Male with or without costal fold, never with tibial tuft. Fig. 13.

Key to the species

1. Primaries with a transverse series of dark dashes............*alpheus*
   Primaries without dark dashes....................................2
2. Secondaries with white spots below...............................3
   Secondaries immaculate...4
3. Under surface pale, yellowish; upper surface of primaries with transverse row of spots complete.................................*lena*
   Under surface usually less pale and with numerous white spots when upper surface is heavily spotted; possibly not distinct from the preceding ....*libya*
4. Head and palpi ochreous..*ceos*
   Head and palpi dark, concolorous with body.......................5
5. Upper surface of an even shade...................................6
   With faint, dark, transverse bands...............................7
6. Undersurface brownish black................................*catullus*
   Under surface grayish glaucous.............................*mejicanus*
7. Primaries with hyaline subapical spots....................*hayhurstii*
   No such spots...*brennus*

1. *PHOLISORA ALPHEUS*

Thanaos alpheus Edw., Trans. Am. Ent. Soc. v, 206, 1876.
Pholisora oricus Edw., Can. Ent. xi, 51, 1879.
Biol. Cent.-Am., Rhop. ii, 442, pl. 90, f. 15, 1897.
Holland, Butterfly Book 331, pl. xlv, f. 2, 1898.

Wright, Butt. W. Coast 235, pl. xxx, f. 407, 1905.

Arizona, New Mexico, and Colorado, March to July.

2. *PHOLISORA LIBYA*

Heteropterus libya Scud., Bull. Geol. Surv. Terr., IV, 258, 1878.
Holland, Butterfly Book 331, pl. XLVIII, f. 14, 1898.
Wright, Butt. W. Coast 234, pl. xxx, f. 406, 1905.

California, June and October. Utah, July. Arizona, April.

3. *PHOLISORA LENA*

Ancyloxypha lena Edw., Can. Ent. XIV, 5, 1882.

There is one specimen in the Barnes collection which appears to be *lena* and is possibly a good species. It is rather pale in color, but this may be due to fading. On the upper surface it resembles a heavily maculate specimen of *libya* while below it has only a few spots. *Libya*, when heavily spotted above, is also well marked below. The one specimen is from Miles City, Montana, the type locality.

4. *PHOLISORA CATULLUS*

Hesperia catullus Fab., Ent. Syst. III, (I), 348, 1793.
Scud., Butt. New Eng. II, 1519, 1889.
Holland, Butterfly Book, 330, pl. XLV, f. 4, 1898.
Wright, Butt. W. Coast 234, pl. xxx, f. 403, 1905.

United States and Southern Canada, April to October.

5. *PHOLISORA MEJICANUS*

Nisoniades mejicanus Reakirt, Proc. Acad. Nat. Sci. Phil. 334, 1866.
Biol. Cent.-Am., Rhop. II, 441, pl. 90, ff. 11, 12, 1897.

Las Vegas, N. M.

The upper surface is practically the same as *catullus* but the glaucous gray appearance of the lower surface is unmistakable.

6. *PHOLISORA CEOS*

Pholisora ceos Edwards, Papilio II, 140, 1882.
Biol. Cent.-Am., Rhop. II, 432, pl. 89, ff. 7, 8, 1896.

Arizona, July.

7. *PHOLISORA HAYHURSTII*

Hesperia hayhurstii Edw., Trans. Am. Ent. Soc. III, 22, 1870.
Scudder, Butt. New Eng. III, p. 1857, 1889.
Biol. Cent.-Am., Rhop. II, 433, pl. 89, f. 16, gen., 1896.
Holland, Butterfly Book, 331, pl. XLVIII, f. 16, 1898.

Florida, north and west to Minnesota and Texas, March to October. Some specimens have merely a trace of the subapical spots.

8. *PHOLISORA BRENNUS*

Nisoniades brennus G. & S., Biol. Cent.-Am., Rhop. II, 434, pl. 89, f. 23, gen., 1896. (Mabille in litt.).

Skinner, Ent. News XII, 171, 1901.

I do not know this species. It is said to occur in our country along the Mexican border.

Genus EANTIS Boisduval

Eantis Boisd., Spec. Gen. pl. 13, f. 6, 1836. Type *Urbanus vetus thraso* Hübner.

Palpi porrect; second joint rather large, densely and smoothly scaled; third small, distinct. Antennae about one-half as long as primaries; club extremely slender and long, the tip curved. Costa of primaries rounded in basal half and almost straight to apex; outer margin excavated below apex, thence well rounded to anal angle; cell about three-fifths as long as wing; vein 5 intermediate between 4 and 6. Secondaries roughly quadrate; costa and inner margin curved, outer bent to an obtuse angle between 3 and 4 and produced between 6 and 7. Fig. 14.

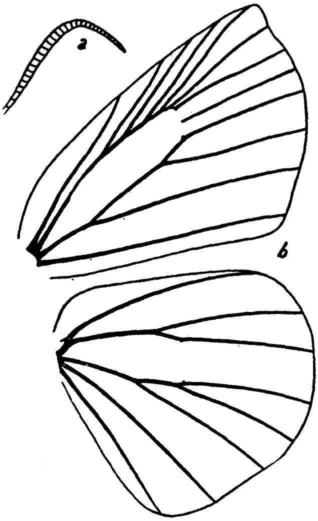


Fig. 14. *Eantis thraso* Hbn. a. Club of antennae. b. Neuration

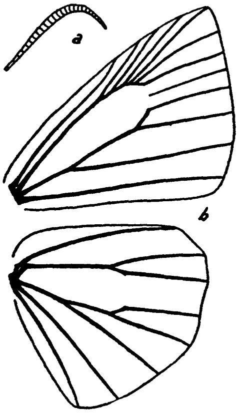


Fig. 15. *Xenophanes tryxus* Cramer. a. Club of antenna. b. Outline of wings

1. *EANTIS THRASO* (Plate I, Fig. 8)

Urbanus vetus thraso Hbn., Samml. exot. *Schmett*, I, t. 151 ff. 1-4, 1807-16.

Hesperia tamenund Edw., Trans. Am. Ent. Soc. III, 215, 1871.

Biologia Cent.-Am., Rhop. II, 405, pl. 87, f. 7, ♂ gen., 1895.

Texas, May and July.

Genus *XENOPHANES Godman* & Salvin

Xenophanes G. & S., Biol. Cent.-Am., Rhop. II, 387, 1895. Type *Papilio tryxus* Cramer.

Palpi oblique; third joint moderate,

conical, not concealed. Club of antennae very slender, curved. Costa of primaries slightly curved; apex rectangular; inner margin nearly straight, outer slightly convex between apex and vein 2, thence nearly straight to anal angle. Costal fold absent. Cell less than two-thirds as long as wing; vein 5 intermediate; 2 slightly nearer to base of wing than to 3. Secondaries broadly rounded; inner margin nearly straight, anal angle sub-rectangular; outer margin slightly concave between veins 4 and 6 and very slightly between 1b and 2. Vein 5 present, very weak; 2 about as near to base of wing as to 3. Fig. 15

1. *XENOPHANES TRYXUS* (Plate I, Fig. 3)

Papilio tryxus Cramer, Pap. Exot. iv, 87, pl. ccxxxiv, G, H, 1781.
Biol. Cent.-Am., Rhop. ii, 387, pl. 85, f. 18, ♂ gen., 1895.

Brownsville, Texas, July.

The species is easy to recognize in our fauna by the many hyaline spots in the discal area of both wings.

Geneus MELANTHES Mabille

Melanthes Mab., Gen. Ins. xvii, 80, 1904. Type *Nisoniades brunnea* H.-S.

In general structure this genus is close to *Thanaos* but the secondaries are relatively a little larger the outer margin of the primaries longer and more oblique, the apex more produced and rectangular and the anal angle more broadly rounded. The antennae are moderate and the club fusiform, sharply pointed and evenly curved. Fig. 16.

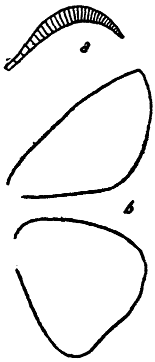


Fig. 16. *Melanthes brunnea* H.-S. a. Club of antenna. b. Outline of wings

1. *MELANTHES BRUNNEA* (Plate I, Fig. 10)

Nisoniades brunnea H.-S., Corr.-Blatt. Regensb. xviii, 172, 1864.

Skinner, Ent. News xiv, 110, 1903.

I have this species from Cuba but Dr. Skinner's record, Sugar Loaf Key, Fla., is the only one which has reached me concerning its occurrence in the United States. The even brown shade of the wings, with a few hyaline points on the primaries, is characteristic.

Genus CHIOMARA Godman & Salvin

Chiomara G. & S., Biol. Cent.-Am., Rhop. ii, 453, 1899. Type. *Achlyodes mithrax* Möschler.

Similar to *Thanaos*; outer margin of primaries only two-thirds as long as inner, strongly curved; vein 11 arising just beyond middle of cell and reaching costa before end of cell. Male with tibial tuft but no costal fold. Fig. 17.

Gesta appears to belong in *Thanaos*; the figure of the genitalia in the Biologia is distinctly of the *Thanaos* type.

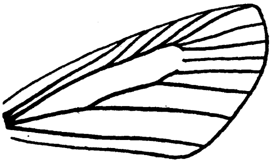


Fig. 17. *Chiomara asychis* Cramer. Neuration of primary

1. *CHIOMARA ASYCHIS*

Papilio asychis Cramer, Pap. Exot. IV, 87, pl. CCCXXXIV, E, F, 1781.

Pyrgus georgina Reakirt, Proc. Acad. Nat. Sci. Phil. 1868, 88 (fide G. & S.).

Biol. Cent.-Am., Rhop. II, 453, pl. 91, ff. 1, 2, 3, 1899; p. 741, 1901.

Texas, Arizona, October. I have one specimen from Corumba, Brazil, taken in March.

Genus THANAOS Boisduval

Thanaos Boisd., Icones 240, 1832-3. Type *Hesperia juvenalis* Fab.

Scudder and Burgess, Proc. Bost. Soc. Nat. Hist. XIII, 282-306, pl. 1870.

Skinner, Trans. Am. Ent. Soc. XL, 195-221, 1914.

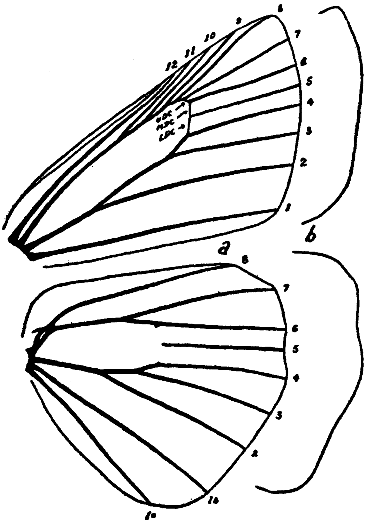


Fig. 18. *Thanaos*. a. Neuration of *juvenalis*, b. Outer margins of wings of *funeralis*

Palpi large, exceeding front by about length of head; vestiture shaggy; third joint stout and roughly scaled. Antennae moderate; club fusiform, curved. Costa of primaries slightly convex, flattened along fold; outer margin in most species evenly rounded, in some more strongly curved opposite cell; relative width of primaries variable. Cell scarcely two-thirds as long as wing; vein 5 intermediate, 7 to 11 in the distal third of the cell, 11 ending beyond end of cell U. D. C. less than half as long as M. D. C. Secondaries variable in size and shape, broad outer margin rounded to wavy; costal fold present except in *gesta.* Hind tibiae of male with tufts in a few species. Fig. 18.

A key to the species of *Thanaos* based on superficial characters is of comparatively little use, for the species are closely related and there are few which do not intergrade with others. The following key is based on fairly typical specimens, but in a long series I have found many which could not be definitely placed by it, so I have thought it wise to speak a word of caution regarding its use. The genitalia of the males offer the ultimate means of determination, and since they can usually be examined fairly well by brushing away the scales from the tip of the abdomen and using a hand lens or binocular, their use in classification of the species should be practiced.

Key to the species

1\. Fringes of hind wings white.......................13
Fringes never white.......................2

2\. Primaries without distinct hyaline spots, sometimes with one or two clouded spots next to costa.......................3
Primaries with at least a subapical row of hyaline spots (or with very dark wings, *terentius* ♂).......................5

3\. Expanse under thirty mm; ♂ with tibial tuft; apex of primaries rather sharply angled.......................*icelus*
Expanse usually over thirty mm; no tuft in male; apex of primaries more obtuse and outer margin more rounded.......................4

4\. Gray powdering heavier toward apex of primaries; distribution general.......................*brizo*
Primaries usually evenly powdered with gray scales; inner part of median band usually obsolete or broken; Southwestern and Californian species.......................*burgessi, lacustra*
Powdering scant or absent; dark marks of primaries united to form broad bands; under surface without distinct spots; ♂ with tuft but no fold; southwestern species.......................*gesta*

5\. Under surface of secondaries with two pale subapical spots, or at least a trace of them.......................6
No subapical spots.......................7

6\. Gray vestiture mostly of fine hairs.......................*propertius*
Gray vestiture scaly.......................*juvenalis*

7\. Hyaline spots large, at least a trace of one in end of cell; dark markings of primaries contrasting (♀), or spots lacking; primaries with little or no gray vestiture (♂).......................*horatius*
Spots small, color very dark, or gray powdering conspicuous.......................8

8\. Very dark, sometimes with a brownish patch at end of cell; maculation obscure; ♂ with tibial tuft.......................*terentius*
Tuft absent; marks more or less contrasting.......................9

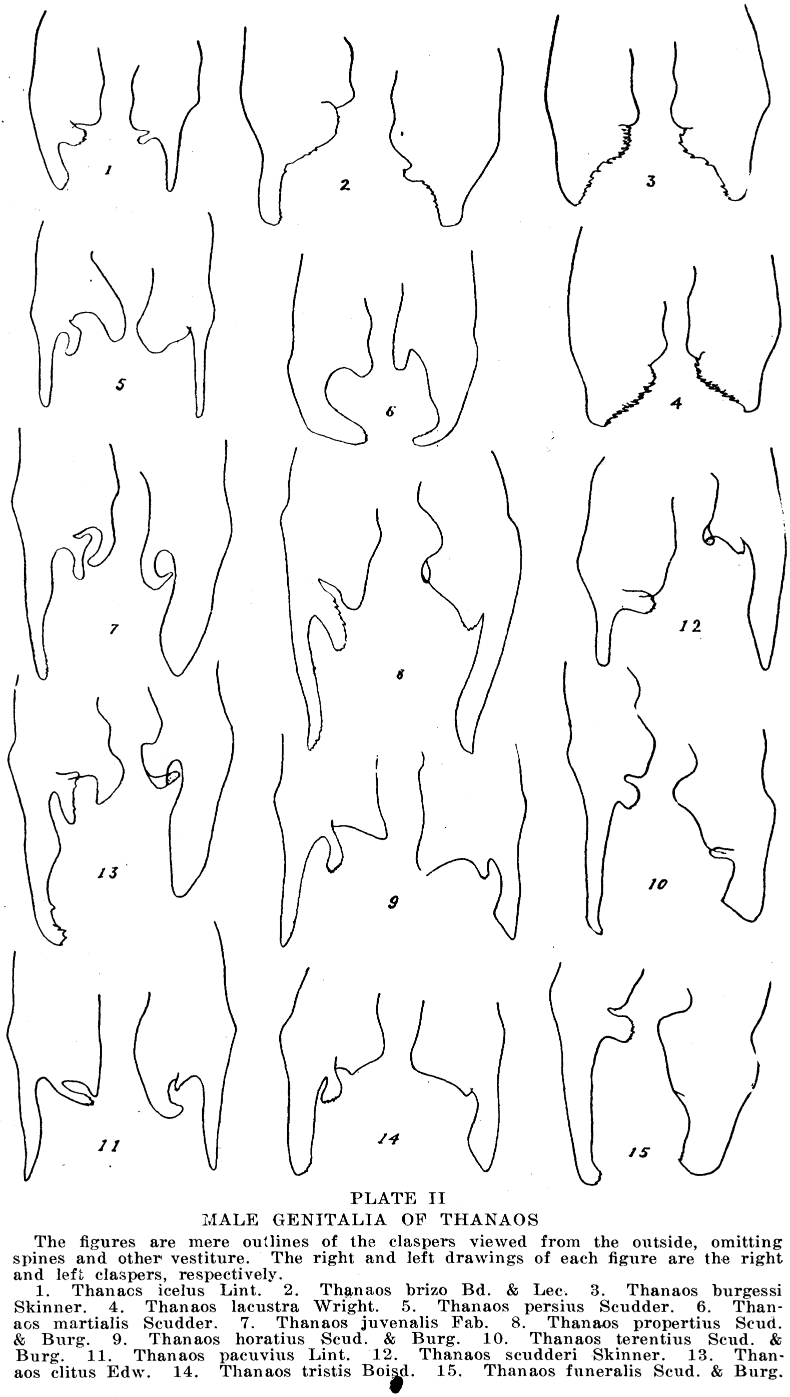


PLATE II
MALE GENITALIA OF THANAOS

The figures are mere outlines of the claspers viewed from the outside, omitting spines and other vestiture. The right and left drawings of each figure are the right and left claspers, respectively.

1. Thanacs icelus Lint. 2. Thanaos brizo Bd. & Lec. 3. Thanaos burgessi Skinner. 4. Thanaos lacustra Wright. 5. Thanaos persius Scudder. 6. Thanaos martialis Scudder. 7. Thanaos juvenalis Fab. 8. Thanaos propertius Scud. & Burg. 9. Thanaos horatius Scud. & Burg. 10. Thanaos terentius Scud. & Burg. 11. Thanaos pacuvius Lint. 12. Thanaos scudderi Skinner. 13. Thanaos clitus Edw. 14. Thanaos tristis Boisd. 15. Thanaos funeralis Scud. & Burg.

9. Dark marks conspicuous, secondaries checkered; fresh specimens with a purplish lustre...*martialis*
Not such insects...10
10. Larger, marks more or less obscured toward base of primaries.... ....*persius, pernigra*
Usually smaller, marks more evenly distinct over entire wing.......11
11. Fringes usually evenly colored.......................................12
Fringes pale tipped; western form............*persius*, race *afranius*
12. Secondaries with pale spots below clear cut..................*lucilius*
Spots absent or diffuse; western species...................*callidus*
13. Tufts of dark scales in base of white fringe all along outer margin ....*scudderi, pacuvius*
Rarely with a suggestion of such tufts...........................14
14. Primaries narrower than normal; ♂ with tibial tuft..........*funeralis*
Primaries normal, no tuft...............................*tristis, clitus*
Under surface of secondaries with some white inside of fringe.... ....*tristis*, var. *tatius*

1. *THANAOS ICELUS*

Nisoniades icelus Scudder & Burgess, Proc. Bost. Soc. Nat. Hist. XIII, 288, 1870.

Lintner, 23rd Ann. Rep. N. Y. St. Cab. Hist. 162, pl. 7, ff. 5, 6, 1872.

Scudder, Butt. New Eng. II, 1507, 1889.

Holland, Butterfly Book 333, pl. XLVIII, 17, 1898.

Arizona, Colorado, Massachusetts, Pennsylvania and southern Canada; May to July. Athabaska and Mackenzie, June (Cary). North Carolina, April (Brimley & Sherman).

2. *THANAOS BRIZO*

Thanaos brizo, Boisd. & Lec., Lep. Am. Sept. pl. 66, 1833.

Scudder, Butt. New Eng., II, 1500, 1889.

Holland, Butterfly Book 332, pl. XLV, f. 7, 1898.

Atlantic coast to Rocky Mountains, Gulf to Southern Canada; April to July. Eastern specimens of this species are easy to identify, but it is difficult to separate *burgessi, lacustra* and *brizo* when all are from the same locality.

2a. race *SOMNUS*

Nisoniades somnus Lintner, Papilio I, 73, 1881.

Florida, February and April. This is merely a very dark form of *brizo.*

3. *THANAOS BURGESSI*

Thanaos burgessi Skinner, Trans. Am. Ent. Soc. XL, 203, 1914.

Arizona and New Mexico; March, April and August.

4. *THANAOS LACUSTRA*

Nisoniades lacustra Wright, Butt. W. Coast 253, pl. XXXII, 480, 1905.

California, June. This is not a form of *brizo*, as has been stated, but is more nearly related to *burgessi*, though the genitalia differ enough to warrant regarding it as a distinct species.

5. *THANAOS GESTA*

Thanaos gesta H.-S., Corr.-Blatt Regensb. XVII, 142, 1863.
Thanaos invisus Butler & Druce, Cist. Ent. I, 114, 1872.
Biol. Cent.-Am., Rhop. II, 455, pl. XCI, ff. 7, 8, 9, 1899.
Nisoniades llano Dodge, Can. Ent. XXXV, 78, 1903.

Texas and Arizona; July.

6. *THANAOS PERSIUS*

Nisoniades persius Scudder, Proc. Ess. Inst. III, 170, 1863.
Scudder, Butt. New Eng. II, 1468, 1889.
Holland, Butterfly Book 334, pl. XLVIII, f. 1, 1898.

The typical form has an expanse of about thirty-five millimeters and is dark and obscurely marked, especially on the basal half of the wings. It occurs throughout the United States and north into Alaska; May to August.

6a. race *PERNIGRA*

Thanaos pernigra Grinnell, Ent. News XVI, 34, 1905.

California, July. A very dark Pacific Coast race.

6b. race *AFRANIUS*

Nisoniades afranius Lintner, 30th Rep. N. Y. Mus. Nat. Hist. 175, 1877.

California, Utah, Colorado, Arizona; May, July and August. *Afranius* does not exceed thirty millimeters and is rather distinctly marked and gray powdered; the fringes are pale, sometimes almost white, at their tips.

6c. race *LUCILIUS*

Nisoniades lucilius Scudder & Burgess, Proc. Bost. Soc. Nat. Hist. XIII, 287, 1870.
Lint., 23rd Rep. N. Y. St. Cab. Nat. Hist. 164, pl. 7, ff. 1, 2, 1872.
Scudder, Butt. New Eng. II, 1458, 1889.
Holland, Butterfly Book 333, pl. XLVIII, f. 10, 1898.

Northeastern United States and southeastern Canada, April and May. Dr. W. T. M. Forbes has kindly identified slides of genitalia in my possession as *lucilius*, which he regards as a species. I am unable to agree with this and follow Skinner in placing it as a race of *persius*, though a careful study of the early stages may show it to be distinct. It is usually smaller than *persius* and more distinctly marked.

7. *THANAOS CALLIDUS*

Thanaos callidus Grinnell, Ent. News XV, 114, 1904.
McDunnough, Ent. News XXVIII, 232, 1917.

After an eventful and troublesome career *callidus* has at last been run down by Dr. McDunnough. It proves to be a good species, treated as *lilius* Dyar by Skinner in his ''Studies in the Genus Thanaos.'' The two names may apply to the same thing, but in that case *callidus* has priority. The genitalia resemble those of *pacuvius*. California, June and July.

8. *THANAOS MARTIALIS*

Nisoniades martialis Scudder, Trans. Chi. Acad. Sci. I, 335, 1869.

Scudder, Butt. New Eng. II, 1493, 1889.

Holland, Butterfly Book 335, pl. XLVIII, f. 4, 1898.

New York, west to Colorado and north into Canada; May, July, August.

Dr. Forbes tells me that eastern specimens of this species have a brassy lustre, but all which I have seen from the middle west were decidedly purplish. The unusually bright, contrasting pattern is the most reliable characteristic.

ab. *AUSONIUS*

Nisoniades ausonius Lint., 23rd Rep. N. Y. St. Cab. Nat. Hist. 166, pl. 7, ff, 11, 12, 1872.

Scudder, Butt. New Eng. II, 1498, 1889.

Ausonius lacks the subapical hyaline spots and has the transverse series of dark dashes unusually prominent. It was described from a single specimen taken at Center, N. Y., on May 12, 1871, and has never been taken since.

9. *THANAOS JUVENALIS*

Hesperia juvenalis Fab., Ent. Syst. III, (I), 339, 1793.

Nisoniades juvenis Hbn., Verz. bek. Schmett. 108, 1820.

Nisoniades costalis Westw. & Hew., Gen. Diurn. Lep. II, 519, pl. 79, f. 3, 1852.

Nisoniades ennius Scud. & Burg., Proc. Bost. Soc. Nat. Hist. XIII, 296, f. 9, 1870.

Scudder, Butt. New Eng. II, 1476, 1889.

Holland, Butterfly Book 335, pl. XLVIII, f. 11, 1898.

Wright, Butt. W. Coast 252, pl. XXXII, 462 ♀, 469 ♂ (not ♀ *tristis*), 1905.

Atlantic coast to Rockies, Gulf to Northern Canada; May to August.

10. *THANAOS PROPERTIUS*

Nisoniades propertius Scud. & Burg., Proc. Bost. Soc. Nat. Hist. XIII, 298, f. 11, 1870.

Nisoniades tibullus Scud. & Burg., op. cit., p. 299, f. 12.

Wright, Butt. W. Coast 252, pl. XXXII, f. 463, 1905.

Texas, Arizona, California and north into Canada; June, July and August. The abundance of hairy gray vestiture in specimens which have not been badly rubbed is very characteristic.

10a. race *BOREALIS*

Thanaos propertius, var. *borealis* Cary, Proc. U. S. N. M. XXXI, 455, 1906.

Type one male from North Nahanni River, Mackenzie, June 4, 1904. Apparently this is a dark race with the pale maculation greatly reduced.

11. *THANAOS HORATIUS*

Nisoniades horatius Scud. & Burg., Proc. Bost. Soc. Nat. Hist. XIII, 301 f. 13, 1870.

Nisoniades virgilius Scud. & Burg., op. cit. p. 302, f. 14.

Nisoniades petronius Lint., Papilio I, 70, 1881.

Scudder, Butt. New Eng. II, 1486, 1889.

Holland, Butterfly Book 336, pl. XLVIII, f. 15, 1898.

Florida and Texas, north to Colorado and Minnesota; May, July, August, October. The females are conspicuously marked but the males resemble *juvenalis* closely.

12. *THANAOS TERENTIUS*

Nisoniades terentius Scud. & Burg., Proc. Bost. Soc. Nat. Hist. XIII, 292, f. 6, 1870.

Nisoniades ovidius Scud. & Burg., op. cit. 295, f. 8.

Nisoniades naevius Lintner, Papilio I, 69, 1881.

Scudder, Butt. New Eng. II, 1490, 1889.

Holland, Butterfly Book 336, pl. XLVIII, f. 3, 1898.

Florida, April, May and July. South Carolina, May. Mississippi, August. The very dark, even color of this species is easy to recognize, and as a rule the brown patch on the primaries is conspicuous.

13. *THANAOS PACUVIUS*

Nisoniades pacuvius Lint., 30th Rep. N. Y. Mus. Nat. Hist. 172, 1878.

Holland, Butterfly Book 336, pl. XLVIII, f. 9, 1898.

California, Arizona, New Mexico and Colorado; March, May, June and August.

14. *THANAOS SCUDDERI*

Thanaos scudderi Skinner, Trans. Am. Ent. Soc. XL, 215, 1914.

Thanaos pacuvius G. & S. (not Lintner), Biol. Cent.-Am., Rhop. II, 458, pl. 91, ff. 16, 17, 1899.

Texas and Arizona, July and August. I am unable to separate this species from *pacuvius* except by the structure of the male genitalia. Skinner points out a slight difference in the hyaline spots.

15. *THANAOS CLITUS*

Thanaos clitus Edw., Papilio II, 180, 1882.

Thanaos maestus G. & S., Biol. Cent.-Am., Rhop. II, 457, t. 91, f. 18, ♂ gen., 1899.

Holland, Butterfly Book 336, pl. XLV, f. 8, 1898.

Arizona, May to August; California and Colorado.

16. *THANAOS TRISTIS*

Thanaos tristis Boisd., Ann. Soc. Ent. France (2), X, 311, 1852.

Oberthür, Etudes IX, (1), pl. CCXL, f. 2081, 1913, figure of type.

California, June and August. Arizona.

form *TATIUS*

Thanaos tatius Edw., Papilio II, 179, 1882.

Arizona, April, June, July, September.

17. *THANAOS FUNERALIS*

Nisoniades funeralis Scud. & Burg., Proc. Bost. Soc. Nat. Hist. XIII, 293, f. 7, 1870.

Holland, Butterfly Book 336, pl. XLVIII, f. 12, 1898.

Wright, Butt. W. Coast 253, pl. XXXII, f. 468 and 464 (not *clitus*), 1905.

California, June. Arizona, Texas and Colorado, June and July. March in the far south. The rather narrow primaries, of a dull, brownish color, and the broad secondaries are unlike the other species of the genus.

The two following species cannot be fixed at present to any known form:

18. *THANAOS PLAUTUS*

Nisoniades plautus Scud. & Burg., Proc. Bost. Soc. Nat. Hist. XIII, 304, f. 16, 1870.

Described from Florida. The figure of the genitalia has some points of similarity with the genitalia of *juvenalis*.

19. *THANAOS LILIUS*

Thanaos lilius Dyar, Proc. U. S. N. M. XXVII, 788, 1904.

Dyar states (Jn. N. Y. Ent. Soc. XIII, 122) that the genitalia of *lilius* are similar to those of *tibullus* (=*propertius*), while Skinner's description of them in his "Studies" suggests those of *callidus*, which was not correctly fixed at the time when his paper was written. Apparently *lilius* will fall before one of these two species, but an examination of the genitalia of the type will be necessary to settle the matter. I am greatly indebted to Dr. McDunnough for his notes on these species, for all data which I am able to give here are based on his researches.

Genus TIMOCHARES Godman & Salvin

Timochares G. & S., Biol. Cent.-Am., Rhop. II, 417, 1896. Type *Leucochitonea trifasciata* Hew.

Palpi moderately large, much as in *Thanaos*, with a hairy second joint and a stout, conical third joint. Antennae less than one-half as long as primaries; club moderate, fusiform, curved. Costa of primaries convex, with a long fold in the male; apex rectangular, subtruncate; outer margin rounded from vein 6 to anal angle. Secondaries trigonate; inner margin about as long as wing measured through cell; outer margin wavy. Neuration practically as in *T. juvenalis*. *T. funeralis* is structurally very close to this genus, but the apex of the primaries is never distinctly subtruncate and the anal angle is much more broadly rounded.

1. *TIMOCHARES RUPTIFASCIATUS*

Antigonus ruptifasciatus Plötz, Jahrb. Nass. Ver. XXXVII, 27, 1884.
Biol. Cent.-Am., Rhop. II, 418, pl. 88, pp. 1, 2, 1896.

I have seen one male from Brownsville, Texas, in the Barnes collection.

Genus GRAIS Godman & Salvin

Grais G. & S., Biol. Cent.-Am., Rhop. II, 381, 1894. Type *Anastrus stigmaticus* Mab.

The structure of this genus is very similar to that of the preceding, but the cell of the primaries is of almost equal width throughout, and is approximately equal to the distance between cell and costa. The male has neither costal fold nor tibial tuft.

1. *GRAIS STIGMATICUS*

Anastrus stigmaticus Mab., Bull. Soc. Ent. Belg. XXVI, LIV, 1883.
Antigonus fumosus Plötz, Jahrb. Nass. Ver. XXXVII, 26, 1884.
Biol. Cent.-Am., Rhop. II, 381, pl. 84, ff. 24, 25, 26, 1894.

Kerrville, Texas; September.

Subfamily PAMPHILINAE

Palpi usually upturned; in a few genera porrect. Antennae very variable in length; club usually short and stout with a very slender apiculus but sometimes longer; apiculus sometimes thick or absent. Primaries more or less trigonate; secondaries trigonate to rounded and lobed. Neuration as in the Hesperiinae but with the L. D. C. usually tubular and vein 5 curved toward the base in the primaries, arising nearer to 4 than to 6. Front tibiae usually with the epiphysis; middle tibiae usually with conspicuous spines; hind tibiae usually with two pairs of spurs and never with a tuft. In the species of group A the spinulation of the mid tibiae furnishes a convenient means for separating the insects from the Hesperiinae. Males often with stigma on primaries.

The loss of the apiculus in the Pamphilinae seems to have been brought about by its gradual reduction, a process of evolution which is nicely illustrated by the transition from *Oligoria* to

Chaerephon in Group B. I regard this as furnishing the phylogenetic basis for the separation of Group A from the Hesperiinae, which makes it necessary to explain their resemblance by parallel or convergent evolution.

In place of the two groups into which the Pamphilinae have commonly been divided I believe that a modification of the system used in the Biologia will be of greater convenience. I have therefore divided our fauna into four groups which are characterized as follows:

Group A. Palpi porrect. Vein 5 of primaries straight, intermediate between 4 and 6; cell less than two-thirds as long as wing. Club of antennae blunt. *Carterocephalus* and *Butleria.*

Group B. Palpi upturned; third joint long and slender. Antennae short; club blunt. Vein 5 of primaries curved slightly toward 4 at base. Cell less than two-thirds as long as wing. *Ancyloxypha, Oarisma, Adopaea* and *Copaeodes.*

Group C. Palpi appressed or oblique; third joint moderate or small, long in *Amblyscirtes.* Antennae with a slender apiculus in most genera. Vein 5 of primaries curved at base, usually arising much nearer to 4 than to 6. Cell less than two-thirds as long as wing. All North American genera not included in A, B and D.

Group D. Palpi closely appressed, smoothly and deeply scaled; third joint small. Club of antennae stout, with a fine, abruptly constricted apiculus. Vein 5 arising much nearer to 4; cell about two-thirds as long as wing and with at least a rudiment of a recurrent vein. *Thespieus, Calpodes* and *Prenes.*

GROUP A

Key to the genera

Hind tibiae with one pair of spurs..........:*Carterocephalus*
Hind tibiae with two pairs of spurs.................*Butleria*

Genus CARTEROCEPHALUS Lederer

Carterocephalus Led., Verh. z.-b. Ges. Wien II, 26, 49, 1852.

Type: *Papilio palaemon* Pallas.

Second joint of palpi oblique, loosely clothed with long hairs; third slender, moderately long, enveloped by hairs of second. Antennae less than one-half as long as primaries; club large, elongate ovate, flattened on its posterior surface, blunt. Primaries trigonate with the outer margin rounded, rather narrow. Vein 5 intermediate between 4 and 6; L. D. C. not tubular, faint. Secondaries rounded; apex prominent and anal angle slightly produced. Hind tibiae with one pair of spurs; middle tibiae spined. Males without secondary sexual structures. Fig. 19.

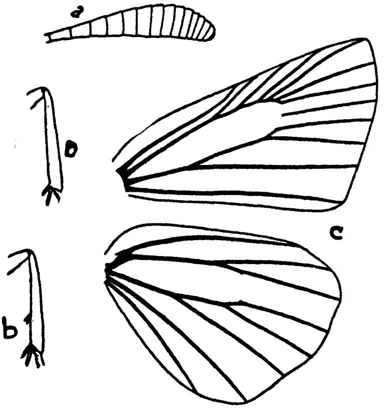


Fig. 19. *Butleria pirus* Edw. a. Club of antenna, b. Hind tibia, c. Neueration, d. Hind tibia of *Carterocephalus palaemon* Pallas

1. *CARTEROCEPHALUS PALAEMON*

Papilio palaemon Pallas, Reise I, 471, 1771.
Papilio paniscus Fab., Syst. Ent. 531, 1775.
Papilio brontes Denn. & Schiff. Wien Verz. 160, 1776.
Hesperia mandan Edw., Proc. Ent. Soc. Phil. II, 20, pl. V, f. 1, 1863.
Hesperia mesapano Scud., Proc. Bost. Soc. Nat. Hist. XI, 383, 1868.
Cyclopides skada Edw., Trans. Am. Ent. Soc. III, 196, 1870.
Stereoptes skada Edw., Trans. Am. Ent. Soc. III, 214, 1871.
Scudder, Butt. New Eng. II, 1569, 1889.
Elwes & Edwards, Rev. Or. Hesp. 167, 1897.
Holland, Butterfly Book 342, XLVII, f. 1, 1898.

Canada, Mountains of New England and Rocky Mountains; June. California, Montana. Europe and Asia. Fort Providence, Mackenzie, July (Cary). Yukon Territory (Winn).

Genus BUTLERIA Kirby

Butleria Kirby, Syn. Cat. 624, 1871. Type *Carterocephalus exornatus* Felder.

Dalla Mab., Gen. Ins. XVII, 107, 1904. Type *Cyclopides eryonas* Hew.

Very similar in structure to *Carterocephalus* but with two pairs of spurs on the hind tibiae. Fig. 19.

Butleria was first characterized by Watson (P. Z. S. 1893, 79) but according to Mabille his description does not fit the genotype. Mabille in turn characterized the genus to correspond with the typical species in vol. XVII of the Genera Insectorum, page 106, at the same time dividing it and naming one part *Dalla*. Such differences as he mentions between the two seem to be slight and transitional through the series of species included, and I therefore sink *Dalla*. The description of *Dalla* does not apply to our species as well as Mabille's diagnosis of *Butleria*, so if the genera be separated again there is a possibility that *Butleria*, and not *Dalla* will still be applicable in our region.

Key to the species

Under surface of secondaries immaculate.......................... *pirus*
With a number of small pale spots.......................... *microsticta*
With a few large spots.. *polingi*

1. *BUTLERIA PIRUS*

Pholisora pirus Edw., Field and Forest III, 119, 1878.
Colorado, Utah, Arizona; June, July.

2. *BUTLERIA MICROSTICTA*

Butleria microsticta G. & S., Biol. Cent.-Am., Rhop. II, 464, pl. 92, ff, 1, 2, 3, 1900.

I have seen no specimens; the species is said to occur near the Mexican border.

3. *BUTLERIA POLINGI*

Pyrgus polingi Barnes, Can. Ent. XXXII, 44, 1900.
Arizona, June and July.

GROUP B

Key to the genera

1. Wings broadly rounded...................... *Ancyloxypha*
   Wings more or less trigonate.......................... 2
2. All wings trigonate; male without stigma; club of antennae about as long as shaft.......................... *Oarisma*
   Males with stigma; secondaries, at least, rounded; club not as long as shaft.................................. 3
3. Secondaries rounded, primaries trigonate; club small
   .... *Copaeodes*
   Outer margin of primaries more oblique and rounded; club large, relatively long.......................... *Adopaea*

Genus ANCYLOXYPHA Felder

Ancyloxypha Feld., Verh. z.-b. Ges. Wien xii, 477, 1862. Type *Hesperia numitor* Fab.

Palpi upturned; second joint normal, deeply scaled; third slender, pointed, almost as long as second. Antennae much less than one-half as long as primaries; club blunt, moderately large. Costa of primaries rounded at base, less so in outer half; outer margin broadly rounded, cell slightly less than three-fifths as long as wing; vein 5 nearer to 4 than to 6; 2 and 3 near end of cell. Secondaries rather long through cell, rounded; outer margin slightly emarginate between veins 4 and 6. Male without stigma. Fig. 20.

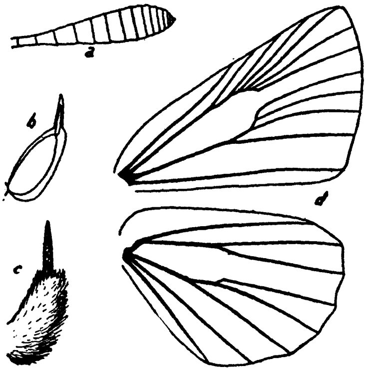


Fig. 20. *Ancyloxypha numitor* Fab. a. Club of antenna, b. Section of palpus; outer line shows limit of vestiture, c. Palpus, d. Neuration

1. *ANCYLOXYPHA NUMITOR*

Hesperia numitor Fab., Ent. Syst. iii, (i), 324, 1793.
Thymelicus puer Hbn., Verz. bek. Schmett. 113, 1820.
Heteropterus marginatus Harris, Ins. Inj. Veg., 3rd ed., 308, 1862.
Scudder, Butt. New Eng. ii, 1558, 1889.
Holland, Butterfly Book 345, pl. xlvii, f. 2, 1898.

Atlantic coast west to Texas, north into Canada; May to August.

The disk of the primaries is black below, while that of the following species is ruddy fulvous.

ab. *LONGLEYI*

Ancyloxypha longleyi French, Can. Ent. xxix, 80, 1897.

Described from Illinois. A form in which the primaries are glossy black above.

2. *ANCYLOXYPHA ARENE*

Heteropterus arene Edw., Trans. Am. Ent. Soc. iii, 214, 1871.
Copaeodes myrtis Edw., Papilio ii, 26, 1882.
Apaustus leporina Plötz, Stett. Ent. Zeit. xlv, 166, 1884, (fide G. & S.).
Holland, Butterfly Book 346, pl. xlvii, f. 11, 1898.
Biol. Cent.-Am., Rhop. ii, 472, pl. 92, ff. 35-38, 1900.

Arizona, August. Differs from *numitor* in the absence of black from the under surface of the primaries.

Genus OARISMA Scudder

Oarisma Scudder, Syst. Rev. 54, (75), 1872. Type *Hesperia poweshiek* Parker.

Paradopaea G. & S., Biol. Cent.-Am., Rhop. II, 469, footnote, 1900.

Palpi as in *Ancyloxypha.* Antennae much less than one-half as long as primaries; club enlongate obovoid, blunt, as long or nearly as long as shaft. Costa of primaries straight except at base and apex; outer margin curved only opposite cell; entire wing trigonate; cell about three-fifths as long as wing; vein 5 near 4 at base; 3 near end of cell; 2 about as far from 3 as from base of wing, variable. Secondaries trigonate, all margins slightly rounded and anal angle very slightly lobed. Male without stigma. Fig. 21.

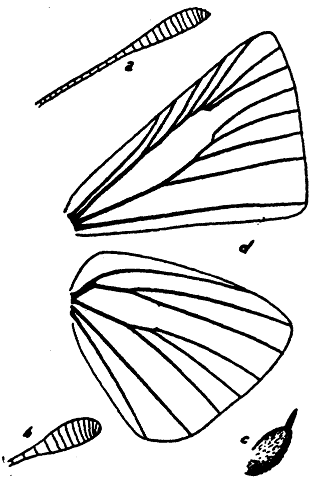


Fig. 21. *Oarisma garita* Reakirt: a. Club of antenna, d. Neuration. *Jopaeodes aurantiaca* Hew. b. Club of antenna, c. Palpus

Key to the species

1. Under surface of secondaries with white veins on a dark ground before vein 1b .... *poweshiek*
   Veins not much paler than ground color 2
2. Upper surface bright yellow-fulvous .... *edwardsi*
   Upper surface fuscous, variably powdered with yellow-fulvous . . *garita*

1. *OARISMA GARITA*

Hesperia garita Reakirt, Proc. Ent. Soc. Phil. VI, 150, 1866.

Thymelicus hylax Edw., Trans. Am. Ent. Soc. III, 274, 1871.

Paradopaea calega G. & S., Biol. Cent.-Am., Rhop. II, pl. 92, ff. 26-29, 1900.

Paradopaea garita G. & S., Biol. Cent.-Am., Rhop. II, pl. 92, ff. 23-24, 1900.

Oarisma poweshiek G. & S., (not Parker) Biol. Cent.-Am., Rhop. II, 469, 1900.

Holland, Butterfly Book 343, pl. XLVII, f. 3, 1898.

Wright, Butt. W. Coast pl. XXX, f. 408, 1905 (not *lena* Edw.)

Manitoba, Montana, Colorado, Idaho, Arizona; July.

Calega G. & S. looks in the figure as if it might be a good species but in the text the authors refer it to *garita.* They also erroneously refer their figures of *garita* to *poweshiek.*

2. *OARISMA EDWARDSI*

Thymelicus edwardsi Barnes, Can. Ent. XXIX, 42, 1897.

Paradopaea garita G. & S. (not Reakirt) Biol. Cent.-Am. Rhop. III, pl. 92, f. 25 ♂ genitalia, 1900.

Colorado, Arizona and New Mexico; June and July.

I have seen the type of this species and the pale upper surface is very different from *garita*.

3. *OARISMA POWESHEIK*

Hesperia powesheik Parker, Am. Ent. & Bot. II, 271, 1870.
Thymelicus garita Plötz (not Reakirt), Stett. Ent. Zeit. XLV, 287, 1884.
Scudder, Butt. New Eng. III, 1859, 1889.
Holland, Butterfly Book 343, pl. XLVII, f. 4, 1898.

Described from thirty-one males and two females taken June 21, 1870, at Grinnell, Iowa. It has also been taken in Colorado and South Dakota, and I have observed it personally so near to the Minnesota line in Iowa that it probably enters that state. Michigan (Wolcott).

Genus ADOPAEA Billberg

Adopaea Billb., Enum. Ins. 81, 1820. Type *Papilio thaumas* Hufn.

Similar to *Copaeodes* but with the antennal club larger and relatively longer, and with a rudiment of the apiculus. The outer margin of the primaries is more oblique, relatively shorter, and more deeply sinuate. The stigma of the male is similar.

This genus has been incorrectly used in the past in our fauna for *eunus* and *wrighti*; it is represented only by an introduced species.

1. *ADOPAEA LINEOLA*

Papilio lineola Ochs., Schmett. Eur. I, (2), 230, 1808.
Morris, British Butterflies, 153, pl. 70, 1890.
Spuler, Schmett. Eur. t. 18, ff. 6a, 6b, 1910.
47th Rep. Ent. Soc. Ont. 142, 1917.

Introduced from Europe. The reference in the report of the Entomological Society of Ontario records its capture at London, Ontario, on July 1, 1910, and every year from then until the date of the publication.

Genus COPAEODES Speyer

Copaeodes Speyer, Edw. Cat. Lep. 49, 64, 1877. Type *Heteropterus procris* Edw.

Palpi upturned; second joint densely scaled; third fine, pointed, not quite as long as in *Ancyloxypha*. Antennae scarcely two-fifths as long as primaries; club rather small, stout, blunt. Primaries trigonate; costa straight except at base and apex; outer margin slightly sinuate; anal angle almost rectangular.

Secondaries rounded, slightly lobed at anal angle. Wings more elongate in female. Primaries of male with a slender, longitudinal stigma. Cell of primaries about three-fifths as long as wing; vein 5 arising much nearer to 4 than to 6. Fig. 21.

1. *COPAEODES AURANTIACA*

Ancyloxypha aurantiaca Hew., Desc. Hesp. 45, 1868.
Hesperia waco Edw., Trans. Am. Ent. Soc. II, 122, 1868.
Heteropterus minima Edw., Trans. Am. Ent. Soc. III, 196, 1870.
Hesperia procris Edw., op. cit. 215.
Thymelicus macra Plötz, Strett. Ent. Zeit. XLV, 284, 1884.
Copaeodes candida Wright, Proc. Cal. Acad. Sci. (2), III, 34, 1890.
Copaeodes nanus Watson, (not H.-S.), Proc. Zool. Soc. London, 1893, 98 (fide G. & S.).
Holland, Butterfly Book 345, pl. XLVII, f. 9, 1898.
Biol. Cent.-Am., Rhop. II, 473, pl. 92, ff. 39-42, 1900.
Wright, Butt. W. Coast 236, pl. XXXI, ff. 409, 411, 1905.
Skinner, Ent. News XXIX, 150, 1918.

Arizona, May, July, August and September. Texas, California, March, May, August.

I cannot agree with Dr. Skinner that this and the following are but one species, but as he suggests, *rayata* may fall before the female of *procris*, in which case the latter name might be restricted to the female type and retained as a species.

2. *COPAEODES RAYATA*

Copaeodes rayata B. & McD., Contributions II, (3), 100, pl. III, ff. 1, 2, 1913.

San Benito, Texas; June and July.

I have seen the types of this species and it is abundantly distinct from *aurantiaca*. The pale ray is variably distinct, but the veins are darker than the ground color and of a somewhat rusty shade on the lower surface of the secondaries. The size is smaller than *aurantiaca*.

GROUP C

Key to the genera

1. Club of antennae blunt or with a rudiment of the apiculus .... *Chaerephon*
   Club of antennae with a sharp apiculus, sometimes very short 2
2. Vein 5 of primaries well curved toward base, arising conspicuously nearer to 4 than to 6........................3
   Vein 5 but slightly curved, only a little nearer to vein 4 at base; L. D. C. weak..............................11

3. Antennae scarcely longer than width of thorax. . *Hylephila*
Antennae distinctly longer. 4
4. Mid tibiae with spines. 5
Mid tibiae without spines. . . . . *Atrytone*
5. Apiculus of antennae shorter than thickness of club or not abruptly constricted. 6
Apiculus at least equal to thickness of club, slender; either abruptly constricted or distinctly longer than thickness of club 9
6. Primaries apically produced and secondaries lobed; apiculus very short. 7
Primaries and secondaries moderate; apiculus usually moderately long. 8
7. Male stigma slender; wings of female moderate. . . . *Pamphila*
Male stigma a large blotch; wings of female similar to those of male. . . . . *Atalopedes*
8. Vein 2 of primaries slightly nearer to base of wing than to vein 3. Secondaries well marked with yellow fulvous; see description . . . . *Augiades*
Vein 2 variably nearer to 3; when doubtful, secondaries with little fulvous, at the most a transverse band; see description . . . . *Polites*
Vein 2 immaterial. Club of antennae very stout, with a fine apiculus, or moderate with a thick apiculus. . . . . *Poanes*
9. Apiculus slender, about twice thickness of club. . . . *Oligoria*
Apiculus shorter or thick. 10
10. Apiculus slender; male stigma large, with large gray scales; under surface fuscous. . . . . *Catia*
Apiculus tapered, not abruptly constricted; male without stigma; under surface not fuscous. . . . . *Poanes*
Apiculus slender, variable, male stigma variable. Under surface gray powdered to dark brown. . . . . *Atrytonopsis*
11. Male stigma large; maculation yellow. . . . . *Epiphyes*
Stigma not large; maculation not pale yellow. 12
12. Apiculus fine; shorter than thickness of club. . . . . . *Lerodea*
Apiculus longer, or wings immaculate. 13
13. Third joint of palpi long (ex. *nanno*); fringes checkered . . . . *Amblyscirtes*
Third joint short; fringes not checkered. 14

14. Vein 5 almost intermediate between 4 and 6; under surface with purplish lustre..............................*Lerema*
Vein 5 considerably nearer to 4; under surface otherwise ....*Mastor*

Genus CHAEREPHON Godman & Salvin

Chaerephon G. & S., Biol. Cent.-Am., Rhop. ii, 474, 1900. Type *Pamphila citrus* Mab.

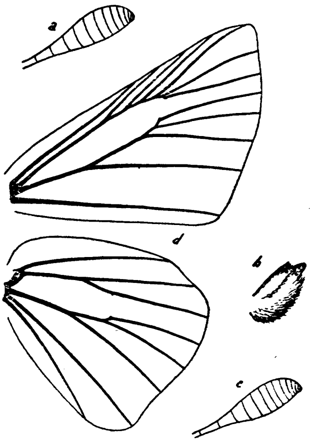


Fig. 22. *Chaerephon*. a. Club of antenna of *rhesus*, b. Palpus of *eunus*, c. Club of antenna of *eunus*, d. Neuration of *eunus*

Second joint of palpi upturned, deeply scaled; third small, oblique, smooth. Antennae less than one-half as long as primaries; club large, obovoid, subacute but without a reflexed apiculus. Costa of primaries straight except at base; apex produced, rounded acute in males, less sharp in females; outer margin rounded in center and straighter nearer apex and anal angle, though almost evenly rounded in some females. Secondaries rounded, lobed at anal angle in male, slightly so in female. Both wings appear shorter and broader in the male than in the female. Primaries of male with a faint stigma composed of an oblique bar above vein 2 followed by two small round patches in line below the vein. Fig. 22.

Key to the species

1. Wings yellow-fulvous...............................*eunus, wrighti*
Wings mostly fuscous..2
2. Under surface gray powdery..............................*simius*
Under surface more or less yellowish..........................3
3. Yellow of under surface of secondaries interspersed with dark patches; maculation distinct...*rhesus*
Yellow pale, dull, even; maculation obscure..................*carus*

1. *CHAEREPHON EUNUS*

Copaeodes eunus Edw., Papilio i, 47, 1881.
Holland, Butterfly Book, pl. xlvii, f. 10, 1898 (as *wrighti*).
Wright, Butt. W. Coast 237, pl. xxxi, ff. 412, 414, 1905.
California, June.

2. *CHAEREPHON WRIGHTI*

Copaeodes wrighti Edw., Can. Ent. xiv, 152, 1882.

Wrighti is probably a synonym of *eunus*; the original description fits *eunus*, the type localities are in the same part of California, and we do not know of two species of these general characteristics. Both of these have been erroneously placed in *Adopaea* in the past, whereas *Adopaea* is closely related to *Copaeodes* and *eunus* is not at all similar in structure.

3. *CHAEREPHON RHESUS*

Pamphila rhesus Edw., Field and Forest iii, 116, 1878.
Biol. Cent.-Am., Rhop. ii, 475, pl. 93, ff. 5-7, 1900.
Skinner, Ent. News xi, pl. ii, ff. 19, 20, 1900.
Kellogg, Am. Ins. pl. ix, ff. 19, 20, 1904.
Colorado, Arizona.

4. *CHAEREPHON CARUS*

Pamphila carus Edw., Can. Ent. xv, 34, 1883.
Texas and Arizona, May, July and September.

5. *CHAEREPHON SIMIUS*

Amblyscirtes simius Edw., Trans. Am. Ent. Soc. ix, 6, 1881.
Holland, Butterfly Book 341, pl. xlvii, f. 8, 1898.
Colorado; Sioux County, Nebraska, July.

This is one of our rarer species. I am indebted to Mr. Leussler for a specimen taken in Sioux County, Nebraska, the only one in my possession.

Genus PAMPHILA Fabricius

Pamphila Fab., Ill. Mag. vi, 287, 1807. Type *Papilio comma* Linn.

Ocytes Scud., Syst. Rev. 55, (76), 1872. Type *Erynnis metea* Scud.

Anthomaster Scud., Syst. Rev. 57, (78), 1872. Type *Hesperia leonardus* Harris.

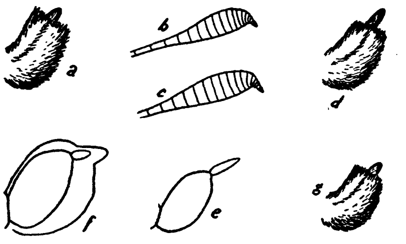


Fig. 23. *Pamphila* and *Augiades*, a. Palpus of *A. snowi*, b. Club of antenna of *P. viridis* ♂, c. Same, female, d. Palpus of *P. viridis*, e. Same, denunded, f. Section of palpus of *A. sylvanus*; outer line shows limit of vestiture, g. Palpus of *A. napa*

Palpi upturned; second joint with a smooth vestiture of scales and some hairs; third about one-half as long as second but partly concealed. Antennae less than one-half as long as primaries; club large with a very small apiculus which is a little longer in the female. Costa slightly emarginate to slightly convex; outer margin slightly sinuate to evenly rounded, usually more rounded in the female. Secondaries rounded, slightly lobed at anal angle. In all of the species the wings of the females are longer and more rounded than those of the males. Vein 5 of primaries arising very near to 4; 3 near end of cell; 2 about intermediate between 3 and base of wing; cell slightly over three-fifths as long as wing. Vein 7 of secondaries slightly nearer to end of cell than to 8. Mid tibiae spiny. Male stigma slender, strong, extending from base of vein 3 to basal third of vein 1 and made up of a long piece in front of vein 2 and a shorter piece behind 2 which is set just outside of the first but is continuous with it. Fig. 23.

Key to the species

This key is not to be regarded as a means of ultimate identification; in *Pamphila* no key can be sufficient in itself, for many of our species and forms intergrade to such an extent that only a practiced eye can even sort them properly. The key to the forms of *comma* included here is based on specimens in the Barnes collection which have been compared with the types, and so may be relied on for typical specimens. It will not, however, suffice for the placing of the multitude of intermediate forms which occur in large series.

1. Under surface of secondaries with alternating greenish and fuscous areas; veins white on disk.................................... *uncas*
   Under surface evenly colored; veins not white..................... 2
2. Upper surface fuscous with reduced, poorly defined, pale spots; under surface of secondaries with a pale band....................... *metea*
   Upper surface more or less fulvous or with well defined spots, or lower surface with separate spots... 3
3. Under surface of secondaries with a pale ray in the cell...... *morrisoni*
   With or without a pale spot in cell.............................. 4
4. Under surface of secondaries yellow to brown with an oblique band of uniform, confluent white spots posterior to vein 6; sometimes with a single spot before this band............................ *columbia*
   Spots making up band, when present, not confluent, unequal, irregularly placed or with more than one spot before vein 6. Under surface usually greenish in forms which are likely to confuse............... 5
5. Under surface of secondaries with sharply defined white spots or yellowish to greenish with the bent macular band traceable............ 6
   Under surface without sharply defined white spots; immaculate or with traces of separate spots, usually poorly defined or not white...... 13
6. Under surface of primaries fuscous; spots on secondaries small and rounded .... *seminole*
   Under surface of primaries with some fulvous or spots on secondaries otherwise 7

7. Spot on under surface of secondaries just behind vein 2 nearer base of wing than rest of band or absent. Band sometimes too much modified to show this difference 8
This spot on a line with rest of band or outside of it; band well marked, white .... *viridis*

8. Spots not confluent, their size variable; under surface usually dark with sparse over-scaling .... *woodgatei*
Spots usually confluent or over-scaling dense 9

9. Upper surface bright with sharp contrasts; costal area of primaries fulvous; white spots of lower surface very large and bright...... *juba*
Upper surface with a variable diffusion of fuscous; when maculation is sharp, the other characters differ. Spots below moderate to greatly reduced, white or yellowish 10

10. Maculation below yellow but not reduced .... *sassacus* 12
Maculation white or greatly reduced 11

11. Macular band with one spot before vein 7, one behind vein 2 followed by a trace of a second; band irregular; superficial vestiture gray-green .... *nevada*
Band equally contrasting but more regular and abbreviated, usually with no spot before 7 and only one reduced spot behind 2; superficial vestiture green .... *colorado*
Spots dull white; superficial vestiture golden brown .... *manitoba*
Under surface of secondaries very smooth in appearance, yellow; spots white .... *idaho*
Spots greatly reduced, white .... *assiniboia*
Spots greatly reduced, yellowish .... *oregonia*

12. Under surface of secondaries pale; maculation faint .... *sassacus*
Under surface dark; maculation contrasting. *sassacus*, race *manitoboides*

13. Under surface of secondaries dark red-brown with pale, cream-white spots .... *leonardus*
Under surface otherwise 14

14. Pale maculation above very diffuse; pale area in end of cell of primaries showing two pale nuclei, always vague. .*sassacus*, race *dacotae*
Cell of primaries with two sharply defined spots in end, or with these indistinguishably fused 15

15. Disk of secondaries above with fulvous spots (♂); under surface very dark (♀) .... *attalus*, race *seminole*
Disk more or less broadly fulvous (♂); under surface pale (♀) 16

16. Under surface of secondaries yellow-fulvous, with or without vague traces of large spots .... *meskei*
Under surface of a lighter shade, more or less yellow; spots small or absent 17

17. Southern species, Florida, Texas, Ohio? .... *attalus*
Prairie species, Iowa, Nebraska, Dakota, Montana, and California
.... *ottoe*, *pawnee*, *pawnee* race *montana*

1. *PAMPHILA UNCAS*

Hesperia uncas Edw., Proc. Ent. Soc. Phil. II, 19, pl. V, f. 3, 1863.
Hesperia ridingsi Reakirt, Proc. Ent. Soc. Phil. VI, 151, 1866.
Hesperia axius Plötz, Stett. ent. Zeit. XLIV, 213, 1883.
Scudder, Butt. New Eng. III, 1862, 1889.
Holland, Butterfly Book 349, pl. XLVII, ff. 27, 28, 1898.

Colorado and Arizona, June and July.

2. *PAMPHILA LASUS*

Pamphila lasus Edw., Papilio IV, 54, 1884.

Described from Arizona. I do not know the species.

3. *PAMPHILA LICINUS*

Pamphila licinus Edw., Trans. Am. Ent. Soc. III, 275, 1871.

I do not know this species.

4. *PAMPHILA METEA*

Hesperia metea Scud., Proc. Ess. Inst. III, 177, 1862.
Scudder, Butt. New Eng. II, 1650, 1889.
Holland, Butterfly Book 348, pl. XLVII, ff. 33, 34, 1898.

New Jersey, New York, Massachusetts, New Hampshire and Rhode Island; May and June. This species is readily distinguished by its dark color, vague, whitish maculation and the tendency of the macular band on the under surface of the secondaries to be produced along the veins. The spots making up this band are neither separate nor very bright as in the other dark colored species.

5. *PAMPHILA MORRISONI*

Pamphila morrisoni Edw., Field and Forest III, 116, 1878.
Hesperia morissoni Plötz, Stett. ent. Zeit. XLIV, 215, 1883.
Biol. Cent.-Am., Rhop. II, 478, pl. 93, ff. 9, 10, 1900.

Colorado, May.

This is a small, bright species which is readily recognized by the elongation of the white mark in the cell of the secondaries below.

6. *PAMPHILA COLUMBIA*

Pamphila columbia Scud., Syst. Rev. 56, (77), 1872.
Pamphila sylvanoides Scud., (not Boisd.) Mem. Bost. Soc. Nat. Hist. II, (3), 351, pl. X, f. 22 (type), pl. XI, pp. 15, 17, 1874.
Pamphila california Wright, Butt. W. Coast 241, pl. XXXI, 423, 1905.
Thymelicus erynnioides Dyar, Jn. N. Y. Ent. Soc. XV, 50, 1907.

California, April and October.

All of the specimens in the Barnes collection have the band very even, as mentioned in the key; in Wright's figure it appears to be somewhat reduced toward the anal angle, but the color of the under surface of the secondary is characteristic.

7. *PAMPHILA NEVADA* (Plate I, Fig. 9)

Pamphila nevada Scud., Mem. Bost. Soc. Nat. Hist. II, 347, pl. x, ff. 1-4, pl. XI, ff. 3, 4, 1874.

Wright, Butt. W. Coast 240, pl. XXX, pp. 418, c, 419, b, c, 421, b, c, 1905.

I follow Dr. McDunnough in making this species distinct from *comma.* There is some difference in the male genitalia and if we restrict *nevada* to the typical form the under surface differs as noted in the key. Arizona to Northern Canada.

8. *PAMPHILA COMMA*

Pamphila comma Linn., Syst. Nat. 484, 1758.

Comma is a European species and does not occur in its typical form in this country.

8a. race *COLORADO* Pl. I, fig. 11

Pamphila colorado Scud., Mem. Bost. Soc. Nat. Hist. II, 349, pl. x, ff. 16, 17, 18, pl. XI, ff. 1, 2, 1874.

Arizona north to Washington, California.

In the typical form the under surface of the secondaries is bright green with the band pure white, short, rather even, and the basal marks united to form a U.

8b. race *MANITOBA*

Pamphila manitoba Scud., Mem. Bost. Soc. Nat. Hist. II, 351, pl. x, ff. 8-11, pl. XI, ff. 7, 8, 1874.

Scud., Butt. New Eng. II, 1646, 1889.

Pamphila manitoba, var. *laurentina* Lyman, Can. Ent. XXIV, 57, 1892.

Northwestern United States and Western Canada.

The typical form is golden brown beneath with whitish maculation.

8c. race *IDAHO*

Pamphila colorado, var. *idaho* Edw., Can. Ent. XV, 148, 1883.

Wright, Butt. W. Coast 241, pl. XXXI, f. 422, 1905.

California, Oregon, north into Canada.

The smooth, yellow appearance of the under surface of the secondaries is characteristic.

8d. race *ASSINIBOIA*

Pamphila manitoba, var. *assiniboia* Lyman, Can. Ent. XXIV, 57, 1892.

Regina, Canada.

8e. race *OREGONIA* Plate I, fig. 13

Pamphila oregonia Edw., Can. Ent. XV, 150, 1883.

Nevada, west to the coast and north into Canada.

The maculation of the under surface is similar to that of *assiniboia* but yellowish instead of white.

9. *PAMPHILA RURICOLA*

Hesperia ruricola Boisd., Ann. Soc. Ent. France (2), x, 315, 1852.

Described from California.

Many things have been referred to this species, which may be one of the forms of *comma*. I know nothing of the type nor of authentic specimens.

10. *PAMPHILA JUBA*

Hesperia comma Boisd. (not Linn.), Ann. Soc. Ent. France (2), x, 313, 1852.

Pamphila juba Scud., Syst. Rev. 56, (77), 1872.

Scudder, Mem. Bost. Soc. Nat. Hist. II, 349, pl. x, ff. 19, 20, pl. XI, ff. 5, 6, 1874.

Wright, Butt. W. Coast 239, pl. XXX, ff. 417, 418b ♂ (not *viridis* ♀), 1905.

Oberthür, Etudes IX, (1), p. 43, pl. CCXL, f. 2082 (*comma* Bdv.).

Utah, Colorado, Nevada, California; May and June.

11. *PAMPHILA WOODGATEI*

Pamphila woodgatei Williams, Ent. News XXV, 266, 1914.

Arizona, Texas and New Mexico; September and October.

This has been placed as a variety of *juba* but I believe that it is distinct. I have had no males for dissection.

12. *PAMPHILA VIRIDIS* (Plate I, Fig. 12)

Pamphila juba var. *viridis* Edw., Can. Ent. XV, 147, 1883.

Colorado, Arizona, New Mexico and Texas; June and September.

The form of the macular band in this species is unique and apparently constant.

13. *PAMPHILA LEONARDUS*

Hesperia leonardus Harris, Ins. Inj. Veg., 3rd ed., 314, f. 138, 1862.

Scudder, Butt. New Eng. II, 1673, 1889.

Holland, Butterfly Book 349, pl. XLVII, ff. 35, 36, 1898.

New York, Rhode Island, Massachusetts, west to the Mississippi; occasional in eastern Iowa; August and September. Scudder records it from Ontario and Florida, the latter in March and April (Butt. New Eng. II, 1676-7).

14. *PAMPHILA CABELUS*

Pamphila cabelus Edw., Trans. Am. Ent. Soc. IX, 4, 1881.

Described from Nevada.

This is another of our lost species of *Pamphila*. Apparently it belongs in the *ottoe* group.

15. *PAMPHILA HARPALUS*

Pamphila harpalus Edw., Trans. Am. Ent. Soc. IX, 3, 1881.

Described from Nevada.

The same may be said of this as of the preceding.

16. *PAMPHILA ATTALUS*

Pamphila attalus Edw., Trans. Am. Ent. Soc. III, 276, 1871.
Scudder, Butt. New Eng. II, 1653, 1889.
Holland, Butterfly Book 349, pl. XLVII, f. 23, 1898.

Florida, Texas. In the Barnes collection several specimens are labelled Ohio, and Scudder (Butt. New Eng. II, 1655) mentions records from Wisconsin, Iowa and New Jersey. I think that the middle western records are more likely to be *pawnee* or *ottoe*. Southern specimens of attalus are darker than these two species, and have the spots of the upper surface darker and more reddish.

16a. race *SEMINOLE*

Ocytes seminole Scud., Syst. Rev. 55, (76), 1872.
Erynnis attalus quaiapen Scud., Butt. New Eng. 1655, 1889.
Pamphila slossonae Skinner, Ent. Amer. VI, 138, 1890.

Florida, April to June, October.

Seminole is very dark both above and below. The maculation is restricted in the male, and the under surface of the primaries very slightly marked with fulvous, while in the female all spots are whitish and the under surface is not marked with fulvous. Scudder describes *quaiapen* as a female form of *attalus.*

17. *PAMPHILA MESKEI*

Pamphila meskei Edw., Can. Ent. IX, 58, 1877.
Pamphila straton Edw., Papilio, I, 78, 1881.

Florida and Texas.

I have seen only three males in the Barnes collection. These resemble *attalus* above; beneath the secondaries are yellow-fulvous, immaculate in one of the three specimens and with traces of large, diffuse, pale spots in the other two.

18. *PAMPHILA OTTOE*

Hesperia ottoe Edw., Proc. Ent. Soc. Phil. VI, 207, 1866.
Scudder, Mem. Bost. Soc. Nat. Hist. II, 348, pl. X, f. 6, pl. XI, f. 13, 1874.

In the typical form the males are tawny above with a very narrow terminal border of fuscous, and compared specimens in the Barnes collection have the under surface bright yellow. I have taken a species at Sioux City, Iowa, in late July and early August which I have placed as *ottoe* and which is distinguished by the ochraceous under surface and the extension of the pale area of the upper surface along the veins into the moderately broad fuscous terminal border. True *pawnee* occurs in this locality at a different season. Specimens in the Barnes collection are from Montana.

19. *PAMPHILA PAWNEE*

Hesperia pawnee Dodge, Can. Ent. VI, 44, 1874.

Montana, July. Colorado, September. Omaha, Neb., June. South Dakota, Sioux City, Iowa, late June and early July, late August and early September. Described from Dodge County, Neb.

The under surface is usually immaculate yellow, in the female sometimes grayish and usually with small pale spots. The spots on the upper surface of the primaries in the female are very pale, and this sex closely resembles *attalus*. The males of this species may be distinguished by the more extensive pale areas of the upper surface and their lighter shade.

19a. race *MONTANA*

Pamphila pawnee subsp. *montana* Skinner, Ent. News XXII, 413, 1911.

California, Colorado, Montana.

A specimen in the Barnes collection which has been compared with the type is much darker than normal *pawnee*, both above and below.

20. *PAMPHILA SASSACUS*

Hesperia sassacus Harris, Ins. Inj. Veg., 3rd ed., 315, 1862.
Scudder, Butt. New Eng. II, 1641, 1889.
Holland, Butterfly Book 348, pl. XLVI, f. 13, 1898.
Holland, Butterfly Book pl. XLVII, f. 44, 1898, (not *sylvanoides*).
Kellogg, Am. Ins. pl. X, f. 5, 1904.

New Jersey, New York and Connecticut, westward into Iowa; June, July, August.

20a. race *MANITOBOIDES*

Pamphila manitoboides Fletcher, Rep. Ent. Soc. Ont. for 1888, p. 85, 1889.

Ontario, Canada.

Dr. W. T. M. Forbes has called my attention to this relationship of *manitoboides*, which seems so close that I am adopting his arrangement. Formerly it has been called a distinct species or a form of *comma*, but it is identical with *sassacus* except in the darker color and greater contrast of the markings of the lower surface.

20b. race *DACOTAE*

Pamphila sassacus, subsp. *dacotae* Skinner, Ent. News XXII, 412, 1911.

South Dakota, June. Sioux City, Iowa.

I have seen paratypes of both sexes in the Barnes collection, and in the males the only difference which I can formulate between this form and *sassacus* is a general darkness of color and obscureness of the under surface. The females have the markings of the upper surface greatly reduced and diffuse, and the lower surface grayish with small, indefinite spots.

21. *PAMPHILA HORUS*

Hesperia horus Edw., Trans. Am. Ent. Soc. III, 277, 1871.
Barnes & McDunnough, Contributions IV, (2), 80, 1918.

Type locality Dallas, Texas. Apparently this species belongs in *Pamphila*, but I know nothing of it except from the description and Barnes and McDunnough's note.

Genus HYLEPHILA Billberg

Hylephila Billb., Enum. Ins. 81, 1820. Type *Papilio phylaeus* Drury.

Euthymus Scud., Syst. Rev. 56, (77), 1872. Type *P. phylaeus* Drury.

This genus closely resembles *Pamphila* in structure but differs in the very short antennae and the straighter stigma. The female, as in *Atalopedes*, does not differ much in general structure from the male; some are almost indistinguishable from *campestris*, but they never have hyaline spots on the primaries. We have but one species of *Hylephila*.

1. *HYLEPHILA PHYLAEUS*

Papilio phylaeus Drury, Ill. Ex. Ent. I, 25, pl. XIII, ff. 4, 5, 1770 and II, app., 1773.

Phemiades augias Hübner, (not Linn.), Zutr. exot. Schmett. II, 10, pl. 531, ff. 227, 228, 1821-23.

Pamphila bucephalus Steph., Ill. Brit. Ent. Haust. I, 102, pl. 10, ff. 1, 2, 1828.

♀ *Pamphila hala* Butler, Trans. Ent. Soc. London, 1870, 504, (fide G. & S.).

Scudder, Butt. New Eng. II, 1631, 1889.

Holland, Butterfly Book, 354, pl. XLVII, f. 40, (not *brettus* ♂), pl. XLVI, ff. 18, 19, 1898.

Wright, Butt. W. Coast pl. XXXI, f. 437 (not *brettus* ♂), 438 ♂, b and c ♀ (not *brettoides*), 1905.

Pennsylvania, August; Illinois, April and October. Southern United States from Florida to Arizona, April to October. California, June and July.

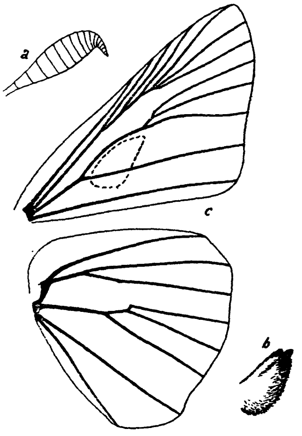


Fig. 24. *Atalopedes campestris* Boisd, a. Club of antenna, b. Palpus, c. Neuration

Genus ATALOPEDES Scudder

Atalopedes Scudder, Syst. Rev. 57, (78), 1872. Type *Hesperia huron* Edw.

Pansydia Scud., Syst. Rev. 60, (81), 1872. Type *Hesperia mesogramma* Poey.

Apiculus of antennae longer than in *Pamphila*, over one-half thickness of club in female. Stigma a large, black blotch, so greatly developed as to cause distortion of the posterior margin of the cell so that opposite the stigma the width of the cell is less than its distance from the margin. Base of vein 3 strongly curved; apical angle of cell more produced than in *Pamphila;* vein 7 of secondaries nearer to 8 than to end of cell in male. There is much less difference in structure between the sexes in this genus than in *Pamphila.* Fig. 24.

1. *ATALOPEDES CAMPESTRIS*

Hesperia campestris Boisd., Ann. Soc. Ent. France (2), x, 316, 1852.
♀ *Hesperia sylvanoides* Boisd., Ann. Soc. Ent. France (2), x, 313, 1852.
Hesperia huron Edw., Proc. Ent. Soc. Phil. II, 16, pl. I, ff, 1, 2, 1863.
Scudder, Butt. New Eng. II, 1661, 1884.
Holland, Butterfly Book 352, pl. XLVI, ff, 4, 5, 1898.
Wright, Butt. W. Coast 245, pl. XXXI, f. 435, 1905.
Oberthür, Etudes IX, (1), pl. CCXL, ff. 2082, ♂ type; 2085, ♀ type of *sylvanoides,* 1905.

Atlantic to Pacific, Gulf to northern Iowa and Illinois; March to October.

The large stigma of the male and the hyaline spots on the primaries of the female furnish a convenient means for the identification of this species.

Genus AUGIADES Hübner

Augiades Hbn., Verz. bek. Schmett. 112, 1820. Type *Papilio sylvanus* Esper.
Ochlodes Scud., Syst. Rev. 57, (78), 1872. Type *Hesperia nemorum* Boisd.

Palpi upturned; third joint oblique, very small, without its vestiture about one-quarter as long as the second. Apiculus of antennae variable but never longer than diameter of club. Costa of primaries flattened; outer margin more strongly curved toward apex; cell about three-fifths as long as wing; vein 5 curving slightly toward 4; discocellulars very oblique. Secondaries rounded, slightly lobed at anal angle. Stigma straight, moderately heavy, extending from base of vein 3 to basal two-fifths of 1, broken on 2. Mid tibiae weakly spined. Fig. 23.

I group this rather varied lot of species because of the extremely short third joint of their palpi. This is not readily seen except when bleached or denuded, but I have carefully examined *sylvanus, sylvanoides, agricola,* and *snowi* and find that they agree, while the others can readily be associated on superficial resemblance. Other structures are rather variable.

Key to the species

1. Spots of primaries shaply defined, often hyaline or subhyaline......2
   Spots more or less ill defined, never hyaline......................3
2. Expanse over one inch; fulvous spots restricted...............*snowi*
   Less than one inch; fulvous of secondaries a diffused discal patch ....*milo, agricola*
3. Large; wings pale, tawny, with a little fuscous along the outer margin ....*yuma*
   Smaller; wings not broadly tawny..............................4
4. Under surface of secondaries with a variably distinct pale transverse band; ground color not pure pale yellowish...........*sylvanoides, napa*
   Under surface without a pale band, yellow........*nemorum, pratincola*

1. *AUGIADES SYLVANOIDES*

Hesperia sylvanoides Boisd., Ann. Soc. Ent. France (2), x, 313, 1852.
♀ *Hesperia pratincola* Boisd., Ann. Soc. Ent. France (2), x, 315, 1852.
Hesperia agricola Plötz, (not Boisd.), Stett, ent. Zeit. XLIV, 219, 1883.
Hesperia francisca Plötz, Stett. ent. Zeit. XLIV, 220, 1883.
Wright, Butt. W. Coast 243, pl. XXXI, ff. 430, c, 432, 433, b, c, 1905.
Oberthür, Etudes IX, (1), pl. CCXL, ff. 2083, 2084, 2089, 1913.

California, Oregon, Washington, British Columbia; June to August.

1a. race *NAPA*

Hesperia napa Edwards, Proc. Ent. Soc. Phil. IV, 202, pl. I, ff. 3, 4, 1864.

Colorado, August.

This is practically the same in appearance as *sylvanoides* but is larger and the under surface of the secondaries is less variable.

2. *AUGIADES NEMORUM*

Hesperia nemorum Boisd., Ann. Soc. Ent. France (2), x, 314, 1852.
Pamphila verus Edw., Trans. Am. Ent. Soc. IX, 4, 1881.
Wright, Butt. W. Coast, pl. XXXI, ff. 430b, 431, 431c?, 1905.
Oberthür, Etudes IX, (1), pl. CCXL, f. 2086, 1913 (type).

California, June.

2a. race *PRATINCOLA*

Hesperia pratincola Boisd., Ann. Soc. Ent. France (2), x, 315, 1852.
Oberthür, Etudes IX, (1), pl. CCXL, f. 2088, 1913 (type).

I follow Barnes and McDunnough's Check List in placing this form. The insect is not represented in the Barnes collection, but Oberthür's excellent figure looks like a specimen of *nemorum* with the fuscous marginal areas of the upper surface greatly reduced.

3. *AUGIADES AGRICOLA*

Hesperia agricola Boisd., Ann. Soc. Ent. France (2), x, 314, 1852.
Hesperia yreka Edw., Proc. Ent. Soc. Phil. VI, 207, 1866.
Pamphila milo Edw., Can. Ent. XV, 34, 1883.

Pamphila nemorum Skinner (not Boisd.), Ent. News XI, pl. II, f. 21, 1900.
Kellogg, Am. Ins. pl. IX, f. 21, 1904.
Oberthür, Etudes IX, (1), pl. CCXL, f. 2087, 1913 (type).
California, May to July.

Edward's description states that *milo* has hyaline spots in the primaries and *agricola* none; Oberthür's figure proves that they are present in the type of *agricola,* hence *milo* is probably merely a synonym.

4. *AUGIADES SNOWI*

Pamphila snowi Edw., Can. Ent. IX, 29, 1877.
Holland, Butterfly Book 350, pl. XLVII, ff. 29, 30, 1898.
Biol. Cent.-Am., Rhop. II, 483, pl, 93, ff. 19-23, 1900.
Arizona and Colorado, June and July.

5. *AUGIADES YUMA*

Hesperia yuma Edw., Trans. Am. Ent. Soc. IV, 346, 1873.
Pamphila scudderi Skinner, Ent. News X, 111, 1899.
Skinner, Ent. News XI, pl. II, ff. 9, 10, 1900.
California, June. Utah and Arizona, July.

Genus POLITES Scudder

Polites Scud., Syst. Rev. 57, (78), 1872. Type *Hesperia peckius* Kirby.

Hedone Scud., op. cit. 58, (79), Type *Hesperia brettus* Bd. & Lec.

Limochores Scud., op. cit. 59, (80). Type *Hesperia manataaqua* Scud.

Pyrrhosidia Scud., Mem. Bost. Soc. Nat. Hist. II, 346, 1874. Type *Hesperia mystic* Edw.

Palpi upturned; third joint about one-half as long as second, slender, distinct. Antennae shorter than in *Augiades,* varying from two-fifths as long as the primaries in some females to one-half in some males; club rather large, usually longer in the female and occasionally almost as long as the shaft; apiculus abruptly constricted and reflexed, shorter than thickness of club though variable in length. Wings variable; costa of primaries usually straight except at base and apex but sometimes slightly emarginate or convex; outer margin very slightly sinuate to evenly rounded, more rounded in the female. Primaries often apically produced in the male, less so in the female. Secondaries broadly rounded, very slightly lobed at the anal angle. Cell of primaries about three-fifths as long as wing; vein 5 much nearer to 4 than to 6 at base; 2 always arising nearer to 3 than to base of wing but variable; discocellulars moderately oblique. Mid tibiae with prominent spines. Stigma of male in its most complex form made up of an outer oblique black line, a black dash from end of cell to vein 2 and a black spot above the basal third of vein 1, the enclosed space filled with gray scales, and the entire stigma followed by a patch of raised gray scales. In many of the species the stigma is much simpler. Fig. 25.

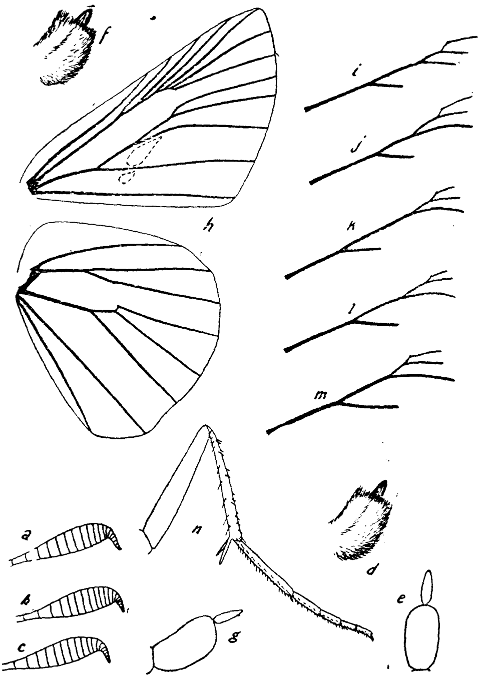


Fig. 25. *Polites.* Antennal clubs: a. *verna*, b. *manataaqua* ♂, c. *manataaqua* ♀. Palpi: d. *verna*, e. *verna*, denuded. dorsal aspect, f. *manataaqua*, g. *brettus*, denuded. Neuration and details: h. *peckius* ♂, i. Posterior margin of cell of primaries of *peckius* , j. Same, *taumas* ♂, k. Same, *mystic* ♀, 1. Same, *sonora* ♂, m. Same, *manataaqua* ♀, n. Middle leg of *verna*

I believe that the action of Barnes and McDunnough with reference to this group of species (Contributions III, 130) is the best possible treatment. It may be possible to split off *Limochores* but I find such a complete transition in the structures that I hesitate to do so. I place *verna* here because its relation to *manataaqua* seems to me much closer than with the species of *Atrytonopsis,* where Barnes and McDunnough place it. The gentitalia of the male are closer to *deva,* but those of the two genera are of a very similar type. The apiculus of the antennae is usually longer than in *Polites,* but I have found it variable, and in some specimens fairly short.

Key to the species

1. Under surface of secondaries immaculate or with a transverse band of pale spots, never sharply bent opposite cell nor with spot at this point much the largest 2
   Secondaries otherwise below 7

2. Upper surface of secondaries immaculate or with a few very vague spots 3
Upper surface always with the transverse row of spots, more or less suffused; usually with a spot in cell................................5
3. Small Florida species. Stigma of male very small, female usually with a few powdery whitish spots on the under surface of the secondaries ....*baracoa*
Usually moderate to large. Stigma large. Spots, when present, not superficial and powdery, and usually showing slightly on upper surface 4
4. Smaller; male stigma with several velvety black areas; female with maculation of primaries tinged with fulvous, costa and cell often partly fulvous..*cernes*
Larger; stigma of male continuous or broken only on vein 2; maculation of female pale, whitish, rarely with a little pale fulvous in cell ....*manataaqua*
5. Under surface of secondaries powdered with yellowish to green scales; macular band slender..*sonora*
Color straw yellow to brown; band broader.......................6
6. Male stigma slender, broken on vein 2; female usually with much yellow-fulvous above; in western specimens pale below and well marked above ....*mystic*
Male stigma with three black areas; female with hazy transverse rows of spots on all wings and some fulvous in cell, not extensively marked; dark below, powdered with yellow. Western species..........*mardon*
7. Pale areas on under surface extending in pale lines along the veins ....*sabuleti*
Pale areas at most angulate on veins...........................8
8. All spots of macular band large, but not equal, that between 4 and 6 largest; color yellow..*peckius*
Spots small except the one between 4 and 6; color white or whitish ....*draco*
Pale area covering entire wing except a few dark patches, not divided into separate spots and rarely defined as a band; secondaries sometimes entirely yellow below. Female with yellow areas heavily powdered with dark scales; secondaries immaculate above.........................9
9. Male stigma very broad.....................................*stigma*
Male stigma moderate..........................*brettus, chuska* (?)

1. *POLITES VERNA*

Pamphila verna Edw., Proc. Acad. Nat. Sci. Phil. 1862, 57.
Pamphila pottawattomie Worth., Can. Ent. XII, 50, 1880.
Scudder, Butt. New Eng. II, 1742, 1889.
Holland, Butterfly Book 360, pl. XLVI, f. 32, 1898.

Eastern United States, west to Colorado, July.

2. *POLITES MANATAAQUA*

Hesperia cernes Harris, (not Boisd.), Ins. Inj. Veg., 3rd ed., 316, 1862.
Hesperia manataaqua Scudder, Proc. Ess. Inst. III, 175, 1863.
Scudder, Butt. New Eng. II, 1720, 1889.
Holland, Butterfly Book 357, pl. XLVI, f. 30, 1898.

Northeastern United States west into Nebraska and South Dakota; June and July.

Holland's figure looks like a dark female of *taumas*. *Manataaqua* is readily distinguished from *taumas* in the female sex by its darker color, paler maculation and larger size, though the difference is difficult to explain in a key.

2a. race *RHENA*

Pamphila rhena Edw., Field and Forest III, 115, 1878.
Pamphila alcina Skinner, Ent. News IV, 212, 1893.
Skinner, Ent. News XI, 414, pl. II, f. 25, 1900 (type of *alcina*).
Kellogg, Am. Ins. pl. IX, f. 25, 1904 (type of *alcina*).

Although retained for many years as a species this is apparently only the western race of *manataaqua*. It is distinguished from the typical form by its paler color, more extensive markings and the larger amount of pale tawny or yellow fulvous which marks the upper surface. Colorado.

3. *POLITES TAUMAS*

Papilio taumas Fab., Mant. Ins. II, 84, 1787.
Hesperia thaumas Fab. (not Hufn.), Ent. Syst. III, (I), 327, 1793.
Hesperia phocion Fab., Ent. Syst., Supp. 431, 1798.
Hesperia cernes Bd. & Lec., Lep. Am. Sept. pl. 76, ff. 1, 2, 1833.
Hesperia ahaton Harris, Ins. Inj. Veg. 3rd ed., 317, f. 140, 1862.
Butler, Cat. Fab. Diurn. Lep. B. M., 277, pl. 2, f. 14; pl. 3, f. 9, 1869.
Scudder, Butt. New Eng. II, 1725, 1889.
Holland, Butterfly Book 357, pl. XLVII, f. 20, 1898.

United States and Canada, April to August.

I see no reason to doubt that Fabricius' name applies to this species.

4. *POLITES BARACOA*

Hesperia baracoa Lucas, Sagra's Hist. Cuba VII, 650, 1857.
Pamphila amadis H.-S., Corr.-Blatt Regensb. XVII, 142, 1863.
Pamphila myus French, Can. Ent. XVII, 33, 1885.

Florida, February to April, July, September. I have seen one record of its occurrence at Toronto, Canada (A List of Butterflies taken at Toronto, Gibson, Ont. Nat. Sci. Bull. No. 6, 1910, 35-44. *Baracoa* det. Skinner) but the only specimens which I have seen came from Florida.

The species is smaller and darker than *taumas* and the males are easily distinguished by the small stigma. Some females of *taumas* run very close, but in most specimens of *baracoa* the powdery spots mentioned in the key are present.

5. *POLITES MARDON*

Pamphila mardon Edw., Papilio I, 47, 1881.
Holland, Butterfly Book 354, pl. XLVII, f. 26, 1898.

Washington, Oregon.

6. *POLITES PECKIUS*

Hesperia peckius Kirby, Faun. Bor. Am. IV, 300, pl. 4, ff. 2, 3, 1837.
Hesperia wamsutta Harris, Ins. Inj. Veg. 3rd ed., 318, f. 141, 1862.
Scudder, Butt. New Eng. II, 1683, 1889.
Holland, Butterfly Book, 353, pl. XLVII, ff. 24, 25, 1898.

Atlantic coast to Texas and Arizona, southern Canada; May to July.

It requires more imagination than I possess to see *peckius* in Cramer's figure of *coras*.

7. *POLITES SABULETI*

Hesperia sabuleti Boisd., Ann. Soc. France (2), X, 316, 1852.
Hesperia genoa Plötz, Stett. ent. Zeit. XLIV, 207, 1883.
Wright, Butt. W. Coast 246, pl. XXXI, 440, 1905.
Oberthür, Etudes IX, (1), pl. CCXL, ff. 2091, 2092, 1913.

California, April, July to September.

The pale marks of the lower surface are yellowish on a background of darker yellowish color.

7a. race *TECUMSEH*

Pamphila sabuleti, var. *tecumseh* Grinnell, Ent. News XIV, 11, 1903.
Pamphila chispa Wright, Butt. W. Coast 247, pl. XXXI, f. 441, 1905.

California, June to August.

Tecumseh is smaller than typical *sabuleti* and has the fulvous areas of the upper surface more restricted. The under surface has a greenish-gray tone and the pale spots are smaller.

8. *POLITES DRACO*

Pamphila draco Edw., Trans. Am. Ent. Soc. III, 274, 1871.
Skinner, Ent. News XI, pl. II, f. 23, 1900.
Kellogg, Am. Ins. pl. IX, f. 23, 1904.

California, Utah and Colorado, June to August.

9. *POLITES SONORA*

Ochlodes sonora Scud., Syst. Rev. 57, (78), 1872.
Pamphila siris Edw., Papilio I, 47, 1881.
Pamphila sylvanoides Skinner, Syn. Cat. N. Am. Rhop. 84, 1898.
Wright, Butt. W. Coast 242, pl. XXXI, f. 425, 426 (not *columbia*), 1905.

Washington, Oregon, California; May, June, July and August.

The only difference which I can see between this and Skinner's variety in the series in the Barnes collection is the more yellow color of the under surface of its secondaries.

9a. race *UTAHENSIS*

Pamphila sylvanoides, subsp. *utahensis* Skinner, Ent. News XXII, 413, 1911.

Idaho, Wyoming, Colorado and Utah; July and August.

I would apply this name to the specimens of *sylvanoides* which are green below.

10. *POLITES MYSTIC*

Hesperia mystic Scud., Proc. Ess. Inst. III, 172, 1863.

Holland, Butterfly Book 351, pl. XLVI, ff. 22, 23, 1898.

New Jersey, north into Canada and west beyond the Missouri River; May to July.

Most specimens from the western limits of the range are of the race *dacotah*, but I have typical *mystic* from Sioux City, Iowa. In this form the under surface of the secondaries is fairly dark with a contrasting pale band.

10a. race *DACOTAH*

Hesperia dacotah Edw., Trans. Am. Ent. Soc. III, 277, 1871.

Pamphila mystic, subsp. *pallida* Skinner, Ent. News XXII, 412, 1911.

Colorado, June; eastward into Iowa. South Dakota.

The under surface of the secondaries is yellow, scarcely darker than the pale transverse band in extreme specimens.

ab. WEETAMOO

Thymelicus mystic weetamoo Scudder, Butt. New Eng. II, 1707, 1889.

A dark brown melanic aberration occurring in the female sex. Ordinary maculation much reduced, of separate spots.

ab. NUBS

Thymelicus mystic nubs Scudder, Butt. New Eng. II, 1707, 1889.

Also a female aberration; dark areas suffused with tawny scales.

11. *POLITES BRETTUS*

Hesperia brettus Boisd. & Lec., Lep. Am. Sept. pl. 75, ff. 3-5, 1833.

Hesperia wingina Scud., Proc. Ess. Inst. III, 173, 1863.

Hesperia unna Plötz, Stett. ent. Zeit. XLIV, 204, 1883.

Scudder, Butt. New Eng. II, 1701, 1889.

Holland, Butterfly Book 351, pl. XLVII, f. 41, 1898.

Gibson, Ont. Nat. Sci. Bull. No. 6, 42, 1910.

Florida, north to Virginia, west to Texas; April, July, August and October. Gibson lists one specimen from Toronto, Canada, determined by Dr. Skinner.

11a. race *BRETTOIDES*

Pamphila brettoides Edw., Papilio III, 71, 1883.

Western Texas and Arizona.

Brettoides has very narrow dark outer margins on the upper surface in the male, with no more than a trace of the patch at the end of the stigma; the under surface is likewise broadly tawny yellow. I do not know the female.

12. *POLITES STIGMA*

Pamphila stigma Skinner, Can. Ent. xxviii, 188, 1896.
Skinner, Ent. News xi, pl. ii, f. 15, 16, 1900 (15 Cotype).
Kellogg, Am. Ins. pl. ix, ff. 15, 16, 1904 (15 Cotype).
Texas, New Mexico.

I have seen the type of *stigma* in the Strecker collection, and it is similar to *brettus* but dark, heavily marked above, and has a very large stigma. *Vibex* is intermediate between it and *brettus* but at present I am not prepared to agree with Dyar's suggestion that they are all the same species (Jn. N. Y. Ent. Soc. xiii, 128, 1905). Godman and Salvin make *stigma* synonymous with *vibex* (Biol. Cent.-Am., Rhop. ii, 480, 1900).

13. *POLITES CHUSKA*

Hesperia chuska Edw., Trans. Am. Ent. Soc. iv, 346, 1873.

I know nothing of this species. It is placed between *sabuleti* and *draco* in Barnes and McDunnough's Check List, but this was done merely with a knowledge of the description. The type locality is Arizona.

Genus CATIA Godman & Salvin

Catia G. & S., Biol. Cent.-Am., Rhop. ii, 481, 1900. Type *Hesperia druryi* Latreille.

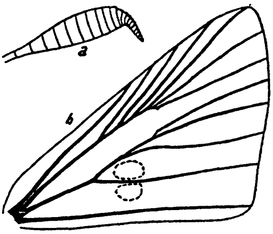


Fig. 26. *Catia otho* A. & S. a. Club of antennae, b. Neuration

Catia is structurally similar to *Polites* but differs in the long slender apiculus of the antennae, which always exceeds the diameter of the club, and in the form of the male stigma. The stigma is composed of a velvety black patch below the end of the cell and a similar patch above the inner third of the anal vein, with large, silky, gray scales between. In the bleached wing it appears as two similar oval spots, one on each side of vein 1. Fig. 26.

In describing *Catia* Godman and Salvin say of the peculiar structure of the stigma that it "is so remarkable that we think it of sufficient importance to put the species possessing this character into a separate genus." *Otho* is closely related to the species now included in *Polites* and was formerly associated with some of them in *Thymelicus*, but the form of the apiculus separates them, and no fundamental or superficial similarity can be traced in the stigmata.

1. *CATIA OTHO*

Papilio otho A. & S., Lep. Ins. Ga. i, 31, pl. 16, 1797.
Hesperia drury Latr., Enc. Meth. ix, 767, 1823.
Thymelicus pustula Geyer, Zutr. exot. Schmett. iv, ff. 625, 626, 1832.
Hedone aetna Scud. (not Boisd.), Syst. Rev. 58, (79), 1872.
Scudder, Butt. New Eng. ii, 1696, 1889.
Biol. Cent.-Am., Rhop. ii, 482, pl. 93, f. 18, ♂ gen., 1900.

Florida and Texas, May and June.

The southern specimens which I refer to *otho* tend to a reddish shade on the under surface; on the upper surface of the secondaries there are some discal spots, while the primaries have fulvous on the basal half of the costa, a complete series of subapical spots, and sometimes other fulvous marks in addition to those found in *egeremet.*

1a. race *EGEREMET*

Hesperia egeremet Scud., Proc. Ess. Inst. iii, 174, 1863.
Pamphila ursa Worth., Can. Ent. xii, 49, 1880.
Hesperia cinna Plötz, Stett. ent. Zeit. xliv, 58, 1883.
Scudder, Butt. New Eng. ii, 1696, 1889.
Holland, Butterfly Book 351, pl. xlvi, ff. 28, 29, 1898.

United States and southern Canada, west to the Rocky Mountains; July. Texas in October.

Under surface pale fuscous, sometimes tinged with brown; secondaries rarely with a trace of discal marks above, and pale spots of primaries limited to three or less beyond the stigma and one or two subapical points.

The females of *otho* and *egeremet* have the same pale marks as the males.

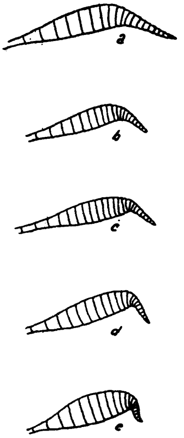


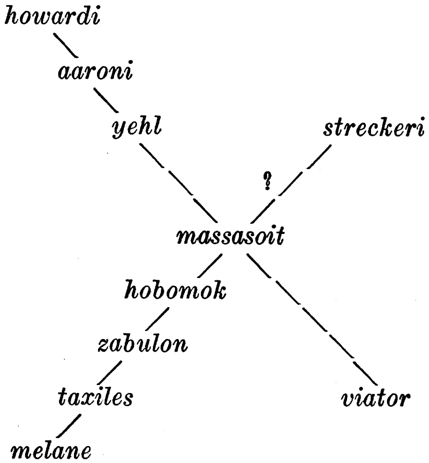
Fig. 27. Antennal clubs of *Poanes*. a. *viator*, b. *massasoit*, c. *hobomok*, d. *taxiles*, e. *melane*

Genus POANES Scudder

Poanes Scudder, Syst. Rev., 55, (76), 1872. Type *Hesperia massasoit* Scud.
Phycanassa Scud., op. cit. 56, (77). Type *Hesperia viator* Edw.
Paratrytone Dyar, Jn. N. Y. Ent. Soc. xiii, 136, 1905. Type *Pamphila howardi* Skinner.

Palpi oblique; second joint shaggy, third small, not long though sometimes rendered prominent by its vestiture. Antennae about one-half as long as primaries; club large, apiculus varying from rather slender and slightly shorter than thickness of club to long, thick, tapering and not well reflexed. Primaries trigonate; costa slightly convex; outer margin slightly to prominently rounded; apex rather prominent. Secondaries broadly rounded, slightly lobed at anal angle. Cell of primaries well over one-half as long as wing; vein 5 moderately curved in basal half, arising nearer to 4 than to 6; 2 nearer to 3 than to base of wing. Cell of secondaries less than one-half as long as wing. Mid tibiae with a few long spines. Fig 27.

Hobomok, zabulon, taxiles, and *melane* were first placed in *Poanes* by Barnes and McDunnough (Contributions III, 132, 1916). Although *melane* is rather anomalous, it apparently belongs with the other species, whose relation to *massasoit* through *hobomok* is obvious. Owing to the great range of variation thus introduced into the genus in the structure of the antennae, palpi, and wings, I have added also *viator*, which differs somewhat in wing form, and the species placed by recent writers in *Paratrytone.* These last possess the stigma in the male but it is so variable that I regard it as in the process of development. In *howardi, aaroni,* and *streckeri* it is very slender, sometimes scarcely visible but often well marked, and in *yehl* it is heavier but very variable. In one of the types it is slender, while in the other it is as heavy as in some specimens of *conspicua.* Including all of these species *Poanes* becomes such a complex genus that I have drawn up the following diagram to show the apparent relations of the several groups:



Key to the species

1. Under surface of secondaries with bright yellow marks..............2
   No clear yellow on under surface................................4
2. Yellow a broad transverse band crossed by a broad ray through cell..3
   Yellow much more extensive..............................*zabulon*
3. Wings broadly yellow-fulvous with narrow fuscous margins; yellow of under surface rather dull..................................*taxiles*
   Wings less broadly fulvous and more or less fuscous within outer margin; yellow of under surface of secondaries very bright......*hobomok*
   Wings dark, with or without small pale spots..............*massasoit*
4. Upper surface of secondaries with pale markings indefinite, or faint; sometimes immaculate..5
   This surface with a bright yellow-fulvous patch....................8
5. Pale spot in cell of primaries at least faintly indicated....*pocahontas*
   No trace of this spot..6
6. Wings immaculate above...................*massasoit* form *suffusa*
   Wings with pale spots..7
7. Under surface with some bluish irroration..................*zabulon* ♀
   Without bluish irroration..................................*melane*
8. Primaries with definite spots or a dark stigma.....................9
   Spots diffuse, extended, or discal area broadly yellow-fulvous; male stigma pale, slender..10
9. ♂ with stigma; ♀ with three small, round, pale spots on under surface of secondaries...*yehl*
   ♂ without stigma; ♀ without such spots.....................*viator*
10. Under surface of secondaries with a vague, pale dash through cell
   ....*howardi, aaroni*
   Under surface partly greenish-fuscous with contrasting pale veins
   ....*streckeri*

1. *POANES VIATOR*

Hesperia viator Edw., Proc. Ent. Soc. Phil. IV, 202, pl. I, f. 5, 1865.
Scudder, Butt. New Eng. II, 1604, 1889.
Holland, Butterfly Book 362, pl. XLVI, f. 15, 1898.

New York, New Jersey, Michigan, Southeastern Canada, Omaha, Neb., (Leussler); June to August.

2. *POANES MASSASOIT*

Hesperia massasoit Scud., Proc. Ess. Inst. III, 171, 1863.
Scudder, Butt. New Eng. II, 1597, 1889.
Holland, Butterfly Book 361, pl. XLVI, ff. 21, 22, 1898.

New Jersey, New York, Rhode Island, Iowa, July. Skinner (Cat. p. 80) records it westward and southward to Texas and Colorado.

The male is either immaculate blackish brown above or with a few small yellow-fulvous spots, while the female frequently has the spots of large size and a very pale shade.

Form *SUFFUSA*

Pamphila massasoit, var. *suffusa* Laurent, Ent. News III, 15, 1892.
Skinner, Ent. News XI, pl. II, f. 22, 1900.
Kellogg, Am. Ins. pl. IX, f. 22, 1904.

New Jersey, New York; June and July.

The pale area of the under surface of the secondaries of this form is heavily powdered with rusty brown scales.

3. *POANES HOBOMOK*

Hesperia hobomok Harris, Ins. Inj. Veg. 3rd ed., 313, f. 137, 1862.
Atrytone zabulon Scud., (not Bd. & Lec.), Butt. New Eng. II, 1617, 1889.
Atrytone zabulon Holland (not Bd. & Lec.), Butterfly Book 364, pl. XLVII, ff. 37, 38, 1898.

West Virginia north into Canada and west into Nebraska; May and June.

♀ form *POCAHONTAS*

Hesperia pocahontas Scud., Proc. Ess. Inst. III, 171, 1863.
Hesperia quadaquina Scud., Proc. Bost. Soc. Nat. Hist. XI, 381, 1868.
Scudder, Butt. New Eng., II, 1617, 1889.
Skinner, Ent. News XI, pl. II, ff. 3, 4, 1900 (not normal *hobomok* ♀).

Northeastern United States, Quebec; June.

Pocahontas differs from the normal female in the pale shade and greater restriction of the spots on the upper surface, and the brown powdering of the secondaries below.

4. *POANES ZABULON*

Hesperia zabulon Boisd. & Lec., Lep. Am. Sept. pl. 76, ff. 6, 7, 1833.
Hesperia zabulon, form *pocahontas* Holland (not Scudder), Butterfly Book 364, pl. XLVII, f. 39, 1898.

Illinois, Pennsylvania, Kentucky, North Carolina; May and August.

Holland's figure looks much more like the true female of *zabulon* than like *pocahontas,* though it is impossible to identify a figure of the upper surface accurately. The under surface of the secondaries of the male of *zabulon* is bright yellow with a few marks of brown. In the female the brown areas are more extensive and the entire wing is so heavily powdered with rusty scales that it is difficult to trace the pale areas at all.

5. *POANES TAXILES*

Pamphila taxiles Edwards, Trans. Am. Ent. Soc. IX, 5, 1881.
Holland, Butterfly Book 365, pl. XLVII, ff. 31, 32, 1898.

Colorado and Arizona, June and July. Nevada, N. M.

6. *POANES MELANE*

Hesperia melane Edw., Trans. Am. Ent. Soc. II, 312, 1869.
Biol. Cent.-Am., Rhop. II, 494, pl. 94, ff. 30-34, 1900.
Holland, Butterfly Book 365, pl. XLVI, ff. 7, 8, 1898.
Wright, Butt. W. Coast 249, pl. XXXI, f. 453, 1905.

California, south into Mexico; May.

Melane and the female of *taxiles* are similar but they are not difficult to separate; usually the locality from which the specimens come is sufficient.

7. *POANES HOWARDI*

Pamphila howardi Skinner, Can. Ent. xxviii, 187, 1896.
Phycanassa viator Holland, (not Edwards), Butterfly Book pl. xlvi, f. 14, 1898. Op. cit. pl. xlvi, f. 38.

Florida.

The expanse of specimens which I have seen runs between thirty-two and thirty-six millimeters. Aside from this and its darker color the species does not differ superficially from *aaroni.*

8. *POANES AARONI*

Pamphila aaroni Skinner, Ent. News i, 6, 1890.
Holland, Butterfly Book 363, pl. xlvi, f. 37, 1898.

New Jersey, June and August. I have seen specimens only from Anglesea and Atlantic City.

Aaroni expands twenty-seven to thirty-three millimeters and is paler, more yellowish, than *howardi. Howardi* may yet prove to be a southern race of *aaroni.*

9. *POANES YEHL*

Pamphila yehl Skinner, Ent. News iv, 212, 1893.
Holland, Butterfly Book 359, pl. xlvi, f. 40, 1898.

Tennessee, Georgia, Mississippi; August and September.

Superficially this species looks more like a relative of *A. conspicua* but the mid tibiae are spined. The white spots on the under surface of the secondaries in the female are unique.

10. *POANES RADIANS*

Hesperia radians Lucas, Sagra's Hist. Cuba vii, 650, 1857.
Pamphila streckeri Skinner, Ent. News iv, 211, 1893.
Skinner, Ent. News xxviii, 82, 1917.

Florida.

The only specimen which I have seen is the type of *streckeri* and since it lacks the middle legs it is impossible to place the species definitely. Barnes and McDunnough place it in the genus Euphyes in the check list, but without specimens at hand. Its superficial resemblance is rather with *aaroni.*

Genus ATRYTONE Scudder

Atrytone Scud., Syst. Rev. 56, (77), 1872. Type *Hesperia iowa* Scud.

Euphyes Scud., Syst. Rev. 59, (80), 1872. Type *Hesperia metacomet* Harris.

Anatrytone Dyar, Jn. N. Y. Ent. Soc. xiii, 140, 1905. Type *Hesperia delaware* Edwards.

Palpi upturned; second joint closely appressed, smoothly and deeply scaled; third moderate, oblique. Antennae about one-half as long as primaries; club long, moderately thick; apiculus about as long as thickness of club, sometimes a little shorter. Costa of primaries flattened or very slightly convex; outer margin moderately and almost evenly rounded; apex usually prominent. Secondaries rather small, rounded, slightly lobed at anal angle; a little more apically elongate in the females. Cell of primaries normal; discocellulars oblique, weak; vein 5 curved, nearer to 4 than to 6; 2 about intermediate between 3 and base of wing. Stigma present or absent, composed of two similar, slender, elliptic pieces placed end to end on opposite sides of vein 1. Mid tibiae without spines.

The long antennal club and spineless mid tibiae make this a very distinct genus as used here, but no characters are available for the separation of *Atrytone* and *Euphyes* of other writers except the male stigma, which is present only in the species formerly placed in *Euphyes*. The types of the two do not resemble each other, but in the species congeneric with them we find an excellent connecting series, in which *arpa* and *byssus* differ very slightly except in the stigma.

Key to the species

1. Under surface of secondaries immaculate or with a faint, pale, transverse band on disk........2
   Under surface of secondaries with two pale rays........*dion*
   Under surface with a few diffuse spots forming a curved transverse row........*conspicua*
2. Fringe of inner margin of secondaries white........*bimacula*
   Fringe of this margin not white........3
3. Wings immaculate fuscous above and below or with a few small pale spots on primaries (♀)........*vestris*
   Wings with more pale markings........4
4. Wings mostly dark brownish-gray below........*palatka*
   Wings tinged with yellow or red below........5
5. Stigma present........*arpa* ♂
   Stigma absent........6
6. Upper surface of secondaries fuscous........7
   Secondaries with fulvous discal marks........8

7. Primaries with a transverse row of fulvous spots..............*arpa* ♀
   With diffuse pale fulvous areas..............................*arogos* ♀
8. Veins black...9
   Veins not black...*arogos*
9. Wings usually broadly yellow-fulvous with a terminal fuscous band above; immaculate yellow or brownish yellow below............*logan*
   Wings with the fulvous definitely limited; under surface of secondaries in most specimens with a faint pale transverse band, never clear yellow ....*byssus*

1. *ATRYTONE AROGOS*

Papilio vitellius A. & S., (not Fab.), Lep. Ins. Ga. I, 33, pl. XVII, 1797.
Hesperia arogos Boisd. & Lec., Lep. Am. Sept. pl. 76, ff. 3, 4, 5, 1833.
Hesperia iowa Scud., Proc. Bost. Soc. Nat. Hist. XI, 401, 1868.
Hesperia mutius Plötz, Stett. ent. Zeit. XLIV, 199, 1883.
Atrytone vitellius Holland (not Fab.), Butterfly Book 364, pl. XLVI, f. 6, 1898.

Florida, August and September. Nebraska and Iowa, June and July. Ocean County, N. J., July (Davis).

The pale tawny wings with their broad, even, fuscous borders distinguish the male; the female is readily associated with the male, but the fuscous is more extensive, encroaching upon the discal area and often almost obliterating the tawny color.

2. *ATRYTONE LOGAN*..

Hesperia logan Edw., Proc. Ent. Soc. Phil. II, 18, pl. I, f. 5, 1863.
Hesperia delaware Edw., op. cit. p. 19, pl. 5, f. 2.
Scudder, Butt. New Eng. II, 1614, 1889.
Biol. Cent.-Am., Rhop. II, 490, pl. 94, ff. 4-6, 1900.
Holland, Butterfly Book 365, pl. XLVI, f. 24, 25, 1898.

Florida to Texas, north to Montana and Illinois; July and August.

2a. race *LAGUS*

Pamphila lagus Edw., Trans. Am. Ent. Soc. IX, 5, 1881.

I regard this as scarcely worth separating from *logan*. It is the western race, and in extreme forms has the fuscous terminal borders reduced to very slender lines and the under surface very pale.

3. *ATRYTONE BYSSUS*

? *Hesperia bulenta* Bd. & Lec., Lep. Am. Sept. pl. 67, ff. 1-5, 1833.
Pamphila byssus Edw., Can. Ent. XII, 224, 1880.
Holland, Butterfly Book 358, pl. XLVI, f. 20, 1898.

Florida, August. Skinner includes Texas (Cat. p. 89).

Dr. McDunnough places *bulenta* tentatively as a synonym of *byssus*. The figure is a striking thing, unlike any known species of North America, but it does bear a remote resemblance to this species.

4. *ATRYTONE ARPA*

Hesperia arpa Boisd. & Lec., Lep. Am. Sept. pl. 68, 1833.

Florida, June, September and October.

The stigma is present in the males of this and all of the following species, which make up the former genus *Euphyes.*

5. *ATRYTONE PALATKA*

Hesperia palatka Edw., Trans. Am. Ent. Soc. I, 287, 1867.
Hesperia floridensis Plötz, Stett. ent. Zeit. XLIV, 196, 1883.
Scudder, Butt. New Eng. III, 1863, 1889.
Holland, Butterfly Book 358, pl. XLVI, f. 21, 1898.

Florida, May, August to October. Skinner gives its range as "Gulf States, Neb." (Cat. p. 89).

In the original description the name of this species was spelled *pilatka* but this was amended by Edwards himself in his later writings. It is the largest species of the genus.

6. *ATRYTONE DION*

Pamphila dion Edw., Can. Ent. XI, 238, 1879.

New York, Ohio, Wisconsin, Michigan, Illinois and Omaha, Neb. (Leussler); June and July. St. Louis, Mo. (Knetzger).

The pale dashes on the under surface of the secondaries are unique in this genus.

7. *ATRYTONE CONSPICUA*

Hesperia conspicua Edw., Proc. Ent. Soc. Phil. II, 17, pl. 5, f. 5, 1863.
♂ *Hesperia pontiac* Edw., op. cit. 17, pl. XI, f. 5.
Hedone orono Scud., Syst. Rev. 58, (79) 1872.
Scudder, Butt. New Eng. II, 1732, 1889.
Holland, Butterfly Book 358, pl. XLVI, ff. 16, 17, 1898.

New Jersey north to Massachusetts and west into Nebraska; July.

8. *ATRYTONE BIMACULA*

Hesperia bimacula G. & R., Ann. Lyc. Nat. Hist. N. Y. VIII, 433, 1867.
Hesperia acanootus Scud., Proc. Bost. Soc. Nat. Hist. XI, 381, 1868.
Hesperia illinois Dodge, Can. Ent. IV, 217, 1872.
Scudder, Butt. New Eng. II, 1718, 1889.

Ontario, New Jersey, New York, Iowa; July. Skinner lists Nebraska (Cat. p. 88). I have taken one specimen at Sioux City, Iowa.

The under surface of the secondaries is usually pale with the veins marked in white. The upper surface has a little yellow-fulvous on each side of the stigma in the male, and only two or three small extradiscal spots in the female which are of a very pale color.

9. *ATRYTONE VESTRIS*

Hesperia vestris Boisd., Ann. Soc. Ent. France (2), x, 317, 1852.
Hesperia metacomet Harris, Ins. Inj. Veg. 3rd ed., 317, 1862.

Pamphila rurea Edw., Proc. Acad. Nat. Sci. Phil. 1862, 58.
Hesperia kiowah Reakirt, Proc. Ent. Soc. Phil. vi, 150, 1866.
Hesperia osyka Edw., Trans. Am. Ent. Soc. i, 288, 1867.
Pamphila osceola Lint., 30th Rep. N. Y. Mus. Nat. Hist. 170, 1878.
Scudder, Butt. New Eng. ii, 1739 and iii, 1865, 1889.
Holland, Butterfly Book 360, pl. xlvi, f. 31, 1898.
Wright, Butt. W. Coast 247, pl. xxxi, f. 442, 1905.
Oberthür, Etudes ix, (1), pl. ccxl, f. 2093, 1913 (type).
United States and Southern Canada; May to July.

♀ form *IMMACULATUS*

Pamphila vestris, var. *immaculatus* Williams, Ent. News xxv, 267, 1914.

Described from the Jemez Mts., New Mexico. I have seen it from the White Mts., Arizona, but not from more northern localities. As the name implies, it lacks the whitish spots usually found on the primaries of the female.

Genus ATRYTONOPSIS Godman & Salvin

Atrytonopsis G. & S., Biol. Cent.-Am., Rhop. ii, 497, 1900. Type *Hesperia deva* Edw.

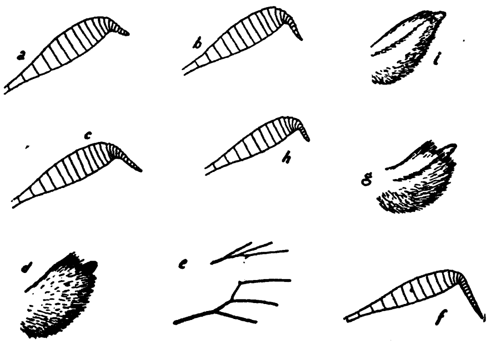


Fig. 28. Antennal clubs: a. *Atrytonopsis deva* Edw., b. *A pittacus* Edw., c. *A. edwardsi* B. & McD., f. *Oligoria maculata* Edw. h. *Lerodea eufala* Edw., Palpi. d. *A. deva Edw*., g. *Mastor bellus* Edw., i. *Lerodea eufala* Edw., e. Detail of neuration: end of cell of primaries, *Lerema accius* S. & A.

Palpi upturned; third joint moderate, oblique, not concealed in vestiture of second. Antennae slightly less than one-half as long as primaries; club moderate, longer in female than male; apiculus shorter than thickness of club in male, equal to it or longer in female. Primaries of male apically produced; costa nearly straight; outer margin slightly rounded; apex rounded-acute. Secondaries rounded; outer margin flattened at end of cell; anal angle slightly lobed; length from humeral angle to anal angle greater than through cell in male and less in female. Cell of primaries three-fifths as long as wing; vein 5 curved at base, nearer to vein 4 than to 6; L. D. C. almost transverse; M. D. C. scarcely visible, very oblique; vein 2 almost intermediate between 3 and base of cell. Stigma rudimentary, consisting of a few modified scales faintly indicating the position of the structure; well developed in a few species, where it is similar to that of *Atrytone* but more slender. Mid tibiae spiny. Fig. 28.

The absence of yellow-fulvous, frequent occurrence of gray scales on the under surface of the wings, and the acute apices of the primaries in the males of most of the species give this genus a very distinctive habitus.

Key to the species

1. Fringes not checkered..2
   Fringes checkered..7
2. Under surface of secondaries with a transverse row and three subasal white spots; not heavily gray-powdered.......................*loammi*
   Spots partly obsolete or hyaline..3
3. Secondaries with hyaline spots..............................*pittacus*
   Secondaries without hyaline spots..4
4. Fringes of secondaries white or whitish..5
   Fringes concolorous with wings or slightly paler..................6
5. Fringes dirty white, usually dark at anal angle...............*lunus*
   Fringes pure white, rarely intermixed with dark scales, usually not very dark at anal angle..*deva*
6. Wings very dark..*hianna*
   Wings pale..*vierecki*
7. Under surface marbled with purplish; spots semi-hyaline......*cestus*
   Under surface heavily gray powdered..............................8
8. Spots yellowish, opaque or nearly so........................*python*
   Spots white, subhyaline..*edwardsi*

1. *ATRYTONOPSIS LOAMMI*

Lerema loammi Whitney, Can. Ent. VIII, 76, 1876.
Pamphila regulus Edw., Trans. Am. Ent. Soc. IX, 5, 1881.
Skinner, Ent. News XI, pl. II, f. 24, 1900.
Kellogg, Am. Ins. pl. IX, f. 24, 1904.

Florida, March and October. North Carolina, July.

The dark brown ground color and the pure white, opaque spots on the under surface of the secondaries separate *loammi* readily from the rest of the genus.

2. *ATRYTONOPSIS HIANNA*

Hesperia hianna Scudder, Proc. Bost. Soc. Nat. Hist. XI, 382, 1868.
Hesperia grotei Plötz, Stett, ent. Zeit. XLIV, 54, 1883.
Scudder, Butt. New Eng. II, 1771, 1889.
Holland, Butterfly Book, 366, pl. XLVI, ff. 9, 10, 1898.

Northeastern United States westward into Nebraska, Manitoba; June.

3. *ATRYTONOPSIS LUNUS*

Pamphila lunus Edwards, Papilio IV, 56, 1884.

Arizona, June to August.

Similar to *deva* but larger and darker, and with the white areas not so pure as in *deva.*

4. *ATRYTONOPSIS DEVA*

Hesperia deva Edw., Trans. Am. Ent. Soc. v, 292, 1876.
Biol. Cent.-Am., Rhop. II, 498, pl. 95, ff. 6-10, 1900.

Arizona and Utah. Skinner lists southern Colorado (Cat. p. 87).

5. *ATRYTONOPSIS VIERECKI*

Pamphila vierecki Skinner, Ent. News XIII, 213, 1902.

Ft. Wingate, New Mexico, June; two males, one compared with the type, in the Barnes collection are all that I have seen.

Vierecki is similar to *deva* but smaller, paler and more grayish, with two spots in the end of the cell of the primaries, sometimes connected, and a well marked stigma in the male.

6. *ATRYTONOPSIS PITTACUS*

Pamphila pittacus Edw., Papilio II, 138, 1882.
Biol. Cent.-Am., Rhop. II, 498, pl. 95, ff. 11-13, and 14, 15 (not *python* Edw.), 1900.
Skinner, Ent. News XI, pl. II, ff. 17, 18, 1900.
Kellogg, Am. Ins. pl. IX, ff. 17, 18, 1904.

Arizona, July.

The straight row of hyaline spots on the secondaries characterizes *pittacus* among our species.

7. *ATRYTONOPSIS PYTHON* (Plate I, Fig. 1)

Pamphila python Edw., Papilio II, 139, 1882.

Arizona, May and June.

Python is the only one of our species in which the spots are distinctly yellowish.

7a. race *MARGARITA*

Pamphila margarita Skinner, Can. Ent. XLV, 426, 1913.

Described from Jemez Springs, New Mexico.

I am not familiar with this form.

8. *ATRYTONOPSIS CESTUS*

Pamphila cestus Edw., Papilio IV, 57, 1884.

Southern Arizona. I am not familiar with this species.

9. *ATRYTONOPSIS EDWARDSI*

Atrytonopsis edwardsi B. & McD., Contributions III, (2), 135, pl. VIII, ff. 9, 10, 1916.

Pamphila cestus Wright, (not Edw.), Butt. W. Coast 249, pl. XXXII, f. 482, 1905.

Arizona.

This species was described to correct a common misconception of *cestus* and the types are undoubtedly distinct from the species on which the description of *cestus* was based. I believe that the name will fall before *Hesperia ovinia* Hew., illustrated in the Biologia (Pl. 97, ff. 1, 2, 1900) under the name *Thespieus ovinia*. The type of *ovinia* in the British Museum will have to be examined to settle the matter definitely, but even from the figures it is easy to see that the species can hardly belong in *Thespieus*.

Genus OLIGORIA Scudder

Oligoria Scud., Syst. Rev. 61, (82), 1872. Type *Hesperia maculata* Edw.

Structure not much different from *Atrytonopsis*. Male primaries less apically prolonged and without stigma. Vein 5 nearer to 4 than in the preceding genus. Middle tibiae with a few long spines. Apiculus of antennae abruptly constricted, sharply reflexed, very slender and usually about twice as long as thickness of club.

Dyar remarks (Jn. N. Y. Ent. Soc. XIII, 137, 1905) that he is unable to separate this genus from *Lerodea* and therefore places *maculata* in the latter. He is followed in this by Barnes and McDunnough in the Check List, but the differences between *maculata* and *eufala* are so striking that they must be separated. Since *maculata* agrees with no other genus known to me, I retain *Oligoria* for the one species. Fig. 28.

1. *OLIGORIA MACULATA*

Hesperia maculata Edw., Proc. Ent. Soc. Phil. IV, 202, pl. I, f. 6, 1865.
Hesperia norus Plötz, Stett. ent. Zeit. XLIV, 36, 1883.
Scudder, Butt. New Eng. II, 1761, 1883.
Holland, Butterfly Book 361, pl. XLVI, f. 35, 1898.

Florida, May to July. Skinner gives its range as the Gulf States and occasionally New York. (Cat. p. 87).

Genus LEREMA Scudder

Lerema Scud., Syst. Rev. 61, (82), 1872. Type *Papilio accius* A. & S.

Palpi oblique; third joint moderate, partly concealed by vestiture of second. Antennae about one-half as long as primaries; club moderate; apiculus slender, longer than thickness of club.

Primaries rather long; costa flattened in middle; outer margin curved, flattened before anal angle; apex rounded-rectangular. Secondaries lobed slightly at anal angle, otherwise rounded. Cell of primaries over three-fifths as long as wing; discocellulars weak, slightly oblique; vein 5 arising a little nearer to 4 than to 6, almost straight. Male with a slender, well developed stigma running from the base of vein 3 to just within the middle of vein 1. Middle tibiae with a few long spines. Fig. 28.

1. *LEREMA ACCIUS*

Papilio accius A. & S., Lep. Ins. Ga. I, 45, pl. 23, 1797.
Hesperia monoco Scud., Proc. Ess. Inst. III, 178, 1863.
Hesperia punctella G. & R., Trans. Am. Ent. Soc. I, 1, 1867.
Hesperia nortonii Edw., Trans. Am. Ent. Soc. I, 287, 1867.
Scudder, Butt. New Eng. II, 1768, 1889.
Holland, Butterfly Book 366, pl. XLVIII, f. 8, 1898.
Biol. Cent.-Am., Rhop. II, 554, pl. 99, f. 44, 1900.

Southern half of United States east of Rockies; May, July, August, October, November. Skinner (Cat. p. 87) mentions a record by Aaron from Eastern Pennsylvania.

Genus EPIPHYES Dyar

Epiphyes Dyar, Jn. N. Y. Ent. Soc. XIII, 132, 1905. Type *Pamphila carolina* Skinner.

I have seen but one poor specimen of the female of *carolina*. From it nothing can be told except that vein 5 is but slightly curved and not much nearer to 4 than to 6. It therefore belongs with Lerema and allied genera, and according to Dyar's description of the male stigma it should constitute a good genus. The original description of Epiphyes is as follows: "Antennal club cylindrical, the point rather obtuse and about equal to the diameter of the club. Palpi with the third joint moderate, rather slender; wings normal, vein 2 arising at the middle of the cell, 3 before the end. Mid tibiae spiny. Male stigma a large, ill defined blotch. Type *Pamphila carolina* Skinner."

1. *EPIPHYES CAROLINA*

Pamphila carolina Skinner, Ent. News III, 222, 1892.
Holland, Butterfly Book 367, pl. XLVI, f. 36, 1898 (type).

North Carolina.

The species is easily recognized by the well defined, pale yellow maculation and the form of vein 5 of the primaries.

Genus MASTOR Godman & Salvin

Mastor G. & S., Biol. Cent.-Am., Rhop. II, 567, 1900. Type *Mastor anubis* G. & S.

? Megistias G. & S., op. cit. 571. Type *Hesperia tripunctata* Latr.

Palpi upturned; third joint small. Antennae slightly more than one-half as long as primaries in male, less in female; apiculus shorter than thickness of club and variously reflexed; club short, rather stout. Costa of primaries flattened; outer margin slightly rounded; apex somewhat produced. Secondaries broadly rounded, relatively small; in the female the primaries are less produced and the apex of the secondaries more prominent than in the male, much as in *Atrytone*. The male possesses a small stigma made up of a dot of scales below vein 2 and a longer patch above, variably developed in different specimens. It is much larger in *bellus* than in *phylace*, very small in oslari and absent in *fusca*. Cell of primaries normal; vein 5 slightly curved, arising a little nearer to 4 than to 6. Mid tibiae with a few spines. Fig. 28.

I believe that *oslari* is more closely related to *A. nanno* than to *bellus*, and am placing *fusca* in this genus rather doubtfully. Unfortunately I have not had sufficient material for dissection in this group and have therefore been unable to make a careful study of the anatomy of the doubtful species. I am unable to find a good basis of separation for *fusca*, which Godman and Salvin say belongs in *Megistias*, but I am not familiar with *tripunctata* so *Megistias* may not fall before *Mastor*.

Key to the species

1. Vestiture of head and fringes golden........................*bellus*
   Head golden; fringes whitish..............................*phylace*
   Without golden vestiture..2
2. Under surface powdery gray................................*oslari*
   More or less yellowish below, never powdery gray..............*fusca*

1. *MASTOR FUSCA*

Hesperia fusca G. & R., Trans. Am. Ent. Soc. I, 2, 1867.

Southern United States, New Jersey, Pennsylvania; April to July. St. Louis, Mo., (Knetzger).

Fusca is usually immaculate grayish fuscous above and slightly tinged with yellowish below, especially on the veins of the secondaries. Occasional specimens show a faint trace of spots on the upper surface of the primaries, and frequently the ground color is darker.

2. *MASTOR BELLUS*

Pamphila bellus Edw., Papilio IV, 57, 1884.
Biol. Cent.-Am., Rhop. II, 568, pl. 100, f. 36, ♂ gen., 1900.
Skinner, Ent. News XI, pl. II, ff. 11, 12, 1900.
Kellogg, Am. Ins. pl. IX, ff. 11, 12, 1904.
Wright, Butt. W. Coast 247, pl. XXXI, f. 443, 1905.

Arizona, May to July.

3. *MASTOR PHYLACE*

Pamphila phylace Edw., Field and Forest III, 117, 1878.

Arizona, Colorado, New Mexico; June.

4. *MASTOR OSLARI*

Pamphila oslari Skinner, Ent. News X, 112, 1899.

New Mexico, Arizona, Colorado; April, June to August.

Oslari is usually pale fuscous above, but occasionally a series will show some yellow fulvous scales on the disk of the primaries and a faint trace of indefinite spots such as are always present in *A. nanno.* Such specimens may be separated from *nanno* by the gray under surface of the secondaries with vague pale spots instead of small sharp ones.

Genus AMBLYSCIRTES Scudder

Amblyscirtes Scud., Syst. Rev. 54, (75), 1872. Type *Hesperia vialis.* Edw.

Stomyles Scud., op. cit. 55 (76). Type *Pyrgus textor* Hbn.

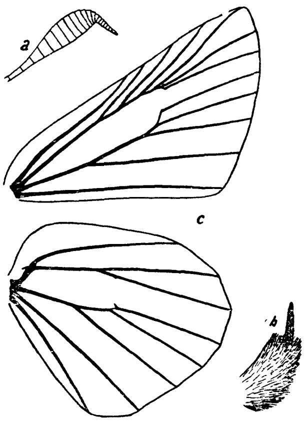


Fig. 29. *Amblyscirtes vialis* Edw. a. Club of antenna, b. Palpus, c. Neuration

Palpi large, upturned; second joint with shaggy vestiture; third slender, smooth, vertical; almost as long as second except in *nanno.* Antennae moderate; club large; apiculus longer than thickness of club. Primaries in most species similar in the two sexes, less apically produced than in the related genera; costa flattened; apex rounded-rectangular; outer margin strongly rounded except toward anal angle; cell about three-fifths as long as wing; discocellulars very weak and only slightly oblique; vein 5 weakly curved toward base, a little nearer to 4 than to 6; secondaries rounded, in most of the species longer through the cell than in the related genera. Male stigma small, sometimes scarcely visible, composed of a short, oblique dash above the base of vein 2 and a smaller longitudinal dash below it. Middle tibiae spiny. Fig. 29.

The checkered fringes of this genus are a convenient superficial character, and indeed the only one by which *nanno* can readily be placed. The other species are readily referred to the genus by the long third joint of the palpi, taken with the apiculus of the antennae. Whether *nanno* should be left in *Amblyscirtes* is a question which I have been unable to settle; its similar habitus would cause me to hesitate to remove it.

Key to the species

1. Vestiture of under surface of secondaries with no suggestion of green. 2
   Under surface of secondaries more or less greenish.................9
2. Spots on under surface of secondaries connected by pale lines on veins...*textor*
   No such lines...3
3. Under surface of secondaries with diffused pale spots or immaculate..4
   With well defined pale spots......................................8
   With a brown patch in the middle...............................*nysa*
4. All maculation above yellow-fulvous...........................*cassus*
   Subapical spots of primaries, at least, whitish...................5
5. Secondaries without pale spots below..........................*vialis*
   With a transverse row of powdery pale spots.......................6
6. Maculation of upper surface tinged with yellow-fulvous.........*aenus*
   No trace of yellow-fulvous..7
7. Irroration of under surface smooth, fine...................*alternata*
   Irroration with a rough appearance.............................*celia*
8. Under surface dark, irroration sparse; spots small and powdery but sharply contrasting.................................*nanno, elissa*
   Under surface finely and smoothly grayish-irrorate; spots very sharply defined, moderate...*comus*
9. Under surface pale greenish-gray; primaries with spots between veins 4 and 6 above; southwestern species.........................*nereus*
   Darker greenish-gray; very bright in fresh specimens; spots at end of cell of primaries usually lacking; eastern species..............*hegon*

1. *AMBLYSCIRTES NANNO*

Amblyscirtes nanno Edw., Papilio II, 142, 1882.
Biol. Cent.-Am., Rhop. II, 504, pl. 95, ff. 31-34, 1900.
Wright, Butt. W. Coast 250, pl. XXXI, f. 455, 1905.
Arizona, July.

The primaries of *nanno* are more apically produced and the secondaries relatively smaller and more rounded than in the normal species of *Amblyscirtes.*

2. *AMBLYSCIRTES ELISSA*

Amblyscirtes elissa G. & S., Biol. Cent.-Am., Rhop. II, 505, pl. 95, ff. 40, 41, 1900.

Skinner, Ent. News XV, 344, 1904.

I have not seen this species. Apparently it is very similar to *nanno.* Skinner reports it from Cochise County, Arizona.

3. *AMBLYSCIRTES AENUS*

Amblyscirtes aenus Edw., Field and Forest III, 118, 1878.

Holland, Butterfly Book 341, pl. XLVII, f. 7, 1898.

Colorado, Texas, Arizona, New Mexico; May to July.

4. *AMBLYSCIRTES CASSUS*

Amblyscirtes cassus Edw., Papilio III, 72, 1883.

Amblyscirtes simius Wright, (not Edw.), Butt. W. Coast pl. XXXI, f. 454, 1905.

Arizona; June, July and September.

The under surface of the secondaries of *cassus* is heavily irrorate with pale gray scales which give these wings a roughened appearance. The spots are large and distinct but vaguely defined.

5. *AMBLYSCIRTES CELIA*

Amblyscirtes celia Skinner, Ent. News VI, 113, 1895.

Texas, March, April and July.

There is a specimen in the Barnes collection which has been compared with the type, and from which I have noted that the under surface of the secondaries is finely but rather sparsely and roughly powdered with gray; spots small but not clear-cut.

6. *AMBLYSCIRTES VIALIS*

Hesperia vialis Edw., Proc. Acad. Nat. Sci. Phil. 1862, 58, 1862.

Scudder, Butt. New Eng. II, 1582, 1889.

Holland, Butterfly Book 340, pl. XLVII, f. 5, 1898.

United States and Southern Canada; May, June, July, August.

7. *AMBLYSCIRTES HEGON*

Hesperia hegon Scud., Proc. Ess. Inst. III, 176, 1863.

Hesperia samoset Scud., op. cit. 176.

Hesperia nemoris Edw., Proc. Ent. Soc. Phil. II, 507, 1864.

Scudder, Butt. New Eng. II, 1589, 1889.

Holland, Butterfly Book 340, pl. XLVII, f. 6, 1898.

Georgia north into Canada and west to central Iowa; May and June; August in the north.

Hegon is more commonly known as *samoset.* It is similar to *nereus* but the transverse row of spots on the primaries is usually less complete and fresh specimens are much more greenish below. The distribution is sufficient to separate specimens which bear locality labels.

8. *AMBLYSCIRTES NEREUS*

Hesperia nereus Edw., Trans. Am. Ent. Soc. v, 207, 1876.
Biol. Cent.-Am., Rhop. II, 502, pl. 95, ff. 27-30, 1900.

Arizona, June to August.

9. *AMBLYSCIRTES ALTERNATA*

Hesperia alternata G. & R., Trans. Am. Ent. Soc. I, 3, 1867.
Hesperia eos Edwards, Trans. Am. Ent. Soc. III, 276, 1871.
Amblyscirtes meridionalis Dyar, Jn. N. Y. Ent. Soc. XIII, 135, 1905.

Georgia; Skinner lists *eos* from Texas, Georgia and Florida.

A specimen which Dr. McDunnough placed as *alternata* in the Barnes collection proved to be the same as Dyar's types of *meridionalis* in the Strecker collection, and the descriptions of all of the species lead me to believe that they are synonyms. The primaries are apically produced, so that the outer margin is longer than in *vialis*, and the fringes are an unusually pure white, as in *nysa.* The under surface has a transverse row of faint, powdery spots on the secondaries and is otherwise similar to *vialis.*

10. *AMBLYSCIRTES NYSA*

Amblyscirtes nysa Edw., Can. Ent. IX, 191, 1877.
Pamphila similis Strecker, Lep. Rhop. & Het. 131, 1878.

Texas and Arizona, March to June.

The under surface of the secondaries is distinctive and the fringes are a clearer white than in any other species than *alternata.* The upper surface of *nysa* is very similar to that of *alternata* in all particulars.

11. *AMBLYSCIRTES COMUS*

Hesperia comus Edw., Trans. Am. Ent. Soc. v, 206, 1876.
Amblyscirtes nilus Edw., Field and Forest III, 118, 1878.
Pamphila quinquemacula Skinner, Ent. News XXII, 413, 1911.
Biol. Cent.-Am., Rhop. II, 502, pl. 95, ff. 25, 26, 1900.

Texas and Arizona, August.

From a specimen in the Barnes collection compared with Edward's material I have noted that the under surface is finely and smoothly grayish irrorate and the spots small, white, sharply defined and not crowded together.

12. *AMBLYSCIRTES TEXTOR*

Pyrgus textor, Hübner, Zutr. exot. Schmett. pl. 89, ff. 515, 516, 1825.
Hesperia oneko Scud., Proc. Ess. Inst. III, 176, 1863.
Hesperia wakulla Edw., Trans. Am. Ent. Soc. II, 311, 1869.
Holland, Butterfly Book 341, pl. XLVII, f. 16, 1898.

North Carolina and Kentucky to Texas; August.

The under side of the secondaries is very strikingly different from any other species, but I see no structural basis for *Stomyles*, of which *textor* is the type.

Genus LERODEA Scudder

Lerodea Scud., Syst. Rev. 59, 1872. Type *Hesperia eufala* Edw.

Palpi upturned, very smoothly scaled; third joint about half as long as second but buried in vestiture of second almost to its tip. Antennae much less than one half as long as primaries; apiculus slender, shorter than thickness of club. Primaries apically produced; costa slightly emarginate or straight except at apex and humeral angle; outer margin slightly sinuate, convex from apex to vein 2. Secondaries rounded, lobed at anal angle. Both primaries and secondaries longer and more rounded in the female than in the male. Cell of primaries about three-fifths as long as wing; discocellulars weak, scarcely oblique; vein 5 almost straight, about two-thirds as far from 4 as from 6; 2 much nearer to 3 than to base of wing in both sexes. Male without stigma. Mid tibiae spined. Fig. 28.

1. *LERODEA ARABUS*

Pamphila arabus Edw., Papilio II, 26, 1882.

Arizona, April.

Differs from *eufala* in the presence of a dark brown discal shade on the under surface of the secondaries.

2. *LERODEA EUFALA*

Hesperia eufala Edw., Trans. Am. Ent. Soc. II, 311, 1869.
Pamphila floridae Mab., Bull. Soc. Ent. France (5), VI, p. IX, 1876.
Holland, Butterfly Book 356, pl. XLVI, f. 33, 1898.
Biol. Cent.-Am., Rhop. II, 500, pl. 95, ff. 16-18, 1900.
Wright, Butt. W. Coast pl. XXXI, f. 445a, b, 1905 (as *nereus*).

Florida, Texas, Arizona; April to July, October and November.

GROUP D

Key to the genera

1. Middle tibiae without spines........................*Prenes*
   Middle tibiae spined..................................2
2. Male with stigma; under surface of secondaries mottled with several shades..............................*Thespieus*
   Male without stigma; under surface of secondaries uniformly colored..................................*Calpodes*

Genus THESPIEUS Godman & Salvin

Thespieus G. & S., Biol. Cent.-Am., Rhop. ii, 519, 1900. Type *Hesperia dalmani* Latr.

This genus is very close to *Calpodes* and the male genitalia of the two illustrated by Godman and Salvin are similar, but I have very little material of *Thespieus* and have not seen the typical species, so I hesitate to sink it.

1. *THESPIEUS MACAREUS*

Goniloba macareus H.-S., Corr. Blatt Regensb. xxiii, 192, 1869.
Biol. Cent.-Am., Rhop. ii, 520, pl. 96, ff. 41-43, 1900.
Skinner, Ent. News xiii, 183, 1902.

Macareus has been recorded from the southwestern part of our country and Marco Id., Fla.; I have not seen the species.

Genus CALPODES Hübner

Calpodes Hbn., Verz. bek. Schmett. 107, 1820. Type *Papilio ethlius* Cr.

Palpi upturned, closely appressed; third joint small, almost entirely concealed. The palpi resemble those of most species of Group A of the Hesperiinae. Antennae less than one-half as long as primaries; club stout, apiculus exceeding thickness of club, sharply reflexed. Primaries with the apex produced and subtruncate, longer in the female than in the male; secondaries strongly lobed at the anal angle, broader and more rounded in the female than in the male. Neuration as in *Prenes*. Mid tibiae with short prostrate spines on the inner surface. Fig. 30.

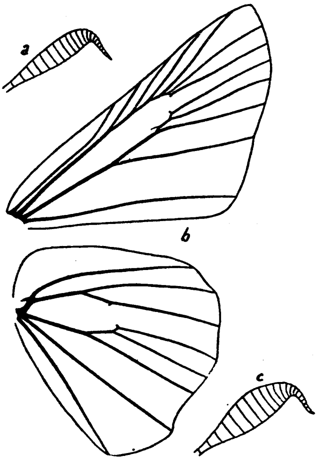


Fig. 30. *Prenes* and *Calpodes*. a. Club of antenna of *P. ocola* Edw., b. Neuration of *ocola*, c. Club of antenna of *C. ethlius* Cramer

1. *CALPODES ETHLIUS*

Papilio ethlius Cramer, Pap. Exot. iv, 212, pl. cccxcii, ff. A, B, 1782.
Hesperia chemnis Fab., Ent. Syst. iii, (i), 331, 1793.
Eudamus olynthus Bd. & Lec., Lep. Am. Sept. pl. 75, ff. 1, 2, 1833.
Scudder, Butt. New Eng. ii, 1750, 1889.
Holland, Butterfly Book 355, pl. xlv, f. 3, 1898.

Biol. Cent.-Am., Rhop. II, 507, pl. 95, ff. 45, 46, 1900.

Florida to Texas, June. Skinner lists it as occasional in New York, (Cat. p. 88). St. Louis, Mo., (Knetzger).

Ethlius is readily distinguished by its large size, the long cell of the primaries, the form of the palpi and the presence of hyaline spots on the secondaries.

2. *CALPODES COSCINIA*

Goniloba coscinia H.-S., Corr.-Blatt Regensb. XIX, 54, 1865.
? *Hesperia ares* Feld., Verh. z.-b. Ges. Wien XII, 477, 1862.

Brownsville and San Antonio, Texas, May.

Barnes and McDunnough list *ares* as a doubtful synonym of *coscinia* while Godman and Salvin in the Biologia make it a synonym without qualification. If the two names refer to the same species, *ares* should be used; I know of nothing which will settle the matter at present. *Coscinia* differs from *ethlius* and *T. macareus* in the absence of hyaline spots from the secondaries.

Genus PRENES Scudder

Prenes Scud., Syst. Rev. 60, (81), 1872. Type *Hesperia panoquin* Scud.

Similar to *Calpodes* but with the wings more angular and the mid tibiae without spines. Fig. 30.

Prenes is very close to the Old World genus *Parnara* and may fall before it. Dr. W. T. M. Forbes tells me that he is unable to separate the two, and from a superficial study of the genotypes I have found nothing which will differentiate them. I prefer to retain *Prenes*, however, until I can make dissections of the type of *Parnara* for more accurate study.

Key to the species

1. Secondaries with a few pale spots below.........................2
   Secondaries immaculate below or with pale dashes or very faint traces of spots.........................4
2. Upper surface powdered with yellowish scales.........*panoquinoides*
   Upper surface without yellowish scales.........................3
3. A pale spot in end of cell of primaries; spots on under surface bluish.........................*nero*
   No spot in cell; spots below not bluish.........................*errans*
4. Two pale dashes on under surface of secondaries.............*panoquin*
   Usually immaculate; never with dashes.........................*ocola*

1. *PRENES NERO*

Hesperia nero Fab., Ent. Syst., Supp. 433, 1798.
Hesperia nyctelius Latr., Enc. Meth. IX, 746, 1823.

Goniloba corrupta H.-S., Corr.-Blatt Regensb. xix, 54, 1865.
Goniloba sylvicola H.-S., op. cit., p. 55.
Hesperia fusina Hew., Desc. Hesp. 30, 1868.
Hesperia fufidia Hew., Ann. & Mag. Nat. Hist. (4), xix, 81, 1877.
Biol. Cent.-Am., Rhop. ii, 509, pl. 96, ff. 4-7, 1900.

Florida.

Differs from *ocola* in the presence of a pale spot in the end of the cell of the primaries and a transverse row of faint, bluish spots on the under surface of the secondaries. The synonymy is that of Godman and Salvin.

2. *PRENES PANOQUIN*

Hesperia panoquin Scud., Proc. Ess. Inst. iii, 178, 1863.
Hesperia ophis Edw., Trans. Am. Ent. Soc. iii, 216, 1871.
Scudder, Butt. New Eng. iii, 1867, 1889.
Skinner, Ent. News xi, pl. ii, ff. 13, 14, 1900.
Kellogg, Am. Ins. pl. ix, ff. 13, 14, 1904.

Florida, New Jersey; April, May, August.

3. *PRENES PANOQUINOIDES*

Pamphila panoquinoides Skinner, Ent. News ii, 175, 1891.
Skinner, Ent. News xi, pl. ii, f. 26, 1900 (type).
Kellogg, Am. Ins. pl. ix, f. 26, 1904 (type).

Florida. This species is slightly powdered with yellowish scales above but less heavily than panoquin, from which it differs also in the absence of the large dashes of the under surface.

4. *PRENES ERRANS*

Pamphila errans Skinner, Ent. News iii, 174, 1892.
Wright, Butt. W. Coast pl. xxxi, f. 445, 1905 (as *nereus*).

California, July and August.

Differs from *ocola*, which it closely resembles, in the presence of a transverse row of pale spots on the under side of the secondaries, which are not bluish as in *nero*.

5. *PRENES OCOLA*

Hesperia ocola Edw., Proc. Ent. Soc. Phil. ii, 20, pl. xi, f. 4, 1863.
Prenes hecebolus Scud., Syst. Rev. 60, (81), 1872.
Pamphila ortygia Möschl., Verh. z.-b. Ges. Wien xxxii, 328, 1882.
Scudder, Butt. New Eng. iii, 1866, 1889.
Pamphila parilis Mab., Comp. Rend. Soc. Ent. Belg. xxxv, clxxi, 1891.
Holland, Butterfly Book 355, pl. xlvi, f. 34, 1898.
Biol. Cent.-Am., Rhop. ii, 511, pl. 96, ff. 13-15, 1900.

Kentucky, Florida, Mississippi and Texas; May, July to October. Skinner (Cat. p. 88) adds Indiana and Eastern Pennsylvania.

Ocola is usually immaculate below but some specimens show a trace of the spots which mark *errans*, though they are not, as a rule, sufficiently well marked as to cause difficulty in separating the species. They never have the marked blue shade found in *nero*. In the synonymy of *ocola* I follow Godman and Salvin (Biol. 511), who say that they have seen the types of all three synonyms and find them to ''show no tangible difference.''

DOUBTFUL SPECIES AND GENERA

Genus POTANTHUS Scudder

Potanthus Scud., Syst. Rev. 54, (75), 1872. Type *Hesperia omaha* Edw.

1. *POTANTHUS OMAHA*..

Hesperia omaha Edw., Proc. Ent. Soc. Phil. II, 21, 1863.
Hesperia mingo Edw., Proc. Ent. Soc. Phil. VI, 207, 1866.
Potanthus californica Scud., Syst. Rev. 54, (75), 1872.
Scudder, Butt. New Eng. III, 1861, 1889.
Potanthus dara Dyar (Kollar?), Bull. 52, U. S. N. M., p. 48, 1902.

The early literature gives the range of this species as West Virginia, Colorado and California. Edwards places the species next to *palaemon* in his catalogue (Cat. Diurn. Lep. 48, 1877), and Dyar regards it as the Oriental species, *Padraona dara* Kollar. It is very difficult to say what it may be from the scanty evidence available.

2. *ATRYTONE KUMSKAKA*

Hesperia conspicua Scud. (not Edw.), Trans. Chi. Acad. Sci. I, 336, 1869.
Atrytone kumskaka Scud., Can. Ent. XIX, 45, 1887.

According to the description this is a true *Atrytone* which Scudder has mistaken for the female of *conspicua*. Dr. McDunnough tells me that Scudder's figure of the male genitalia resembles those of *byssus*, but it seems to me that the description itself suggests a dark female of *hobomok*. The type locality is Dennison, Iowa, but I have never taken anything in western Iowa which might be the species.

3. *THANAOS RUTILIUS* (*nomen nudum*)

Nisoniades rutilius Mead, U. S. Geog. Surv. W. 100th Merid. V, 787, 1875.

The reference reads as follows: ''One individual, now in Mr. Scudder's hands for description, was taken June 23, at Turkey Creek Junction.'' The specimen was probably placed by Scudder with another species.

Family MEGATHYMIDAE

Barnes and McDunnough, Contributions I, number III, 1912, Revision of the Megathymidae.

Head small, much narrower than the thorax. Palpi rather small, oblique. Antennae moderate; club large, stout and pyriform to more cylindrical with a rudimentary apiculus. Venation much as in the Pamphilinae; vein 3 of the primaries varying in position between the sexes of several species. Larvae borers in stems of plants. Fig. 31.

Barnes and McDunnough's revision of this family is so satisfactory that I am going into very little detail in treating it. I have worked out the following key to the North American species of Megathymus from the material in the Barnes collection, and believe that it will suffice for the determination of most of the material likely to fall into the hands of collectors; those who are deeply interested in the family will doubtless obtain the few articles which are useful to students who make these insects a hobby. Only one genus is represented in our fauna.

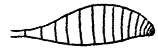


Fig. 31. *Megathymus streckeri* Skinner. Club of antenna

Genus MEGATHYMUS Scudder

Megathymus Scud., Syst. Rev. 62, (83), 1872. Type *Eudamus yuccae* Boisd. & Lec.

Characters of the family.

Key to the species

1\. Under surface with a large white patch contiguous to vein 8 of the secondaries, or this spot the largest on the wing; no more than a trace of extra-median pale spots on secondaries.................*yuccae* 2
Under surface of secondaries with a more or less complete transverse row of pale spots and with larger spot on vein 8 outward...........3

2\. Size large, 55 to 75 mm. Spots of upper surface bright yellow. Under surface of secondaries gray at margins.......................*yuccae*
Size smaller, seldom over 55 mm. Spots pale yellow. Outer margin of secondaries narrowly or not at all pale............race *coloradensis*
Size similar to *coloradensis*. Spots yellowish to white. Secondaries with a broad pale outer border.........................race *navajo*

3\. Size very large, 65 to 90 mm. Spots of primaries bright yellow. Secondaries without discal spots above and with at most a slender, linear pale margin...*ursus*
Size smaller, not over 70 mm. Secondaries with discal spots, a crenulate marginal band or with pale areas not bright yellow.............4

4\. Under surface of secondaries smooth, powdered with blue-gray scales at outer margin...*cofaqui*
Under surface of shaggy appearance, washed with gray scales and hairs over entire surface, sometimes most evidently between transverse row of spots and outer margin...................................5

5\. Upper surface of primaries with a pale basal area contiguous to vein 1; spots yellow to yellowish-fulvous, or with a transverse sub-basal row of spots on the under surface of the secondaries...............6
This area seldom present, if so powdery and not contiguous to vein 1

and with maculation not bright yellow. No transverse row of spots near base of secondaries below.................................7

6. Expanse 40 to 50 mm. Larger specimens females with pale spots of primaries broadly confluent and veins concolorous.............*polingi*
Expanse 50 to 70 mm., smaller specimens males with spots separated by dark veins or by broader dark areas..........*aryxna, neumoegeni*
Expanse 50 mm. or slightly over. Spots small, rounded and whitish. Southern California.................................race *stephensi*

7. Spots yellowish white to pale yellow; at least one extra-discal spot on under surface of secondaries and rarely some above..........*streckeri*
Spots deeper yellow; extra-discal spots obsolete, not more than one or two fine points present, or with discal spots above........race *texana*
Spots greatly reduced, yellowish; extra-discal band on under surface of secondaries evenly curved but irregular. Spot in end of cell of primaries linear, bent, in apical angle........................*smithii*

1. *MEGATHYMUS YUCCAE*

Eudamus yuccae Boisd. & Lec., Lep. Am. Sept. pl. 70, 1833.
Riley, 8th Rep. St. Ent. Mo., 169-182, 1876 (Biol.).
Florida, Georgia, South Carolina; April and May.

1a. race *COLORADENSIS*

M. yuccae, var. *coloradensis* Riley, Trans. Acad. Sci. St. Louis III, 567, 1877.
Colorado, April.

1b. race *NAVAJO*

M. yuccae, var. *navajo* Skinner, Ent. News XXII, 300, 1911.
Skinner, Trans. Am. Ent. Soc. XXXVII, 209, pl. X, 1911.
Texas, New Mexico, Arizona, S. California; April to June.

2. *MEGATHYMUS URSUS*

Megathymus ursus Poling, Ent. News XIII, 97, pl. 4, 1902.
Skinner, Trans. Am. Ent. Soc. XXXVII, 205, 1911.
Pima County, Arizona; August.

3. *MEGATHYMUS COFAQUI*

Aegiale cofaqui Strecker, Proc. Acad. Nat. Sci. Phil. 148, 1876.
Skinner, Trans. Am. Ent. Soc. XXXVII, 203, 1911.
Georgia, Florida; March.

The male type is a form of *streckeri* to which Barnes and McDunnough have given the name *texana.* The female type represents *cofaqui.* This sex may be distinguished by the slightly emarginate outer margin of the primaries and the resultant sharpness of the apex.

4. *MEGATHYMUS STRECKERI*

Aegiale streckeri Skinner, Can. Ent. XXVII, 179, 1895.
Skinner, Trans. Am. Ent. Soc. XXXVII, 204, 1911.

Southwestern Colorado, New Mexico, Cherry County, Nebraska (Leussler); May and June.

race *TEXANA*

M. streckeri, subsp. *texana* B. & McD., Contr. I, no. III, 39, pl. II, f. 9, 1912.

Southern Texas.

5. *MEGATHYMUS SMITHI*

Megathymus smithi Druce, Biol. Cent.-Am., Het. II, 320, pl. 69, f. 5, 1896.
Skinner, Trans. Am. Ent. Soc. XXXVII, 205, 1911.

I have seen one specimen from Corpus Christi, Texas, in the Barnes Collection.

6. *MEGATHYMUS NEUMOEGENI*

Megathymus neumoegeni Edw., Papilio II, 27, 1882.
Megathymus aryxna Dyar, Jn. N. Y. Ent. Soc. XIII, 141, 1905 (partim); (fide B. & McD.).
Skinner, Trans. Am. Ent. Soc. XXXVII, 206, 1911.
Skinner, Trans. Am. Ent. Soc. XXXVII, 207, 1911 (fide B. & McD.).

Arizona, September.

According to Barnes and McDunnough's revision the females can readily be separated from *aryxna*. They say: ''in every instance the ♀ could be separated at once on wing pattern, the yellow band on primaries being much broader and either touching or broadly coalescing with the costal spot at end of cell.'' Of the male they say that *neumoegeni* is usually a smaller and slighter species, and give the following points of difference:

''(1) in *neumoegeni* the spots are often small, well separated, irregularly rounded; when forming a more or less coalescent band spot 2 from anal angle is usually almost square and its inner margin is not prominently wedge-shaped as in *aryxna*.

''(2) The fulvous hairing at base of both wings is much more extended in *neumoegeni*, covering on the secondaries most of the area between the subterminal spots and the base of wing. The presence or size of yellow spots in the basal area beneath the fulvous hairs we have found of no specific value.

''(3) The underside of secondaries of *neumoegeni* is usually distinctly paler in color, due to a greater sprinkling of white scales (compare Figs. 2 and 7). The whitish subterminal band is very variable in both species, in both distinctness and extent, and of no value for purposes of separation.''

In spite of this great similarity of the two species, the form of the male genitalia verifies their distinctness.

6a. race *STEPHENSI*

Megathymus neumoegeni Wright (not Edw.), Butt. W. Coast 255, pl. XXXII, f. 483, 1905.

Megathymus neumoegeni subsp. *stephensi* Skinner, Ent. News xxiii, 126, 1912.

Barnes & McDunnough, Contributions i, (5), 44, 1912.

Southern California, Texas.

7. *MEGATHYMUS ARYXNA*

Megathymus aryxna Dyar, Jn. N. Y. Ent. Soc. xiii, 141, 1905.

Arizona; July, September and October.

8. *MEGATHYMUS POLINGI*

Megathymus polingi Skinner, Ent. News xvi, 232, 1905 (♀ only, fide B. & McD.).

Skinner, Trans. Am. Ent. Soc. xxxvii, 207, 1911.

Arizona, September.

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FIRST SERIES NO. 45 MARCH 15, 1921

UNIVERSITY OF IOWA STUDIES

STUDIES IN NATURAL HISTORY

VOLUME IX NUMBER 5

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PUBLISHED BY THE UNIVERSITY, IOWA CITY

Issued semi-monthly throughout the year. Entered at the post office at Iowa City, Iowa, as second class matter. Acceptance for mailing at special rates of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

PROFESSOR CHARLES CLEVELAND NUTTING, M. A., Editor

CONTINUATION OF BULLETIN FROM THE LABORATORIES OF NATURAL HISTORY
OF THE STATE UNIVERSITY OF IOWA

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The Ophiurans	AUSTIN H. CLARK
The Brachyura	MARY J. RATHBUN
The Tanidacea and Isopoda	PEARL L. BOONE
The Amphipods	CLARENCE R. SHOEMAKER
The Echinoidea	HUBERT LYMAN CLARK

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REPORT ON THE CRINOIDS

Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918

AUSTIN H. CLARK
Curator, Division of Echinoderms, U. S. National Museum

PREFACE

It was most gratifying to me to be honored with a request to prepare an account of the crinoids of the State University of Iowa's Barbados-Antigua Expedition for I have myself visited Barbados four, and Antigua three times in connection with my studies on the terrestrial fauna of the West Indies, and I naturally take a keen interest in everything that concerns these islands.

Perhaps it may not be out of place here to list the titles of my previous contributions to the zoölogical literature of the Lesser Antilles. These are the following:

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The present Status and Breeding Season of the Giant Toad (*Bufo agua*) in Barbados, St. Vincent, Trinidad and Demerara. Copeia, No. 27, February 24, 1916, pp. 13–14.

My notes on the mammals of the Lesser Antilles with references to the specimens obtained are incorporated in the following paper:

Mammals of the West Indies, by Glover M. Allen. Bull. Mus. Comp.

Zoöl., vol. **54**, No. 6, pp. 175–263, July, 1911. [On p. 201 under Leporidæ the heading *Oryctolagus cuniculus* should read *Lepus europaeus*, and *Lepus europaeus* in the last line on the page should read *Oryctolagus cuniculus*.]

HISTORICAL INTRODUCTION

The island of Barbados has long been well known as a locality for recent crinoids. The first recent stalked crinoid discovered was a specimen of *Isocrinus asteria* from Martinique described by Guettard under the name of "Palmier marin" in 1761; but in the very next year Ellis described another specimen of the same species from Barbados. A second individual from Barbados was described by J. S. Miller in 1821, together with one from Nevis.

The second known recent stalked crinoid was also from Martinique, and was described by d'Orbigny in 1837 under the name of *Holopus rangii*. It had only four rays, and was altogether such an extraordinary form that Dujardin and Hupé in 1862 suggested that possibly it was a barnacle rather than a crinoid.

In 1871 Mr. (later Sir) Rawson W. Rawson, the Governor of Barbados, sent to Dr. J. E. Gray a drawing of another specimen of this species which was published by the latter under the name of *Holopus rawsoni*. The actual specimen Gray never saw.

During his residence at Barbados Sir Rawson Rawson was so fortunate as to obtain, in addition to several specimens of *Holopus rangii*, examples of *Isocrinus decorus* and *Endoxocrinus parræ*, and of several species of comatulids.

In 1858 d'Orbigny described from a recent breccia at Guadeloupe, which also contained a human skeleton, a fragment of a crinoid which he called *Bourgueticrinus hotessieri*. In 1871 the United States Coast Survey steamer "Hassler" dredged some specimens of a closely related, possibly the same, species off Sandy Bay, Barbados, which were described by Count Pourtalès in 1874 under the name of *Rhizocrinus rawsonii*.

Comatulids were first reported from the West Indies in 1825 by the Reverend Lansdown Guilding of St. Vincent, who mentioned them incidentally in connection with the description of a new pentacrinite which he called *Encrinus milleri*. In this paper he published the first notice of the curious brachial articulation now known as the syzygy.

Sir Rawson Rawson had secured a number of comatulids at Barbados, but the first published record for that island was Pourtalès' description of *Antedon* [*Neocomatella*] *pulchella* and *A.* [*N.*] *alata,* which appeared in 1878.

In 1912 Dr. Clemens Hartlaub's memoir on the comatulids collected by the United States Coast Survey steamer "Blake" was published, in which were listed a number of species from twenty stations off Barbados. Isolated records of individual specimens from Barbados appeared in 1912 and 1913.

THE OCCURRENCE OF ISOCRINUS ASTERIA AND OF HOLOPUS

It is an extraordinary fact that in spite of all the dredging that has been done in the Caribbean Sea and about the West India Islands only four specimens of *Isocrinus asteria* have been brought up, one at Montserrat by the "Blake," one at Guadeloupe by the "Blake", one off Saba by the "Investigator," and a part of a stem off Havana by the "Albatross," and only two of *Holopus rangii,* one, a fragment, at Montserrat, and one off Cuba, both by the "Blake." The majority of the known specimens of both these species have been taken on fishermen's lines, or by shore parties working from a small boat, or discovered on the beaches.

The apparent rarity of these species, in contrast to the other species of *Isocrinus,* the species of *Democrinus* and the species of *Bythocrinus,* is undoubtedly due to the fact that they inhabit shallow water, living amongst the gorgonians and corals, like the similarly rare West Indian astrophytons.

This hypothesis is supported by the occasional occurrence of *Holopus rangii* washed up on the windward beaches of Barbados, where it is recorded also that once after a hurricane a large number of individuals of *Isocrinus* of all ages and sizes were cast ashore, and by the capture by Sir Rawson Rawson of two specimens of *Holopus* in 5 fathoms of water.

Speaking of the habitat of *Isocrinus* Sir Rawson wrote in a letter to Dr. Gray: "I have only procured one specimen of the

Pentacrinus caput-medusæ [*Endoxocrinus parræ*], and it was the first; I am therefore more uncertain about the place where it was procured than I am about the habitat of the *Pentacrinus mülleri* [*Isocrinus decorus*]. But I believe that they are all procured on the same bank, which, instead of five or six miles from the shore, as I was first informed, cannot be more than a mile, within the hundred-fathom line.''

From this it is apparent that *Endoxocrinus parræ* and *Isocrinus decorus* occur in relatively shallow water at Barbados as elsewhere in the West Indies.

THE RESULTS OF THE BARBADOS-ANTIGUA EXPEDITION

While a considerable number of species have been described from the Caribbean region our knowledge of the crinoids of that area is still in its infancy, and any information of any kind regarding them is therefore of interest and value.

To illustrate the paucity of the data regarding the crinoids from the very shallow water in the western Atlantic I may mention that, except for *Tropiometra picta* which is locally abundant from Tobago, Trinidad, and Venezuela to southern Brazil, there are only six records, one from Bahamas (*Nemaster iowensis*), one from the Tortugas, Florida (*Nemaster iowensis*, discovered by the University of Iowa's Bahamas Expedition), one from St. Thomas (*Antedon dübenii*), one from Dominica (*Nemaster iowensis*), and two from Brazil (*Antedon dübenii* and *Nemaster* sp.).

We probably already know a majority of the species inhabiting the Caribbean region; but these have been described from specimens long preserved and without notes regarding the details of their occurrence, color, or other points of interest, while in order to understand any animal we must have far more information than that included in a mere description of its differential structural characters and one or two records of its occurrence.

Considering the relative rarity of littoral and sublittoral crinoids in the Caribbean region and the difficulties attending their capture owing to the roughness of the bottom frequented by them the collection by the Expedition of representatives of this group at no less than twenty-five out of one hundred and one stations constitutes quite a remarkable record.

The species represented are the following:

Nemaster iowensis
Nemaster discoidea
Leptonemaster venustus
Comactinia meridionalis
Analcidometra armata
Coccometra hagenii
Democrinus rawsonii

Of these seven species one, *Analcidometra armata,* is new to the fauna of Barbados, having previously been known only from near the Tortugas, Florida, and from off Colon. The record of *Nemaster discoidea* from Antigua is the first record of any crinoid from that island.

Professor Nutting's notes on the occurrence and color of the comatulids at Barbados are very interesting and instructive.

He says that "as a whole they seemed much more brilliant than the forms encountered on the 'Pentacrinus ground' off Havana and on the Pourtalès plateau by the Bahama expedition. Few marine animals are harder to secure intact than these, as the very fragile arms are almost sure to be broken in dredging, either with the dredge or tangles. We secured a number of perfect specimens by taking them from the crannies in large coral rocks brought up from time to time in the dredge. Here they had been protected and could be taken out without injury; but their colors, alas, soon vanished in preservatives. This habit of living in rocks . . . . was quite the usual thing off Barbados. We often found these crinoids far in the interior of masses of old coral rock brought up in the dredge, and we were careful to break such rock very thoroughly, as fine comatulæ were often found within a cavity in the very heart of such masses.

"It is hard to imagine the use of these brilliant colors in a habitat such as this. Of course the rocks themselves were often brilliantly colored by the assemblage of corallines, sponges and gorgonians with which they were overgrown. The predominating colors of these were red and yellow, which also characterized the comatulids as well. I find the following colorations of free crinoids mentioned in my notes: 'yellow and white; yellow and red; purple and white; black arms, with yellowish pinnules;

rich deep vermillion, with bright yellow pinnules; lemon yellow, with black upper surface to the arms; grayish in color; violet in tinge; a crimson crinoid arm; black, with greenish yellow arms; magenta, with dark yellowish arms; one specimen very dark gray, almost black, with whitish cirri.' ''

The Crinoid Fauna of Barbados

Crinoids have been dredged by the steamers of the United States Coast Survey at the following stations at Barbados:

''Hassler'' Station, December 30, 1871, off Sandy Bay, 100 fathoms

Neocomatella pulchella
Neocomatella alata
Comactinia echinoptera
Democrinus rawsonii

''Blake'' Station 272, off Barbados, 76 fathoms

Comactinia meridionalis
Crinometra coronata

''Blake'' Station 273, off Barbados, 103 fathoms

Neocomatella pulchella
Democrinus rawsonii

''Blake'' Station 274, off Barbados, 209 fathoms

Bythocrinus robustus

''Blake'' Station 277, off Barbados, 106 fathoms

Neocomatella pulchella
Neocomatella alata
Comactinia echinoptera
Comactinia meridionalis
Democrinus rawsonii

''Blake'' Station 278, off Barbados, 69 fathoms

Comactinia meridionalis

''Blake'' Station 280, off Barbados, 221 fathoms

Endoxocrinus parræ

''Blake'' Station 281, off Barbados, 200 fathoms

Isocrinus blakei

''Blake'' Station 283, off Barbados, 237 fathoms

Endoxocrinus parræ

''Blake'' Station 285, off Barbados, 13–40 fathoms

Nemaster rubiginosa

‘‘Blake’’ Station 286, off Barbados, 7–45 fathoms
Comactinia meridionalis

‘‘Blake’’ Station 287, off Barbados, 7½–50 fathoms
Neocomatella pulchella

‘‘Blake’’ Station 290, off Barbados, 73 fathoms
Neocomatella pulchella
Stylometra spinifera
Democrinus rawsonii

‘‘Blake’’ Station 291, off Barbados, 200 fathoms
Isocrinus blakei
Endoxocrinus parræ

‘‘Blake’’ Station 292, off Barbados, 56 fathoms
Stylometra spinifera

‘‘Blake’’ Station 294, off Barbados, 137 fathoms
Neocomatella pulchella
Neocomatella alata

‘‘Blake’’ Station 295, off Barbados, 180 fathoms
Isocrinus blakei
Endoxocrinus parræ

‘‘Blake’’ Station 296, off Barbados, 84 fathoms
Neocomatella pulchella
Isocrinus decorus
Endoxocrinus parræ
Democrinus rawsonii

‘‘Blake’’ Station 297, off Barbados, 123 fathoms
Comactinia meridionalis
Stylometra spinifera
Democrinus rawsonii

‘‘Blake’’ Station 298, off Barbados, 120 fathoms
Neocomatella pulchella
Neocomatella alata
Leptonemaster venustus
Stylometra spinifera
Isocrinus decorus

‘‘Blake’’ Station 299, off Barbados, 140 fathoms
Neocomatella pulchella
Stylometra spinifera

According to P. H. Carpenter Sir Rawson Rawson obtained at Barbados the following crinoids:

Exocyclic comatulids
Endocyclic comatulids
Isocrinus decorus
Endoxocrinus parræ
Holopus rangii

There are in the British Museum the following crinoids from Barbados:

Comactinia echinoptera
Stylometra spinifera
Endoxocrinus parræ
Holopus rangii

The Kiel Museum contains two crinoids from Barbados, collected in 1873:

Nemaster discoidea
Comactinia meridionalis

In the Hamburg Museum there is the following crinoid from Barbados:

Isocrinus decorus

Thus the known crinoid fauna of Barbados in 1913 included the following seventeen species:

Neocomatella pulchella
Neocomatella alata
Nemaster rubiginosa
Nemaster discoidea
Leptonemaster venustus
Comactinia echinoptera
Comactinia meridionalis
Stylometra spinifera
Crinometra coronata
Coccometra hagenii
Isocrinus asteria
Isocrinus decorus
Isocrinus blakei
Endoxocrinus parræ
Holopus rangii
Democrinus rawsonii
Bythocrinus robustus

It is interesting that specimens of the following, practically half of the total number, had been brought up on fishermen's lines or captured in other ways without the assistance of elaborate dredging gear:

Nemaster discoidea
Comactinia echinoptera
Comactinia meridionalis
Stylometra spinifera
Isocrinus asteria
Isocrinus decorus
Endoxocrinus parræ
Holopus rangii

Indeed, *Isocrinus asteria* and *Holopus rangii* have both been found washed up on the beaches.

The West Indian Crinoid Fauna

There are known from recent seas 576 described species of crinoids, representing 142 genera which are distributed among 28 families and subfamilies; of these, 76 species, included in 22 genera and 6 families, are stalked, while 500 species, included in 120 genera and 22 families and subfamilies, are of the unstalked comatulid type.

In the West Indian region there occur 51 species (exclusive of two inadequately described) distributed among 30 genera and 16 families and subfamilies; of these 12 species belonging to 8 genera and three families are stalked, and 39 species belonging to 22 genera and 12 families and subfamilies are comatulids.

It will be remembered that Dr. P. H. Carpenter in 1881, after a cursory examination of the "Blake" comatulids estimated the number of West Indian species as slightly less than 55.

The families and subfamilies represented in the West Indian region are

Capillasterinæ
Comactiniinæ
Colobometridæ
Tropiometridæ
Thalassometridæ
Charitometridæ
Antedoninæ
Thysanometrinæ
Perometrinæ
Zenometrinæ
Bathymetrinæ
Pentametrocrinidæ
Atelecrinidæ
Pentacrinidæ
Holopodidæ
Bourgueticrinidæ

Of the genera the following 16 are confined to the West Indian region, though all of these, excepting *Holopus,* are closely related to Indo-Pacific genera

NEMASTER
LEPTONEMASTER
COMATONIA
COMATILIA
MICROCOMATULA
COMACTINIA
ANALCIDOMETRA
STYLOMETRA
HORAEOMETRA
CRINOMETRA
HYBOMETRA
COCCOMETRA
ZENOMETRA
HYPALOMETRA
HOLOPUS
ISOCRINUS

The following 3 genera occur also in the eastern Atlantic, but not in the Indo-Pacific region

NEOCOMATELLA
ANTEDON
RHIZOCRINUS

The following 11 genera occur in the Indo-Pacific region as well as in the West Indies

TROPIOMETRA
CROTALOMETRA
ADELOMETRA
TRICHOMETRA
PENTAMETROCRINUS
ATELECRINUS
ENDOXOCRINUS
BATHYCRINUS
MONACHOCRINUS
DEMOCRINUS
BYTHOCRINUS

This shows graphically the isolation of the crinoid fauna of the Caribbean area.

The Geological Significance of the West Indian Crinoid Fauna

Of the six fossil groups which are represented by recent species, the Zygometridæ, Pentacrinidæ, Holopodidæ, Apiocrinidæ, Bourgueticrinidæ and Plicatocrinidæ, three, the Pentacrinidæ, Holopodidæ and Bourgueticrinidæ, occur in the West Indian region, and the Plicatocrinidæ, inhabiting the abysses and known from off west Africa, probably will eventually be found there.

The genera occurring in the West Indies which include both recent and fossil species are the following

Family Pentacrinidæ

Isocrinus

Range of the recent species.—West Indies.

Horizons.—Trias and Jurassic; Europe and North America.

Family Holopodidæ

Holopus

Range of the recent species.—West Indies.

Horizon.—Tertiary; Italy.

Family Bourgueticrinidæ

Rhizocrinus

Range of the recent species.—West Indies to Massachusetts, and northwestern Europe.

Horizons.—Cretaceous, New Jersey; Eocene, Europe.

Democrinus

Range of the recent species.—Tropical Atlantic and East Indies.

Horizon.—Recent; Guadeloupe.

As in all the rest of the world there are only two genera, Catoptometra and Eudiocrinus, both belonging to the Zygometridæ and both ranging from the Malayan region to southern Japan, which are definitely known to include both recent and fossil species, it would seem that the Caribbean region has a closer affinity with the past faunas than has any other area.

The relative antiquity of the West Indian crinoid fauna seems to be attested by the following facts:

Of the 8 genera of stalked crinoids represented 4, or one-half, occur also as fossils; in the Indo-Pacific region out of 19 stalked genera only 1 occurs as a fossil.*

Of the 30 genera of comatulids 23, or 77%, include only five or ten armed species. The Comasterinae, Himerometridae, Stephanometridae and Mariametridae, including only multibrachiate species, are not represented; the Zygometridae, many species of which are conspicuous for the great number of arms, is also unrepresented.

Of these 30 comatulid genera 23, or 77%, are monotypic, or are represented by a single species.

KEY TO THE GENERA OF CRINOIDS REPRESENTED IN THE CARIBBEAN SEA AND ADJACENT WATERS

a^1 No stem; the center of the dorsal side of the animal is occupied by a single more or less thick plate or knob bearing jointed appendages by means of which the animal attaches itself.

b^1 five very long and slender arms

Pentametrocrinus

b^2 ten or more arms

c^1 one or more of the proximal pinnules bears in its terminal portion a comb-like structure formed by the production of the distal outer side of each of the segments in the form of a long thin triangular process

d^1 more than ten arms

e^1 all of the division series are composed of two ossicles; the lowest pinnule is on the second brachial following the last axillary

Neocomatella

e^2 first division series of two ossicles, the second of four of

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*Cf. The Ontogeny of a Genus, American Naturalist, vol. 45, No. 534, June, 1911, pp. 372-374; The Comparative Age of the Recent Crinoid Faunas, American Journal of Science [4], vol. 32 (whole No. 182), No. 188, August, 1911, pp. 127-132; Das relative Alter der rezenten Seelilienfaunen, Naturwiss. Rundschau, JG. 27, No. 15, April 11, 1912, pp. 191-192; On the Deep Sea and Comparable Faunas, Intern. Revue der ges. Hydrobiol. und Hydrogr., vol. 6, 1913, Heft 1, pp. 17-30, Heft 2/3, pp. 133-146.

which the two outer are united by syzygy, the following of three of which the two outer are united by syzygy; sometimes the division series are very irregular; the first pinnule following the outermost axillaries is on the first brachial

Nemaster

d^2 ten arms

e^1 cirri short and stout with the dorsal profile smooth, there being no processes on the distal ends of the segments; the segments of the middle pinnules are short and broad, with the distal corners more or less produced

Comactinia

e^2 cirri longer and more slender, the outer segments bearing more or less prominent processes on the dorsal side of the distal ends

f^1 the three pairs of pinnules following the first pair on each arm are absent

Comatilia

f^2 all of the pinnules are present

g^1 first and second segments of the proximal pinnules with a very high and prominent carinate process of which the outer edge, at least on the second segment, is parallel with the longitudinal axis of the pinnule

Leptonemaster

g^2 there are no carinate processes on the basal segments of the proximal pinnules

h^1 cirri slender, but not excessively so; terminal comb arising at about, or even within, the proximal third of the pinnules of the first pair, composed of exceptionally large rounded teeth which usually much exceed in height the lateral diameter of the segments which bear them, and frequently absent; 4th–7th brachials with prominent spinous median knobs or keels; usually one or more of the earlier segments of P_1 is twice as long as broad, or even longer; size moderate

Comatonia

h^2 cirri excessively slender and threadlike, the enormously elongated segments with greatly swollen articulations; the penultimate segment, which is much shorter than those preceding, is twice as long as broad; terminal comb confined to the tip of the proximal pinnules, and of the usual type; no carination of the earlier brachials; none of the segments of P_1 elongated *Microcomatula*

- c² no comb-like structures on the proximal pinnules
  - d¹ there are no deposits in the ventral perisome of the pinnules visible to the naked eye
    - e¹ each cirrus socket is bordered proximally and laterally by a prominent raised rim; a narrow circlet of basals separates the centrodorsal from the radials; centrodorsal conical, the cirrus sockets arranged in ten equidistant columns; first syzygial pair and following brachials very obliquely wedge-shaped or triangular *Atelecrinus*
    - e² no raised rim about the proximal and lateral portions of the cirrus sockets; no basals; first syzygial pair oblong; following brachials oblong or slightly wedge-shaped, later becoming triangular, or at least more obliquely wedge-shaped
      - f¹ centrodorsal elongate, conical or columnar, with the cirrus sockets arranged in 10 definite columns
        - g¹ the ten columns of cirrus sockets are closely crowded on a conical centrodorsal; size small; color yellow *Adelometra*
        - g² the ten columns of cirrus sockets are segregated in five radial pairs separated by high interradial ridges; centrodorsal columnar; size medium or large; color red or purple *Zenometra*
      - f² cirrus sockets closely crowded, and without definite arrangement
        - g¹ proximal pinnules absent; lowest pinnule on the fifth brachial *Hypalometra*
        - g² proximal pinnules present; the second and following brachials bear pinnules
          - h¹ first pinnule extraordinarily flexible, composed of more than 30 segments which are about as long as broad with their corners cut away, appearing like a string of minute beads; second and following pinnules of the

same length, but composed of about half as many much longer segments, and much less flexible

Coccometra

h2 most or all of the segments of the first pinnule longer than broad

i1 proximal pinnules all of the same character; first pinnule shorter than the second, which is shorter than the third

j1 each brachial has the midline of the dorsal surface raised into a high prominent keel; the division series and first two brachials are very broad, in close lateral contact with their neighbors, and only slightly convex dorsally; the genital pinnules are very long, the longest pinnules on the arm; the centrodorsal is very large, columnar or broad truncated conical; the cirri are short and stout, without dorsal processes; the general habitus is stout

Tropiometra

j2 the dorsal surface of the brachials is unmodified, but their distal edges are produced in a frill of long spines; the division series and lower brachials are narrow and well rounded dorsally; the genital pinnules are shorter than the proximal or distal pinnules, which are of the same length; all the pinnules are very slender and stiff, especially the lower, which are thorn-like, the component segments with numerous long spines on their distal ends

Hybometra

i2 first pinnule markedly longer than the second and following

j1 first pinnule very stout, and so large at the base as to give the second brachial the appearance of an axillary; edges of the elements of the division series armed with coarse

short spines; cirri short and stout, with short subequal segments most of which bear high dorsal spines, the more proximal with a transversely elongate chisel-like edge
Analcidometra

j2 first pinnule much elongated, but not especially stout; no true dorsal spines on the cirrus segments

k1 centrodorsal rounded conical, almost entirely covered with from 40 to 60 cirrus sockets; cirri long, rather slender, composed of from 25 to 30 segments; proximal brachials with the distal edge abruptly everted and conspicuously spinous; first pinnule more slender than those following; division series and lower brachials in close lateral apposition and flattened against their neighbors
Trichometra

k2 centrodorsal very low, flattened hemispherical, with less than 35 cirrus sockets; cirri short, rather stout, with not more than 15 segments; no eversion of the distal borders of the earlier brachials; first pinnule stouter than those succeeding; division series and arm bases narrow and widely separated; a cluster of perisomic interradial plates in each interradial angle
Antedon

d2 the ambulacral grooves on the pinnules and arms are bordered by two rows of minute plates easily seen in dried specimens of which those of the inner row can be closed down over them

e1 cirri short and stout, strongly curved, with not more than 20 segments none of which bear dorsal spines; centrodorsal very broad, more or less columnar or broad truncated conical, the cirrus sockets closely crowded and irregularly arranged; first two pinnules similar, slender,

composed of numerous short segments; 20–30 arms; proximal portion of animal usually highly ornamented with spines or tubercles, though sometimes plain
Crinometra

e² cirri long, with more than 30 segments of which the outer bear prominent dorsal spines; centrodorsal rather small, more or less conical, the cirrus sockets arranged in ten columns; first pinnule longer and stouter than the following

f¹ the segments in the basal half of the genital pinnules are much broadened, forming a roof over the gonads; 10 arms
Horaeometra

f² the segments of the genital pinnules are not expanded; usually between 20 and 30 arms

g¹ very spinous; the edges of the elements of the division series and lower brachials are armed with long spines, and each of the middle and outer brachials bears a single long curved laterally compressed spine which overlaps the base of the brachial succeeding; division series and arm bases narrow, strong convex dorsally and more or less separated
Stylometra

g² smooth; the edges of the elements of the division series and brachials are unmodified; division series and arm bases broad and in close lateral apposition
Crotalometra

a² A stem is present

b¹ the short thick stem or stalk consists of a single unjointed element by which the animal is solidly attached to corals or other hard objects; the arms are very short and stout, six of them being considerably larger than the other four
Holopus

b² the stem is long and many jointed; its distal end is never attached bearing five articulated processes or cirri; the stem ends abruptly, exposing the distal face of one of the columnals, which is usually more or less worn; size large

d¹ all of the division series are of two elements
Endoxocrinus

d² the first division series is of two elements, the following always of more than two, the number increasing distally
Isocrinus

- e^2 there are no modified columnals, and no cirri; at the end of the stem there is a cluster of roots, or radicular cirri, which may extend upward over a number of columnals
  - d^1 the third, sixth and ninth brachials (the fifth, eighth and eleventh ossicles beyond the radials) have a muscular articulation at either end; the basals are fused into a solid ring which is broader than long, cylindrical or truncated conical *Bathycrinus*
  - d^2 all the ossicles following the radials are united in pairs by non-muscular articulations; that is, muscular and non-muscular articulations regularly alternate throughout the arm; the basals are separated, or fused into a solid ring which is truncated conical, longer than broad
    - e^1 ten arms (twelve arms in six-rayed species) *Monachocrinus*
    - e^2 five arms
      - f^1 no sutures visible between the basals, which are fused into a solid conical ossicle; four to seven rays *Rhizocrinus*
      - f^2 basals always separated by distinct sutures; always five rays
        - g^1 stem relatively slender, the longest columnals at least twice as long as broad; calyx more or less conical *Bythocrinus*
        - g^2 stem stout, the longest columnals rarely so much as twice as long as broad, usually only slightly longer than broad; calyx almost or quite cylindrical *Democrinus*

THE PLANT-LIKE INTERRELATIONSHIPS OF THE CARIBBEAN CRINOIDS

Some years ago I stated that the study of the fixed and sedentary marine animals was often rendered exceptionally difficult through the more or less complete assumption of that type of variation which we find among the plants. Individuals of many species of plants vary very widely according to the dampness or dryness, richness or barrenness, and brightness or darkness of the locality inhabited, while in other types which will grow only within a relatively small range of conditions the variation is slight.

The same thing is true in the fixed and sedentary marine animals, and is well illustrated by the Caribbean crinoids.

The thermal and actinic range of the stalked species is small, as they are for the most part inhabitants of deep water where conditions are practically uniform; their range of variation is therefore slight and there is little difficulty in delimiting their species.

But many, if not most, of the unstalked species in the Caribbean Sea have an unusually great bathymetrical range, their representatives in the littoral and sublittoral zones living under a great variety of conditions varying in temperature and illumination, and therefore also in the quality and quantity of the food. From this circumstance it comes about that each of the more abundant types occurs in a number of more or less distinct varieties which, intergrading in every conceivable way, are quite plant-like in their interrelationships, and which appear to be proportionate in number to the thermal and actinic range of the species.

Thus the interrelationships of the forms in the genus COMACTINIA—Hartlaub recognizes fifteen varieties of *Comactinia echinoptera*—and in the genus CRINOMETRA, with fifteen nominal species, recall the interrelationships of the more difficult sections of such plant genera as CRATÆGUS, RUBUS or ROSA, and those of the forms in the genus NEMASTER the interrelationships of our local species of CIRCÆA.

The comatulids differ from all the other fixed and sedentary animals in being reduced to practically nothing but a food collecting apparatus, the organs not concerned, as are the arms and pinnules, in the collection of food being reduced to an absolute minimum. In the plants the species of Rafflesiaceæ are for the most part reduced to a flower only, without leaves, stem or true root, and it is interesting to note that the range in size of the species of Rafflesiaceæ and of the comatulids is the same, from less than an inch in diameter to about three feet (*Rafflesia arnoldi* and *Heliometra maxima*).

In the crinoids the excretion of waste products is for the most part effected by the formation of small globules (sacculi) chiefly along the ambulacral grooves which are superficially quite similar to the "glands" dotting the leaves in the Hypericaceæ and other plants. As a rule in the crinoids, as in many, if not most, other sedentary and fixed types, the pigment is more or less distributed throughout the entire animal (it may even be chiefly or entirely internal in some of the Polyzoa) as in most of the plants used for dyeing purposes, and is not chiefly or exclusively superficial as in most active animals. When it is recalled that the variations in the symmetry of flowers are duplicated with great exactness in the zoöids of the fixed animal types and in the crinoids, the odorous features of the Menthaceæ, most Solanaceæ, etc., are equally characteristic of sponges, the acrid juice of the Brassicaceæ is duplicated in most cœlenterates (small millepores are called "sea ginger" in Barbados), the pleasant odor of many plants is equally a feature of *Flustra* and other marine animals, etc., etc., the comparison between the fixed and sedentary animals and the plants is seen to be quite justified.

ANNOTATED LIST OF THE SPECIES OBTAINED

Family **Comasteridæ**

Subfamily **Capillasterinæ**

Nemaster iowensis (Springer)

Actinometra iowensis 1902. SPRINGER, American Geologist, vol. **30,** p. 98 (Florida reefs, 3 feet).—1903. SPRINGER, Bull. Lab. Nat. Hist. State Univ. Iowa, vol. **5,** No. 3, pp. 217–221, plate 1.

Nemaster iowensis 1909. A. H. CLARK, Vid. Medd. fra den naturhist. Foren. i Köbenhavn, 1909, p. 118.

Station 53:

Arms only; "arms black, pinnules lemon yellow at tips, shading into black."

Station 97:
Arms only.
Station 98:
Arms only.
Station 99:
Arms only.
Station 100:
Arms only.

Barbados; Engineers' Pier, in 25 feet of water.

One specimen; the centrodorsal is very thin, discoidal, the flat dorsal pole 5 mm. in diameter, slightly sunken in a circular area 2 mm. in diameter in the center.

The cirri, which are arranged in a single very irregular marginal row, are XXII, 13–15, 13 mm. or 14 mm. long.

The 43 arms are about 90 mm. long.

The color in life was "sulphur yellow."

Barbados.

Arms only; "nearly black."

Nemaster discoidea (P. H. Carpenter)

Actinometra discoidea 1883. VON GRAFF, Bull. Mus. Comp. Zoöl., vol. **11,** No. 7, p. 127 (*nomen nudum;* myzostomes).—1884. VON GRAFF, "Challenger" Reports, vol. **10,** Zoölogy, part 27, p. 14 (*nomen nudum;* myzostomes).—1888. P. H. CARPENTER, "Challenger" Reports, vol. **26,** Zoölogy, pp. 58, 316, 317, 368, 382 (Caribbean Islands, 88–118 fathoms).

Actinometra echinoptera var. *discoidea* 1912. HARTLUB, Mem. Mus. Comp. Zoöl., vol. **27,** No. 4, p. 463, pl. 17, figs. 7, 9, 15 (fig. 14, also given as this species, is probably *iowensis*).

Nemaster insolitus 1917. A. H. CLARK, Proc. Biol. Soc. Washington, vol. **30,** p. 65 ("Albatross" Station 2146, Caribbean Sea, 34 fathoms).

Station 50:

Arms only.

Station 51:

One magnificent specimen; the centrodorsal is thin, discoidal, the flat dorsal pole 5 mm. in diameter with a shallow central depression; the cirri are XXIV, 13, from 12 mm. to 14 mm. long; the twenty slender arms are about 150 mm. long; all of the IIBr series are 4(3+4).

Station 70:

Arm fragments.

Station 79:

Arms only.

Station 85:

Part of an arm.

Station 92:
Arms only.
Barbados.

One small specimen with 15 arms 45 mm. long. The color in life was "very dark gray, pinnules and cirri whitish, the former banded with darker."

Detached arms, presumably from another station. The color in life was "black, with yellow pinnules."

Station 101:
One much broken specimen with 19 arms.

Leptonemaster venustus A. H. Clark

Leptonemaster venustus 1909. A. H. Clark, Proc. U. S. Nat. Mus., vol. **36,** p. 499 ("Grampus" Station 5104).

Station 3:
One small specimen; this had "a greenish tinge when fresh."
Station 7:
One small specimen; in life this was "pale yellow."
Station 11:
Twenty specimens, with arms from 20 mm. to 50 mm. in length; in life these were "yellow."
Station 13:
One small specimen.
Station 18:
One specimen.
Station 46:

One specimen with arms about 65 mm. long. The color in life is described as follows: "Arms barred with cadmium yellow; the base of each arm is of this color up to the main division, and for an eighth of an inch or more distal to this point; beyond this for a quarter of an inch, more or less, the usual white color prevails, then a yellow bar for three-sixteenths of an inch, again a white bar for about the same distance; beyond this the white prevails, the yellow bars being irregularly spaced and one-sixteenth of an inch or less in width; there are from five to seven bars, as a rule, on each arm; the pinnules over each bar tend to be yellowish; the tips of the arms are also yellowish; the cirri are a paler yellow."

Station 56:

One specimen with arms about 30 mm. long.

Station 59:

One specimen with arms 50 mm. long. The color in life was "yellow."

Station 67:

Five specimens with arms up to 65 mm. in length. The color in life was "brownish."

Station 78:

One small specimen.

Subfamily **Comactiniinæ**

Comactinia meridionalis (Agassiz and Agassiz)

Alecto meridionalis 1865. Agassiz and Agassiz, Seaside Studies p. 121, figs. 153, 154 ("A. Agassiz, MS.;" coast of South Carolina).

Comactinia meridionalis 1909. A. H. Clark, Vid. Med. fra den naturhist. Forening i Köbenhavn, 1909, p. 150.

Station 9:

Arms only. In life these were either "light yellow," or "body of arm light yellow, the pinnules deep carmine, tipped with yellow in most cases."

Station 11:

Four specimens, with the arms about 60 mm. long. In life these had the arms "dark carmine, the pinnules orange with red and yellow spots and tipped with yellow;" or the arms were "bright purple, the pinnules more so."

Station 14:

One small specimen, with the "base of the pinnules strongly purple."

Station 51:

One young specimen with the arms 40 mm. long.

Station 67:

Five specimens with very slender arms up to about 70 mm. in length. In life one was "a rich carmine;" another was "rich carmine with yellow spots, the pinnules orange yellow."

Station 78:

Two specimens, the larger with the longest arms about 70 mm long.

Station 85:

One specimen with arms about 70 mm. long.

Station 96:

Four specimens, the largest with the anterior arms 85 mm. and the posterior 47 mm. in length, closely resembling those collected by the "Corwin" off French Reef. In life one was "dark yellow;" the others had the "arms dark rose pink, the cirri pale yellow, the pinnules pale yellow, banded with burnt sienna."

Barbados.

One specimen, which had the "arms deep mauve, and the pinnules very pale straw yellow banded with grayish purple."

Family **Colobometridæ**

Analcidometra armata (Pourtalès)

Antedon armata 1869. POURTALES, Bull. Mus. Comp. Zoöl., vol. **1,** No. 11, p. 356 (west of the Tortugas, in 35 fathoms).

Oligometra caribbea 1908. A. H. CLARK, Proc. U. S. Nat. Mus., vol. **34,** p. 238 (off Colon, in 34 fathoms).

Station 11:

One very small specimen with arms 15 mm. long.

Family **Antedonidæ**

Subfamily **Thysanometrinæ**

Coccometra hagenii (Pourtalès)

Comatula (Alecto) hagenii 1868. POURTALES, Bull. Mus. Comp. Zoöl., vol. **1,** No. 6, p. 111 (of Sand Key, Florida, in 100 fathoms).

Coccometra hagenii 1908. A. H. CLARK, Proc. Biol. Soc. Washington, vol. **21,** p. 129.

Station 15:

Four small and young specimens; the segments of P_1 are much longer than usual, probably owing to their small size.

Family **Bourgueticrinidæ**

Democrinus rawsonii (Pourtalès)

Rhizocrinus rawsonii 1874. POURTALES, Ill. Cat. Mus. Comp. Zoöl., vol. **4,** No. 8, p. 27.

Station 7:

One extraordinarily well preserved specimen, agreeing in all details with Pourtalès' types, which were also from Barbados.

The total length is 178.7 mm.; the arms are 19 mm. long, the calyx (including the radials) 4.7 mm. long, and the stem, which is composed of 58 columnals plus a portion of the root, is 155 mm. long.

LIST OF THE STATIONS, WITH THE SPECIES REPRESENTED AT EACH

Station 3: *Leptonemaster venustus*
Station 7: *Leptonemaster venustus*
Democrinus rawsonii
Station 9: *Comactinia meridionalis* (arms)
Station 11: *Leptonemaster venustus*
Comactinia meridionalis
Analcidometra armata
Station 13: *Leptonemaster venustus*
Station 14: *Comactinia meridionalis*
Station 15: *Coccometra hagenii*
Station 18: *Leptonemaster venustus*
Station 46: *Leptonemaster venustus*
Station 50: *Nemaster discoidea* (arms)
Station 51: *Nemaster discoidea*
Comactinia meridionalis
Station 53: *Nemaster iowensis* (arms)
Station 56: *Leptonemaster venustus*
Station 59: *Leptonemaster venustus*
Station 67: *Leptonemaster venustus*
Comactinia meridionalis
Station 78: *Leptonemaster venustus*
Comactinia meridionalis
Station 79: *Nemaster discoidea* (arms)
Station 85: *Comactinia meridionalis*
Station 92: *Nemaster discoidea* (arms)
Station 96: *Comactinia meridionalis*
Station 97: *Nemaster iowensis* (arms)
Station 98: *Nemaster iowensis* (arms)

Station 99: *Nemaster iowensis* (arms)
Barbados; Engineers' Pier, 25 feet: *Nemaster iowensis*
Barbados: *Nemaster iowensis* (arms)
Nemaster discoidea
Comactinia meridionalis
Station 101: *Nemaster discoidea*

REPORT ON THE OPHIURANS

Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918

AUSTIN H. CLARK

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PREFACE

By a fortunate combination of circumstances it happened that just before and during the early dredging operations of the U. S. Coast Survey between 1867 and 1879 (by the steamers "Corwin," "Hassler" and "Blake"), which were the first intensive deep sea investigations ever undertaken, interest in the ophiurans had reached a pitch of intensity quite comparable to that of the revival of the past ten years centering in the Indo-Pacific and Antarctic, and new material was studied and described as rapidly as it was obtained. The two authors of those days chiefly interested in the West Indian ophiurans were Theodore Lyman of Harvard, who studied the ophiurans collected by the ships of the Coast Survey, and later those of the "Challenger," and Christian F. Lütken of Copenhagen to whom were sent a large number of specimens from the Danish West Indies, mostly from St. Thomas, collected by A. H. Riise. As many of Riise's specimens were later also sent to Lyman, the latter was enabled to study authentic examples of many of Lütken's species from the original locality.

The completeness of the early collections and the thoroughness and accuracy with which the early authors worked are attested by Professor Kœhler's report upon the ophiurans secured by the "Albatross" in the West Indies (1914) and by Dr. Hubert Lyman Clark's memoir on the ophiurans of Porto Rico (1902) and catalogue of known ophiurans (1915) in which a negligible number of new Caribbean types are described, and almost none of the earlier species placed in synonymy.

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Within the last few years the study of the ophiurans has taken on a renewed impetus, and a number of large and important memoirs have appeared. A rather unusual feature of this activity has been that all of the authors concerned have worked in perfect harmony and without a trace of other than the most friendly coöperation, with the result that, instead of a mass of new and conflicting ideas and testily debated new genera and species we have before us today an entirely new classification of these animals in its perfected form only two years old yet accepted by all the authorities on the subject, and an increase of something like 300% in the number of known species, over 400 having been described by a single author, very few of which it has been found necessary to place in the synonymy of older forms.

To the energy and activity of Professor René Kœhler of Lyons we are indebted for the greatest increase in the number of known types, and to Professor Hikoshichiro Matsumoto of Sendai for our new classification; to Dr. Hubert Lyman Clark of Harvard we are indebted not only for an important increase in the number of known genera and species, second only to that which we owe to Professor Kœhler, but also for a magnificent memoir in which all of the recently described new species are included, assembled under Matsumoto's revised classification.

The classification here adopted follows that employed in Dr. Clark's memoir except that, with Professors Kœhler and Verrill, I recognize the family Ophiomycetidæ, the genera of which are placed by Matsumoto and by H. L. Clark in the Ophiacanthidæ.

The memoirs which should be consulted in connection with the present paper are the following:

REPORT ON THE OPHIUROIDEA COLLECTED BY THE BAHAMA EXPEDITION IN 1893. Addison E. Verrill. Bulletin from the Laboratories of the State University of Iowa, vol. **5,** No. 1 (Bulletin of the University of Iowa, N. S., vol. **1,** No. 6), September, 1899, pp. 1–86, plates 1–8.

A CONTRIBUTION TO THE STUDY OF OPHIURANS OF THE U. S. NATIONAL MUSEUM. René Kœhler. Bulletin **84,** U. S. National Museum, 1914, pp. i–vii, 1–173, plates 1–18.

A NEW CLASSIFICATION OF THE OPHIUROIDEA. Hikoshichiro Matsumoto. Proceedings of the Academy of Natural Sciences, Philadelphia, 1915 (April 12, 1915), pp. 43–92.

CATALOGUE OF RECENT OPHIURANS: based upon the collection of the Museum of Comparative Zoölogy. Hubert Lyman Clark. Memoirs of the Museum of Comparative Zoölogy, vol. **25,** No. 4, December, 1915, pp. 165–376, plates 1–20.

A MONOGRAPH OF JAPANESE OPHIUROIDEA, arranged according to a new Classification. Hikoshichiro Matsumoto. Journal of the College of Science, Imperial University of Tokyo, vol. **38,** Art. 2, March 31, 1917, pp. 1–408, plates 1–7.

OPHIURES [collected by Kükenthal and Hartmeyer in the West Indies, a number at Barbados]. René Kœhler. Zoölogischer Jahrbuch, Supplement 11, Heft 3, 1913, pp. 351–380, plates 20, 21.

THE CARIBBEAN ECHINODERM FAUNA

On the basis of the available data it is difficult to make any statements of value regarding the subdivisions of the echinoderm fauna of the American side of the tropical Atlantic. There is a certain homogeneity about it which suggests that it should be regarded as a single faunal unit locally modified, as a result of diverse ecological conditions, by the partial or complete elimination of certain types which results in local changes in the faunal balance; that is to say, the faunal characteristics of any given region are more closely dependent upon the size and character of the adjacent land mass (features determining the amount and kind of food) than they are upon fundamental faunal considerations.

The Brazilian section of this fauna includes several characteristic types not known elsewhere in the region. Perhaps the most striking of these is *Paracentrotus gaimardi,* which also occurs in west Africa. This species appears to be rare and local and it is not by any means certain that it does not occur in the next section.

The fauna of the continental shores of the Caribbean region, with Trinidad and Tobago, seems, so far as we can tell, to be essentially similar to the Brazilian, minus certain types and plus a few others. The most conspicuous of the latter is the littoral *Thyraster serpentarius,* but this is known only from Vera Cruz and from off Tampa Bay, Florida (Cat. No. 36995 U. S. National Museum).

The third division, which appears to be merely the preceding minus a number of its characteristic types and plus a few which possibly are not in reality confined to it, includes the Antillean Islands north of Tobago and the Atlantic coast of North America to Carolina, some of the species even reaching Cape Cod. This division is richest in species in the Greater Antilles and southern Florida, and poorest in the southern Lesser Antilles, especially on the oceanic island of Barbados.

THE OPHIURANS COLLECTED BY THE EXPEDITION

The expedition brought back representatives of forty-three species of ophiurans; of these 26 were found at Barbados only, 14 were found both at Barbados and at Antigua, and 3 were found only at Antigua.

Of the 40 species collected at Barbados the following 11 were there found for the first time:

Ophiomyxa flaccida
Astrophytum muricatum
Ophioplus tuberculosus
Amphiura diducta
Amphipholis limbata
Amphiodia planispina
Ophiactis savignyi
Ophiothrix lineata
Ophiothrix pallida
Ophiomusium sculptum
Ophiolepis elegans

The 17 species collected at Antigua constitute new records; they were:

Ophiomyxa flaccida
Ophiactis mülleri
Ophiothrix angulata
Ophiothrix öerstedii
Ophiothrix suensonii
Ophionereis reticulata
Ophiocoma echinata
Ophiocoma pumila
Ophiocoma riisei
Ophioderma appressa
Ophioderma brevicauda
Ophioderma cinerea
Ophioderma rubicunda
Ophiura acervata
Ophiomusium validum
Ophiolepis elegans
Ophiolepis paucispina

THE WEST INDIAN OPHIURAN FAUNA

There are known from the recent seas 1420 described species of ophiurans representing 192 genera which are distributed among 13 families.

In the West Indian region there occur 255 species representing 88 genera and all the known families.

Whereas in the case of the crinoids all the species occurring in the Caribbean region are confined to that area, a considerable number of the ophiurans occur more or less generally throughout the Atlantic basin, or are represented by closely related types in the east Atlantic and Mediterranean Sea, and some are almost universally distributed.

As examples of wide ranging forms the following may be mentioned.

Amphipholis squamata, which is found from Norway to the Cape of Good Hope, on both sides of the Atlantic, and from Australia and New Zealand to Juan Fernandez, California and Hawaii.

Amphiura otteri, occurring on both coasts of the north Atlantic and in Lower California.

Ophiactis savignyi, occurring in shallow water in all warm seas.

Ophiacantha vepratica, found in the West Indies and in Fiji.

Ophiomusium lymani, occurring everywhere in water of moderate depth and temperature.

Ophiomusium planum, found on both coasts of the middle Atlantic and in the Indian Ocean.

Amphiophiura sculptilis, found in the West Indies, the Indian Ocean, the East Indies and Japan.

Asteronyx loveni, found in all northern seas and southward to the West Indies, Lower California and Japan.

The following 21 genera are known from the Caribbean region only; those marked with an asterisk (*) are monotypic.

*OPHIOBRACHION
OPHIOSCIASMA
*OPHIOPHRIXUS
*OPHIOHOLCUS
*OPHIOPLUS
*HEMIEURYALE

*Astrocnida
*Astrophytum
*Astrogordius
*Astrocyclus
*Astrocynodus
[?Ophiochondrus]
*Ophiochondrella
Ophiomitra
*Ophiacanthella
*Microphiura
*Ophioblenna
*Ophionema
*Ophiothyreus
*Amphipholizona
*Ophiopæpale

While a number of these genera will undoubtedly eventually be found in other parts of the world, still the fact that they represent 24% of the total number of genera occurring in the West Indies is significant, and the fact that all but three of them, or 83%, are monotypic is still more so.

The existence in the West Indian region of these endemic genera indicates that this region constitutes a very marked faunal entity, while the occurrence of so many monotypic genera suggests that faunal stability was attained a long while ago; in other words that, as compared to the other portions of the oceans, faunal evolution has been retarded so that the West Indian region may be described as faunally the most ancient portion of the recent seas.

So far as we are able to judge from the geological record, taken in connection with the recent fauna, there are two quite distinct types of distribution, always, however, more or less superimposed, in every homogeneous animal group.

A newly arisen animal type immediately spreads to the limits of its possible distribution, and within the area overrun by it all sorts of variants appear which may be considered as of varietal, subspecific or specific value.

Thus a genus or any other homogeneous group represented in a given faunal district by a number of closely related types is a group of recent origin, or of recent introduction.

As time passes a number of factors begin to assert themselves, internal and external parasitism, economic pressure of great numbers of individuals, and economic pressure of competing types, which tend to restrict the possible scope of variation and to confine the variants within well marked limits which constantly become narrower and narrower until only a few well marked and distinct types remain each of which has now acquired the status of a monotypic genus.

Thus a group of animals represented in a given region wholly or chiefly by a number of very distinct types, or monotypic genera, has been more or less isolated in that region for a very considerable period.

It is interesting to compare the occurrence of the ophiurans in the Caribbean region with that of the crinoids.

Total number of ophiuran families, 13; of crinoid families, 28.

Total number of ophiuran genera, 192; of crinoid genera, 142.

Total number of ophiuran species, 1420; of crinoid species, 576.

Ophiuran families in the West Indies, 13; percent of total, 100.

Crinoid families in the West Indies, 16; percent of total, 54.

Ophiuran genera in the West Indies, 88; percent of total, 46.

Crinoid genera in the West Indies, 30; percent of total, 21.

Ophiuran species in the West Indies, 255; percent of total, 18.

Crinoid species in the West Indies, 51; percent of total, 9.

Endemic ophiuran genera, 21; percent of total in West Indies, 24.

Endemic crinoid genera, 16; percent of total in West Indies, 53.

Monotypic ophiuran genera, 18; percent of total in West Indies, 20.

Monotypic crinoid genera, 11; percent of total in West Indies, 37.

The recognized families and subfamilies in the recent crinoids are in almost all cases better differentiated than the same divisions among the ophiurans as we understand them now. This indicates a phylogenetic advancement of the crinoid over the ophiuran fauna whereby the former has become more definitely crystallized into well circumscribed types.

The relationships of the ophiuran and crinoid families, genera and species may be analyzed as follows:

	OPHIURANS	CRINOIDS
Number of families	13	28
Average number of genera per family	16	5
Average number of species per genus	7	4

The greater number of crinoid families indicates that the recent crinoid fauna, if not actually older than the recent ophiuran fauna, at least developed earlier, as the various forms have become more definitely circumscribed and segregated into well differentiated units. The relative state of undevelopment of the ophiuran fauna is also indicated by the much larger number of genera in each family and of species in each genus, as well as by the larger number of species in each genus in any given locality.

Only about one-half of the higher groups of crinoids are represented in the West Indies, while all of the higher groups of ophiurans occur there. One crinoid family, the Holopodidæ, is known only from the Caribbean Sea. Assuming that the Malayan region is the present center of distribution for marine animals and the place of origin of most recent types, this is easily accounted for by the much greater facilities for dispersal possessed by the vast majority of the ophiurans, through their pelagic young.

Only 21% of the known crinoid genera are found in the West Indies, while 46%, or more than twice as many, of the ophiuran genera occur there. This also is probably due to the greater facilities for dispersal possessed by the ophiurans.

Of the known ophiuran species 18% occur in the West Indies, as against 9%, half as many, of the known crinoids. This would seem to indicate that as the Caribbean crinoid fauna had grown old and become crystallized along definite lines no new accessions had come in from the rapidly developing fauna of the Malayan region, whereas the interchange of ophiurans from east to west has kept the ophiuran fauna younger.

Among the crinoids 53% of the Caribbean genera are not represented elsewhere, while among the ophiurans the number is less than half as large, only 24%. This is the result of the crystallization of the West Indian crinoid fauna and the lack of interchange with other faunas, which has taken place to a much greater degree than in the case of the ophiurans.

Exactly the same explanation holds for the fact that 37% of the endemic genera of crinoids are monotypic, while only about half as many of the ophiuran genera, 20%, are monotypic.

The 192 genera of ophiurans may be classified according to their geographical ranges as follows:

Universally distributed, or occurring in all warm seas	68
Indo-Malayan region only	57
Caribbean region only	21
Antarctic only	8
South Australia, Tasmania and New Zealand	7
Arctic and north Atlantic	6
North Pacific	5
North Pacific and north Atlantic	3
Middle Atlantic	3
Caribbean Sea and west coast of Central America	3
Peru to southern California	3
Caribbean Sea to Galapagos Islands	1
Caribbean Sea and Mediterranean	1
Indo-Pacific and Mediterranean	1
Southern California and New Zealand	1
[Unclassified	4]

In order fully to understand the affinities of the West Indian ophiuran fauna the following apparently anomalous ranges of certain genera, supplemented by similar cases among the starfishes and echinoids, must be considered.

Warmer parts of the eastern and western Atlantic; Mexico to Chile

Narcissia
Arbacia

Both coasts of tropical America

Encope
Mellita

West Indies and western coast of Central America

Hemipholis
Ophiocryptus
Ophiozona

West Indies and Galápagos Islands (probably in reality the same as the preceding)

Sigsbeia

Peru to southern California (some only in part)

Astrocaneum
Diopederma
Gymnophiura
Platasterias
Paulia (Galápagos Islands also)
Pharia
Phataria

NIDORELLIA
HELIASTER
AMPHIASTER
CÆNOCENTROTUS (Galápagos Islands also)
TETRAPYGUS

West Indies and eastern Atlantic; Hawaiian Islands; southern Japan; Kei Islands

CÆNOPEDINA

Western coast of Mexico; Hawaiian Islands; Australia, Tasmania and Lord Howe Island; Mediterranean Sea and eastern Atlantic

CENTROSTEPHANUS

Southern and Lower California, southern Japan, and southern Australia

HELIOCIDARIS

West Indies and the Hawaiian Islands

PODOCIDARIS

West Indies and southern Australia

OPHIOPRIUM

Southern California and New Zealand

OPHIOPTERIS

In view of the past intercommunication between the Caribbean Sea and the Pacific the similarity of certain elements of the Caribbean fauna and of that of the western coast of tropical America is not surprising; the latter, however, includes a very considerable number of genera which occur nowhere else, together with a few species of characteristic Indo-Malayan types, such as *Mithrodia, Acanthaster, Anthenea, Leiaster, Astropyga,* etc., which are not represented in the Caribbean Sea.

A significantly large number of genera, including well known and conspicuous littoral types, inhabit a more or less extensive portion of the following anomalous range—Mediterranean Sea, Caribbean Sea, southern Australia and New Zealand, southern Japan, the Hawaiian Islands, and the western coast of tropical America.

This discontinuous range, though indicated by very diverse types and only in part by each, nevertheless must be considered a zoögeographic unit. Its outstanding feature is the fact that it represents the extreme outer limits of a tropical and subtropical faunal region the center of which is the Indo-Malayan region.

The types inhabiting it, that is to say occurring only on the extreme periphery of the Indo-Pacific faunal area (of which the Mediterranean Sea was at one time a part) may be considered, therefore, as relics of a previous fauna at one time characteristic of the central Indo-Malayan region from which they have now been extirpated through the competition of younger and more efficient types.

The same facts are brought out equally well in many other groups of marine animals, and are also reflected in a modified way in the terrestrial faunas.

In the faunas of the colder seas all intergradations are found between types which are quite unique, and types differing little or not at all from others in the Indo-Malayan region, and this intergradation is complete enough so that we are justified in considering the fauna of the colder waters as similarly ultimately derived from the (past or present) fauna of the East Indian region largely through the intermediary of deep water forms. Some of these genera of the colder waters, as ASTRICLYPEUS and GLYPTOCIDARIS, are extraordinarily restricted in their distribution and rare, while others are abundant and widely spread.

One of the peculiarities of the West Indian ophiuran fauna is the relatively poor representation of Ophiotrichidæ. This family includes 13 genera and 157 species of which 126 belong to the genus OPHIOTHRIX, occurring in all the warmer portions of the recent seas and represented by 7 species in the West Indies. One monotypic genus, OPHIOTRICHOIDES, is only known from the Cape Verde Islands, but the remaining 11 genera are exclusively Indo-Malayan. All of the species of this family are more or less conmmensal in habit, and some are almost parasitic. The species of four of the genera, OPHIOMAZA, OPHIOÆTHIOPS, OPHIOPHTHIRIUS and OPHIOSPHÆRA, live upon comatulids. In one genus, OPHIOPTERON, the arm spines are webbed together and resemble little fins which has given rise to the idea that it is able to swim.

The greatest mystery connected with the Caribbean ophiurans concerns the genus OPHIOBLENNA. The only known species, *Ophioblenna antillensis,* was described in 1859 from two specimens collected at Water Island, St. Thomas. In spite of all the collecting that has since been done in the West Indies, and even at Water Island itself, no others have ever come to light.

THE OPHIURANS OF THE CARIBBEAN REGION

Those designated with an asterisk (*) have been recorded from Barbados.

Family **Ophiomyxidæ**

Ophiomyxa flaccida
*_Ophiomyxa tumida_
Ophiomyxa brevicauda
*_Ophiobyrsa serpens_
Ophiobyrsa perrieri
Ophiobrachion uncinatus
*_Ophiogeron supinus_
*_Ophiosciasma granulatum_
Ophiosciasma attenuatum
Ophiophrixus quadrispinosus
Ophiodera stimpsonii
Ophioscolex disacanthus
*_Ophioscolex glacialis_
*_Ophioscolex tropicus_
Ophioscolex serratus
Ophioleptoplax atlantica

Family **Trichasteridæ**

*_Astroschema arenosum_
Astroschema intectum
Astroschema brachiatum
*_Astroschema læve_
*_Astroschema oligactes_
Astroschema sulcatum
*_Astroschema tenue_
Astroschema clavigerum
Astroschema elongatum
Astroschema nuttingi
Astroschema vicinum
*_Ophiocreas lumbricus_
Ophiocreas oedipus
*_Ophiocreas spinulosum_
Asteronyx lovéni
Astrodia tenuispina

Family **Gorgonocephalidæ**

Astrogomphus vallatus
Astrogomphus rudis
*_Asteroporpa annulata_
*_Asteroporpa pulchra_
*_Astrocnida isidis_
Astrospartus mucronatus
Astrophytum muricatum
Astrogordius cacaoticus
*_Astrocyclus cæcilia_
Astrocynodus herrarai

Family **Hemieuryalidæ**

Ophiochondrus armatus
*_Ophiochondrus convolutus_
Ophiochondrus crassispinus
Ophiochondrus gracilis
Ophiochondrella squamosa
*_Sigsbeia murrhina_
Ophioholcus sexradiatus
Ophioplus tuberculosus
*_Hemieuryale pustulata_

Family **Ophiacanthidæ**

Ophiolebes claviger
Ophiolebes humilis
Ophiacantha anomala
**Ophiacantha aspera*
Ophiacantha bidentata
Ophiacantha cosmica
Ophiacantha curima
Ophiacantha echinulata
**Ophiacantha hirsuta*
Ophiacantha lineata
**Ophiacantha mesembria*
**Ophiacantha metallacta*
Ophiacantha oligacantha
Ophiacantha ophiactoides
**Ophiacantha pentacrinus*
Ophiacantha robusta
**Ophiacantha scutata*
**Ophiacantha stellata*
**Ophiacantha valenciennesi*
Ophiacantha affinis
Ophiacantha levis
Ophiacantha segesta
Ophiacantha vepratica
Ophiothamnus chariis
**Ophiothamnus exiguus*
Ophiothamnus vicarius
Ophiomitrella lævipellis
Ophiomitrella glabra
**Ophiomitra valida*
Ophiomitra ornata
**Ophioplinthaca incisa*
Ophioplinthaca chelys
Ophioplinthaca dipsacos
Ophioplinthaca spinissima
**Ophiocamax fasciculata*
**Ophiocamax hystrix*
Ophiocamax austera
**Ophiacanthella troscheli*
Ophioprium cervicorne
Ophioprium imperfectum
Ophioprium permixtum
Ophiotreta lineolata
Ophiotreta mixta
**Ophiotreta sertata*
Ophiotreta littoralis
Ophialcœa nuttingi
Ophiotoma bartletti
Ophiotoma gracilis
Ophioconis miliaria
**Ophiohelus umbella*
Microphiura decipiens
Ophioblenna antillensis
Ophiologimus secundus

Family **Ophiomycetidæ**

**Ophiomyces frutectosus*
Ophiomyces mirabilis
Ophiotholia mitrephora

Family **Amphiuridæ**

**Amphiura goniodes*
Amphiura grandisquamata
Amphiura lunaris
Amphiura otteri
Amphiura kinbergiensis
Ophiochytra tenuis
Amphiodia atra
Amphiodia gyraspis
Amphiodia limbata
Amphiodia planispina

*Amphiura palmeri
Amphiura semiermis
*Amphiura stimpsonii
Amphiura bihamula
Amphiura complanata
Amphiura crassipes
Amphiura diducta
Amphiura fibulata
Amphiura flexuosa
Amphiura kükenthali
Amphiura rathbuni
Amphiura vivipara
Hemipholis elongata
Ophiophragmus brachyactis
Ophiophragmus pulcher
Ophiophragmus lütkeni
Ophiophragmus würdemanni
Ophiophragmus filogranea
Ophiophragmus septa
Ophionephthys limicola
Ophionema intricata
Amphipholis abnormis
Amphipholis gracillima
Amphipholis pachybactra
Amphipholis pentacantha
Amphipolis squamata
Amphipolis subtilis
Ophiostigma isacanthum
Amphiodia pulchella
Amphiodia repens
Amphiodia rhabdota
Amphiodia riisei
Amphiodia trychna
Amphiodia lütkeni
Amphiodia tymbara
Ophiocnida lovéni
Ophiocnida scabriuscula
Ophiocnida cubana
Ophiocnida scabra
Amphioplus abditus
Amphioplus agassizii
Amphioplus coniortodes
Amphioplus cuneata
Amphioplus incisa
Amphioplus nereis
Amphioplus thrombodes
Amphioplus tumida
Amphioplus verrilli
Amphilimna olivacea
Amphilimna caribea
Ophiactis cyanosticta
*Ophiactis duplicata
*Ophiactis mülleri
Ophiactis plana
Ophiactis savignyi
Ophiactis lymani
Ophiactis loricata

Family **Ophiotrichidæ**

*Ophiothrix angulata
Ophiothrix angulata megalaspis
Ophiothrix brachyactis
Ophiothrix lineata
*Ophiothrix oerstedii
Ophiothrix pallida
*Ophiothrix suensonii
Ophiothrix rathbuni

Family **Ophiochitonidæ**

Ophiochiton grandis
*Ophionereis reticulata

*_Ophioplax ljungmani_
Ophioplax reducta
Ophionereis olivacea
Ophionereis squamulosa

Family **Ophiocomidæ**

*_Ophiocoma echinata_
*_Ophiocoma pumila_
*_Ophiocoma riisei_
Ophiopsila fulva
*_Ophiopsila hartmeyeri_
*_Ophiopsila polysticta_
*_Ophiopsila riisei_
Ophiopsila maculata
Ophiopsila vittata

Family **Ophiodermatidæ**

*_Ophioderma appressa_
*_Ophioderma brevicauda_
*_Ophioderma brevispina_
*_Ophioderma cinerea_
Ophioderma elaps
Ophioderma guttatum
Ophioderma holmesi
?_Ophioderma januarii_
Ophioderma clypeata
Ophioderma rubicunda
Ophioderma pallidum
Ophiomusium rugosum
Ophioderma squamosissima
Ophiocryptus dubius
Ophiarachnella angulata
Ophiarachnella petersi
Bathypectinura lacertosa
Bathypectinura tessellata

Family **Ophiolepididæ**

*_Ophiomastus secundus_
Amphiophiura bullata
?_Amphiophiura convexa_
Amphiophiura coronata
Amphiophiura fasciculata
Amphiophiura metabula
Amphiophiura oedignatha
Amphiophiura sculptilis
Amphiophiura scutata
Stegophiura macrarthra
*_Ophiura acervata_
*_Ophiura falcifera_
Ophiura irrorata
Ophiura lepida
Ophiura ljungmani
Ophiura tenera
?_Ophioglyphina robusta_
Ophiomusium planum
Ophiomusium dugosum
*_Ophiomusium serratum_
*_Ophiomusium testudo_
*_Ophiomusium validum_
Ophiomusium sculptum
Ophiomusium stellatum
Ophiomisidium speciosum
Ophiomisidium pulchellum
Ophiolipus agassizii
Ophiophyllum petilum
Ophiothyreus goësii
*_Amphipholizona delicta_
*_Ophioceramis albida_
*_Ophioceramis januarii_
*_Ophiozona impressa_
*_Ophiozonella antillarum_

Homalophiura abyssorum
Homalophiura inornata
**Ophiomusium acuferum*
Ophiomusium armigerum
**Ophiomusium eburneum*
Ophiomusium lymani
**Ophiomusium monoplax*
Ophiomusium oligoplacum
Ophiozonella clypeata
**Ophiozonella marmorea*
**Ophiozonella nivea*
Ophiozonella nivea compta
**Ophiozonella tessellata*
Ophiomidas dubius
Ophiolepis elegans
**Ophiolepis paucispina*

Family **Ophioleucidæ**

Ophioleuce depressa
**Ophiopœpale goësiana*
Ophiopyren longispinus
**Ophiernus adspersus*

The following names are based upon color varieties:

Amphiura vivipara var. *annulata* H. L. Clark
Ophiothrix oerstedii var. *lutea* H. L. Clark
Ophiothrix angulata var. *atrolineata* H. L. Clark
Ophiothrix angulata var. *violacea* Müller and Troschel
Ophiothrix angulata var. *phoinissa* H. L. Clark
Ophiothrix angulata var. *phlogina* H. L. Clark
Ophiothrix angulata var. *poecila* H. L. Clark

THE OCCURRENCE OF OPHIURANS AT BARBADOS AND AT ANTIGUA

In his account of the natural history of Barbados published in 1750 the Reverend Griffith Hughes wrote under the heading "The Sea Scorpion," "What we call here the Scorpion is by Petiver called *Stella marina Scolopendroides.* Its five rays might perhaps properly cause it to be called the *Stella marina.*" This is the only ophiuran mentioned by Hughes.

The Sea Scorpion, *Ophiocoma echinata,* still called by the same name, I found to be abundant in 1903, and Professor Nutting states that it occurs almost literally under every stone and scuttles away with amazing celerity when disturbed. It was the most abundant and conspicuous form of animal life under the loose coral rocks uncovered at low tide on both sides of the laboratory at Pelican Island. It is most commonly brown in color, with the club shaped spines almost black. The disk shows great variation, often having a central oval or pentagonal area of cream color showing in sharp contrast to the dark brown spines. Besides *Ophiocoma echinata, O. riisei* and *O. pumila* were secured, but were much less abundant. Professor Nutting also mentions the common association of *Ophiocoma echinata* with *Echinometra viridis.*

The species of *Ophiocoma* were the most common ophiurans along the shores at Barbados, although several other species were more or less abundant.

Three species of *Ophiothrix, O. angulata, O. oerstedii* and *O. suensonii,* the last named the most abundant, fairly swarmed over some of the gorgonians brought up near Hastings by the diver. Often the large profusely branched gorgonians were fairly covered with the wriggling ophiurans.

Professor Nutting writes that one of the most beautiful serpent stars he ever saw was taken at Station 64, in from 60 to 70 fathoms. It was a large specimen with a spread of about ten inches, with a very distinct band of vivid crimson on a background of light pink along the dorsal surface of the arms and extending to the center of the disk. The spines were very slender, 8 mm. long, quite transparent, with saw-like sides and in three series on each side of the arms. This individual has not come to hand, but undoubtedly it was a particularly fine example of *Ophiothrix suensonii.*

Of the simple armed basket fish Professor Nutting says that perhaps the most conspicuous and strikingly marked were *Asteroporpa* and *Astrocnida* from deep water. The arms in *Asteroporpa* are unbranched, while those of *Astrocnida* from Stations 55, in — fathoms, and 89, in 80 fathoms, are slightly branched at the tip and ornamented throughout with transverse elevated bands of light gray alternating with depressed bands of deep chocolate. These circular ridges are beset with thorny stubby spines. The bases of the arms are swollen, and the swellings invade the dorsal surface of the disk in the center of which is a star shaped area formed by similar ridges. Another simple armed basket fish, *Astroschema oligactes,* is from Station 7, and is orange colored and exceedingly hispid all over, feeling like coarse sandpaper, wiry in texture, with arms tapering to a mere coiled thread which can wind itself closely around a support and cling there most tenaciously. A certain flabellate red and white gorgonian was very common in the dredging and almost always a species of simple armed basket fish (*Astroschema*, spp.) was coiled closely around the branches which it matched so perfectly in color that it was very apt to be overlooked. The protective coloration is so commonly found in serpent stars living as symbionts on alcyonarians that many writers have noticed it.

Professor Nutting says that at Antigua "our favorite collecting ground was near what we called 'Rocky Point,' across from Barclay Point and inside of the Pillars of Hercules. . . . . The echinoderms were perhaps the most conspicuous group at this place, although most of the species were the same as those secured at Barbados. At the foot of the Pillars of Hercules certain species found a refuge in the cracks of the rocks that were continually being scoured by the waves. On these rocky flats everything seemed to be stuck tight and had to be forcibly pried loose. There were small holothurians that wedged themselves in these cracks and held on with remarkable tenacity."

OPHIURANS PREVIOUSLY OBTAINED AT BARBADOS

The Ophiurans collected by the "Hassler" at Barbados in 100 fathoms

Astroschema oligactes
Astroschema tenuis
Asteroporpa annulata
Astrocnida isidis
Ophiacantha hirsuta
Ophiacantha stellata
Ophiomitra valida
Amphiura palmeri
Ophiomyces frutectosus
Ophiactis duplicata
Ophiothrix angulata
Ophiothrix suensonii
Ophioplax ljungmani
Ophiura acervata
Ophiomusium acuferum
Ophiomusium testudo
Ophioceramis albida
Ophioceramis januarii
Ophiozonella nivea
Ophiopœpale goësiana

The Ophiurans collected at Barbados by the "Blake"
Station 272; 76 fathoms

Ophiomyxa tumida
Astroschema læve
Astroschema oligactes
Asteroporpa annulata
Ophiactis mülleri
Ophiothrix suensonii
Ophiomusium acuferum
Ophiomusium testudo

Ophiomitra valida
Ophiactis duplicata
Amphipholizona delicata
Ophiozona impressa
Ophiopæpale goësiana

Station 273; 103 fathoms

Ophioscolex tropicus
Astroschema læve
Asteroporpa annulata
Ophiacantha hirsuta
Ophiacantha stellata
Ophiactis duplicata
Ophioplax ljungmani
Ophiomusium acuferum
Ophiomusium testudo
Amphipholizona delicata
Ophiozonella marmorea
Ophiozonella nivea
Ophiozonella tessellata

Station 274; 209 fathoms

Ophiocamax hystrix
Ophiotreta sertata
Ophiactis duplicata
Ophiomusium acuferum
Ophiomusium eburneum
Ophiomusium serratum
Ophiozonella nivea

Station 275; 218 fathoms

Ophiactis duplicata

Station 276; 94 fathoms

Ophiomyxa tumida
Astroschema læve
Astroschema oligactes
Astroschema tenue
Asteroporpa annulata
Hemieuryale pustulata
Ophiactis duplicata
Ophiothrix suensonii
Ophionereis reticulata
Ophiomusium acuferum
Ophiomusium testudo
Ophiozona impressa
Ophiozonella antillarum

Station 277; 106 fathoms

Asteroporpa annulata
Sigsbeia murrhina
Hemieuryale pustulata
Ophiomitra valida
Ophiothrix suensonii
Ophioplax ljungmani
Ophiomusium acuferum

Station 278; 69 fathoms

Ophiomyxa tumida
Ophiobyrsa serpens
Ophionereis reticulata
Ophioderma cinerea

Astroschema oligactes
Amphiura stimpsonii
Ophiactis mülleri
Ophiomusium acuferum
Ophiomusium testudo
Ophiozona impressa

Station 279; 118 fathoms

Ophiocreas spinulosum

Station 280; 221 fathoms

Ophiochondrus convolutus
Ophiacantha pentacrinus
Ophiocamax hystrix
Ophiotreta sertata
Ophiomusium eburneum
Ophiomusium serratum
Ophiozonella nivea

Station 281; 288 fathoms

Ophiomyxa tumida
Astroschema arenosum
Ophiocreas lumbricus
Ophiocreas spinulosum
Ophiacantha scutata
Ophiomyces frutectosus
Amphiophiura fasciculata
Ophiomusium acuferum

Station 282; 154 fathoms

Ophiomyces frutectosus
Ophiozonella tessellata

Station 283; 237 fathoms

Ophiacantha aspera
Ophiacantha valenciennesi
Ophiomitra valida

Station 285; 13–40 fathoms

Ophiomyxa tumida
Ophiothrix angulata
Ophiothrix suensonii
Ophiopsila riisei
Ophioderma brevispina

Station 286; 7–45 fathoms

Ophiothrix suensonii

Station 287; 7½–50 fathoms

Ophiopsila polysticta

Station 288; 399 fathoms

Ophiacantha metallacta
Ophiacantha pentacrinus
Ophioplinthaca incisa
Amphiura goniodes
Ophiomastus secundus
Ophiomusium monoplax
Ophiozonella antillarum
Ophiernus adspersus

Station 290; 73 fathoms

Ophiomyxa tumida
Astroschema læve
Astroschema oligactes
Asteroporpa annulata
Astrocnida isidis
Astrocyclus cæcilia
Ophiacantha aspera
Ophiacantha stellata
Ophiomitra valida
Ophiocanthella troscheli
Ophiactis duplicata
Ophiothrix suensonii
Ophiomusium acuferum
Ophiomusium testudo
Ophiozonella tessellata

Station 291; 200 fathoms

Ophiomyxa tumida
Ophiogeron supinus
Ophiacantha pentacrinus
Ophiacantha scutata
Ophiocamax hystrix
Ophiotreta sertata
Ophiura falcifera
Ophiomusium acuferum
Ophiomusium validum
Ophiozonella antillarum
Ophiozonella nivea
Ophiernus adspersus

Station 292; 56 fathoms

Astroschema læve
Asteroporpa annulata
Astrocnida isidis
Ophiacantha stellata
Ophiothrix angulata
Ophiothrix suensonii
Ophiomusium acuferum
Ophiozonella nivea

Station 293; 82 fathoms

Ophioscolex glacialis
Ophiacantha hirsuta
Ophiacantha stellata
Ophiothrix suensonii
Ophiomusium acuferum
Amphipholizona delicata
Ophiopæpale goësiana

Station 294; 137 fathoms

Ophiothrix suensonii
Ophiozonella nivea

Station 295; 180 fathoms

Ophiocamax fasciculata

Station 296; 84 fathoms

Ophiomyxa tumida
Astroschema læve
Astroschema oligactes
Asteroporpa annulata
Astrocnida isidis
Astrocyclus cæcilia
Hemieuryale pustulata
Ophiothamnus exiguus
Ophiomitra valida
Ophiomusium acuferum

Station 297; 123 fathoms

Astroschema oligactes
Asteroporpa annulata
Ophiomitra valida
Ophiotreta sertata
Ophioplax ljungmani
Ophiomusium acuferum
Ophiozonella tessellata
Ophiopæpale goesiana

Station 298; 120 fathoms

Astroschema oligactes
Asteroporpa annulata
Astrocnida isidis
Ophiopæpale goësiana
Ophiozona impressa

Station 299; 140 fathoms

Ophiacantha pentacrinus
Ophiomusium acuferum
Ophiozonella tessellata

Station 300; 82 fathoms

Ophiacantha hirsuta
Ophiohelus umbella
Ophiomusium acuferum

Ophiuran recorded as in Sir Rawson W. Rawson's collection:

Astrocyclus cæcilia

Ophiurans recorded from Barbados by Professor René Kœhler in 1907:

Ophioplax ljungmani
Astrocyclus cæcilia
Ophioscolex glacialis; 82 fathoms

Ophiurans recorded from Barbados by Professor Kœhler in 1913:

Ophioderma appressa
Ophioderma brevicauda
Ophioderma cinerea
Ophiozona impressa
Ophiolepis paucispina
Ophionereis reticulata
Ophiocoma echinata
Ophiocoma riisei
Ophiocoma pumila
Ophiothrix angulata
Ophiothrix oerstedii
Ophiothrix suensonii

Ophiurans recorded from Barbados by Professor Kœhler in 1914:

Ophioplax ljungmani
Astrocyclus cæcilia

Ophiurans recorded from Barbados by Dr. Hubert Lyman Clark in 1915:

Ophiosciasma granulatum, 94 fms.
Asteroporpa pulchra, 56–125 fms.
Ophiacantha mesembria, 140–221 fms.
Amphiura palmeri, 100 fms.
Ophiopsila polysticta, 7½–50 fms.
Ophiopsila hartmeyeri, 69 fms.
Amphipholizona delicata, 76–103 fms.
Ophiomusium monoplax, 399 fms.
Ophiozonella marmorea, 103 fms.

ANNOTATED LIST OF THE SPECIES OBTAINED

Ophiurans collected by the Barbados-Antigua Expedition from the State University of Iowa, together with the collecting stations listed by the Expedition:

ANNOTATED LIST OF THE SPECIES OBTAINED

Order PHRYNOPHIURIDA

Family **Ophiomyxidæ**

OPHIOMYXA FLACCIDA (Say)

Pelican Island, Barbados; tide pools.—One specimen.
English Harbour, Antigua.—One specimen.

OPHIOSCIASMA GRANULATUM Lyman

Station 26: One specimen.

Family **Trichasteridæ**

Astroschema arenosum Lyman

Station 46: Two specimens.

ASTROSCHEMA LAEVE Lyman

Station 36: One specimen.

ASTROSCHEMA OLIGACTES Lütken

Station 7: Five specimens.
Station 34: One specimen.
Station 35: One specimen.

Astrochema tenue Lyman

Station 59: part of an arm.

Family **Gorgonocephalidæ**

Asteroporpa annulata Lütken

Station 7: One specimen.
Station 41: One small specimen.
Station 58: One small specimen.

Astrocnida isidis Lyman

Station 55: One specimen.

Astrophytum muricatum (Lamarck)

Carlisle Bay, Barbados; 20 feet; found on a gorgonian.—One small specimen with the disc 14 mm. in diameter.

Carlisle Bay, Barbados; 5 fathoms.—One small specimen with the disc 12 mm. in diameter.

Barbados; from fish pots.—Two specimens, one with the disc about 50 mm., the other with the disc 30 mm. in diameter.

Astrocyclus cæcilia (Lütken)

Station 97: One small specimen with the disc 8 mm. in diameter.

Order LÆMOPHIURIDA

Family **Hemieuryalidæ**

Sigsbeia murrhina Lyman

Station 97: Four very small specimens, the largest with the disc 4 mm. in diameter.

Ophioplus tuberculosa (Lyman)

Barbados.—One specimen.

Hemieuryale pustulata von Martens

Station 2: Two specimens.
Station 36: One specimen.
Station 51: Six specimens.
Station 57: Fifteen specimens.
Station 64: One specimen.
Station 70: Six specimens.
Station 82: One small specimen.

Family **Ophiacanthidæ**

Ophiacantha mesembria H. L. Clark

Station 9: Two small specimens.
Station 15: One specimen.
Station 28: Four small specimens.
Station 37: Two small specimens.
Station 59: One specimen.

Order GNATHOPHIURIDA

Family **Amphiuridæ**

Amphiura diducta Kœhler

Station 1: One specimen.

Amphiura palmeri Lyman

Station 96: Two specimens.

Amphipholis limbata (Grube)

Station 79: One specimen.

Amphiodia planispina (von Martens)

Station 1: One specimen, with the disc lacking.

Ophiactis mülleri Lütken

Station 11: One specimen.
Station 67: Two specimens; one of these has three mouth papillæ.
Station 101: Twenty-two specimens.
No locality: Two specimens.

Ophiactis savignyi Müller and Troschel

Station 1: One specimen.

Ophiactis duplicata (Lyman)

Station 6: Three specimens.
Station 45: One specimen.

Family **Ophiotrichidæ**

Ophiothrix angulata Ayres

Station 1: Six specimens.
Station 11: Eight specimens.
Station 13: One specimen.

Station 18: One specimen.
Station 51: One specimen.
Station 65: One specimen.
Station 67: Three specimens.
Station 70: One specimen.
Station 78: Two specimens.
Station 85: Two specimens.
Station 96: Three specimens.
Station 100: Five specimens.

Barbados; Engineers' Pier, 15–20 feet.—Fragments.

Barbados; off Pelican Island, 4 fathoms; from gorgonians and corals.—Seven specimens.

Barbados; off Pelican Island, 50 feet.—One small specimen.

Barbados; off Needham's Point; diver.—Eight specimens.

Station 101: Four specimens.

Antigua; English Harbour; in eel grass.—Two specimens.

Ophiothrix lineata Lyman

Barbados; off Pelican Island, 4 fathoms; from gorgonians and corals.—One specimen.

Ophiothrix oerstedii Lütken

Barbados; Engineers' Pier, 15–20 feet; from gorgonians; May 18, 1918.—Two specimens.

Barbados; Needham's Point; diver.—Ten specimens.

Antigua; English Harbour; in eel grass.—Three specimens.

Antigua; English Harbour; rocks.—One specimen.

Ophiothrix suensonii Lütken

Station 53: One specimen.
Station 59: One specimen.

Station 62: One specimen with the disc 14 mm. in diameter; the spines on the disc are much more numerous and shorter than usual. In life the disc was olive gray with five radial red bands, and the arms were whitish with the dorsal arm plates dark coral red and the ventral plates lighter.

Station 89: One specimen.

Barbados; Engineers' Pier, 15–20 feet; from gorgonians; May 18, 1918.—Fifty-four specimens.

Barbados; off Pelican Island.—Two specimens.

Barbados; off Pelican Island, 4 fathoms; from gorgonians and corals.—Thirteen specimens.

Barbados; Carlisle Bay, 20 feet; on gorgonians.—Twenty-nine specimens.

Barbados; off Needham's Point; diver.—Twenty specimens.

Barbados; off Hastings; June 5, 1918.—Thirteen specimens.

Station 101: Two specimens.

Antigua; English Harbour.—Seven specimens.

Ophiothrix pallida Ljungman

Station 96: Two specimens.

Order CHILOPHIURIDA

Family **Ophiochitonidæ**

Ophionereis reticulata (Say)

Station 1: Three specimens.

Station 67: One specimen.

Station 70: One specimen.

Station 79: One small specimen.

Station 101: One specimen.

Antigua; English Harbour.—Seven specimens.

Family **Ophiocomidæ**

Ophiocoma echinata L. Agassiz

Station 96: One specimen.

Barbados; Pelican Island; tide pools.—One specimen.

Barbados; Bathsheba; tide pools.—Eleven specimens.

Station 101: One specimen.

Antigua; English Harbour; rocks.—Three specimens.

Antigua; English Harbour; in eel grass.—One specimen.

Antigua; English Harbour.—Fifteen specimens.

Antigua.—One specimen.

Ophiocoma pumila Lütken

Station 96: One specimen.

Barbados; Pelican Island; tide pools; May 11, 1918.—Four specimens.

Barbados; Pelican Island.—One specimen.

Barbados; Needham's Point; June 8, 1918.—Four specimens.

Antigua; English Harbour; rocks.—Fifteen specimens.

Antigua; English Harbour.—Ten specimens.

Ophiocoma riisei Lütken

Station 1: Five specimens.

Station 96: Two specimens; one of these, small and without granules on the disc, was kindly identified for me by Dr. H. L. Clark.

Station 100: Three specimens.

Station 101: Five specimens.

Antigua; English Harbour; rocks.—Seven small specimens.

Antigua; English Harbour.—Seven specimens.

Antigua; Falmouth Harbour.—One specimen which in life was "deep reddish brown."

No label.—One specimen.

Ophiopsila hartmeyeri Kœhler

Station 53: One specimen.

Station 96: One specimen.

Family **Ophiodermatidæ**

Ophioderma appressa (Say)

Station 11: One small specimen.

Barbados; Pelican Island; tide pools; May 11, 1918.—Two specimens.

Barbados; Pelican Island.—Ten specimens.

Barbados; off Needham's Point; June 6, 1918.—Four specimens.

Station 101: Three specimens.

Station 103: Five specimens.

Station 104: Two specimens.

Antigua; English Harbour; in eel grass.—Sixteen specimens.

Antigua; English Harbour.—Sixteen specimens.

Antigua; Falmouth Harbour; in eel grass; collected by W. K. Fisher.—Eighteen specimens.

Ophioderma brevicauda (Say)

Barbados; Pelican Island; tide pools.—Six specimens.

Barbados; Pelican Island.—Seventeen specimens.

Barbados; off Needham's Point; June 8, 1918.—One specimen.

Antigua; English Harbour.—Nine specimens.

Ophioderma cinerea (Lyman)

Station 78: One specimen.
Antigua; English Harbour.—Five specimens.

Ophioderma rubicunda Lyman

Station 98: One specimen.
Pelican Island: One specimen.
Station 101: Three specimens.

Family **Ophiolepididæ**

Ophiura acervata Lyman

Station 116: One specimen.

Ophiomusium testudo Lyman

Station 2: One small specimen.
Station 11: One small specimen.
Station 26: Two small specimens.
Station 51: Three small specimens, kindly determined for me by Dr. H. L. Clark.
Station 79: One small specimen.

Ophiomusium validum Ljungman

Station 116: One specimen.

Ophiomusium sculptum Verrill

Station 4: Three specimens.
Station 7: One specimen; "arms banded with orange on whitish."
Station 15: One specimen.
Station 28: One specimen.
Station 44: One specimen.
Station 49: One specimen.

Ophiozona impressa (Lütken)

Station 51: One small specimen.

Ophiozonella nivea (Lyman)

Station 1: One specimen.
Station 3: One specimen.
Station 26: One specimen.

Ophiozonella tessellata (Lyman)

Station 62: One specimen.

Ophiolepis elegans Lütken

Station 11: One specimen.
Station 18: One specimen.
?Barbados.—Three specimens.
Antigua; English Harbour.—Eleven specimens.

Ophiolepis paucispina Müller and Troschel

Station 1: One specimen.
Antigua; English Harbour; in eel grass.—Thirteen specimens.

LIST OF THE STATIONS, WITH THE SPECIES REPRESENTED AT EACH

The Crinoids collected at these Stations are also given.

Station 1:

Amphiura diducta
Amphiodia planispina
Ophiactis savignyi
Ophiothrix angulata
Ophionereis reticulata
Ophiocoma riisei
Ophiozonella nivea
Ophiolepis paucispina

Station 2:

Hemieuryale pustulata
Ophiomusium testudo

Station 3:

Leptonemaster venustus

Station 4:

Ophiomusium sculptum

Station 7:

Astroschema oligactes
Asteroporpa annulata
Ophiomusium sculptum
Leptonemaster venustus
Democrinus rawsonii

Station 9:

Ophiacantha mesembria
Comactinia meridionalis

Station 11:

Ophiactis mülleri
Ophiothrix angulata
Ophioderma appressa
Ophiomusium testudo
Ophiolepis elegans
Leptonemaster venustus
Comactinia meridionalis
Analcidometra armata

Station 13:

Ophiothrix angulata
Leptonemaster venustus

Station 14:
Comactinia meridionalis

Station 15:
Ophiacantha mesembria
Ophiomusium sculptum
Coccometra hagenii

Station 18:
Ophiothrix angulata
Ophiolepis elegans
Leptonemaster venustus

Station 26:
Ophiosciasma granulatum
Ophiomusium testudo

Station 28:
Ophiacantha mesembria
Ophiomusium sculptum

Station 34:
Astroschema oligactes

Station 35:
Astroschema oligactes

Station 36:
Astroschema læve
Hemieuryale pustulata

Station 37:
Ophiacantha mesembria

Station 41:
Asteroporpa annulata

Station 44:
Ophiomusium sculptum

Station 46:
Astroschema arenosum
Leptonemaster venustus

Station 49:
Ophiomusium sculptum

Station 50:
Nemaster discoidea

Station 51:
Hemieuryale pustulata
Ophiothrix angulata
Ophiomusium testudo
Ophiozona impressa
Nemaster discoidea
Comactinia meridionalis

Station 53:
Ophiothrix suensonii
Nemaster iowensis

Station 55:
Astrocnida isidis

Station 56:
Leptonemaster venustus

Station 57:
Hemieuryale pustulata

Station 58:
Asteroporpa annulata

Station 59:
Astroschema tenue
Ophiacantha mesembria
Ophiothrix suensonii
Leptonemaster venustus

Station 62:
Ophiothrix suensonii
Ophiozonella tessellata

Station 64:
Hemieuryale pustulata

Station 65:
Ophiothrix angulata

Station 67:
Ophiactis mülleri
Ophiothrix angulata
Leptonemaster venustus
Comactinia meridionalis

Station 70:
Hemieuryale pustulata
Ophiothrix angulata
Ophionereis reticulata

Station 78:
Ophiothrix angulata
Ophioderma cinerea
Leptonemaster venustus
Comactinia meridionalis

Station 79:
Amphipholis limbata
Ophionereis reticulata
Ophiomusium testudo
Nemaster discoidea

Station 82:
Hemieuryale pustulata

Station 85:
Ophiothrix angulata
Comactinia meridionalis

Station 89:
Ophiothrix suensonii

Station 92:
Nemaster discoidea

Station 96:

Ophiothrix angulata
Ophiocoma echinata
Ophiocoma pumila
Ophiocoma riisei
Comactinia meridionalis

Station 97:

Astrocyclus cæcilia
Sigsbeia murrhina
Nemaster iowensis

Station 98:

Nemaster iowensis

Station 99:

Nemaster iowensis

Station 100:

Ophiothrix angulata
Ophiocoma riisei

Barbados; Engineers' Pier, 15–20 feet

Ophiothrix angulata
Ophiothrix oerstedii
Ophiothrix suensonii

Barbados; Engineers' Pier, 25 feet

Nemaster iowensis

Barbados; Pelican Island, tide pools

Ophiomyxa flaccida
Ophiocoma echinata
Ophiocoma pumila
Ophioderma appressa
Ophioderma brevicauda

Barbados; off Pelican Island, 4 fathoms

Ophiothrix angulata
Ophiothrix lineata
Ophiothrix suensonii

Barbados; off Pelican Island, 50 feet

Ophiothrix angulata

Barbados; off Pelican Island

Ophiothrix suensonii
Ophiocoma pumila
Ophioderma appressa
Ophioderma brevicauda

Barbados; Carlisle Bay, 5 fathoms

Astrophytum muricatum

Barbados; Carlisle Bay, 20 feet

Astrophytum muricatum
Ophiothrix suensonii

Barbados; off Needham's Point

Ophiothrix angulata
Ophiothrix oerstedii
Ophiothrix suensonii
Ophiocoma pumila
Ophioderma appressa
Ophioderma brevicauda

Barbados; off Hastings

Ophiothrix suensonii

Barbados; Bathsheba

Ophiocoma echinata

Barbados; from fish pots

Astrophytum muricatum

Barbados

Sigsbeia murrhina
Nemaster iowensis
Nemaster discoidea
Comactinia meridionalis

?Barbados

Ophiolepis elegans

Station 101:

Ophiactis mülleri
Ophiothrix angulata
Ophiothrix suensonii
Ophionereis reticulata
Ophiocoma echinata
Ophiocoma riisei
Ophioderma appressa
Ophioderma rubicunda
Nemaster iowensis

Station 103:

Ophioderma appressa

Station 104:

Ophioderma appressa

Station 116:

Ophiura acervata
Ophiomusium validum

Antigua; English Harbour, in eel grass

Ophiothrix angulata
Ophiothrix oerstedii
Ophiocoma echinata
Ophioderma appressa
Ophiolepis paucispina

Antigua; English Harbour, rocks

Ophiothrix oerstedii
Ophiocoma echinata
Ophiocoma pumila
Ophiocoma riisei

Antigua; English Harbour

Ophiomyxa flaccida
Ophiothrix suensonii
Ophionereis reticulata
Ophiocoma echinata
Ophiocoma pumila
Ophiocoma riisei
Ophioderma appressa
Ophioderma brevicauda
Ophioderma cinerea
Ophiolepis elegans

Antigua; Falmouth Harbour

Ophiocoma pumila
Ophioderma appressa

Antigua

Ophiocoma echinata

REPORT ON THE BRACHYURA

Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918

MARY J. RATHBUN
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INTRODUCTION

Hughes in his "Natural History of Barbados", 1750,[1] enumerates fifteen kinds of crabs, but the descriptions are so brief and the names so trivial that it is impossible to determine most of the species with any great degree of certainty. Only two of the brachyuran crabs are figured; one, the Horned Crab (pl. XXV, fig. 3) is an undoubted *Stenocionops furcata*, the other, the Lazy Crab, (pl. XXV, fig. 1) is a composite, having the chelipeds and ambulatory legs of *Mithrax spinosissimus* attached to the body of a Parthenopid crab, *Daldorfia horrida* (= *Parthenope horrida* of authors), an Indo-Pacific species.

From the dredgings of the U. S. Coast Survey steamers "Blake" and "Hassler", A. Milne Edwards[1] in 1880 published a list which includes thirty-eight species of brachyuran crabs from the waters about Barbados. This is supplemented by the later report (1902) on the Oxystomes of the same collection by Milne Edwards and Bouvier,[1] which adds three species to the earlier list.

The present expedition obtained ninety-three species of brachyurans of which only one species is found to be undescribed. The range of twenty-nine species is extended by their capture at Barbados.

LIST OF SPECIES

Tribe *Brachyura*

Subtribe *Oxystomata*

Family **Dromiidæ**

DROMIA ERYTHROPUS (George Edwards)

Rathbun, Ann. Inst. Jamaica, vol. I, 1897, p. 39.

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[1] See bibliography on page 89.

Carlisle Bay, Barbados; in fish pot; 1 ♀.

Brought up by diver off Pelican Island, Barbados; 1 ♀ ovigerous.

DROMIDIA ANTILLENSIS Stimpson

Rathbun, Ann. Inst. Jamaica, vol. I, 1897, p. 39.

Barbados; 1 ♀ ovigerous.

Family **Dorippidæ**

CYCLODORIPPE PERPUSILLA (Rathbun)

Clythrocerus perpusillus Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 90, text-fig. 4.

One mile S. W. of Pelican Island, Barbados; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 ♀, the same size as the type.

Known only from the type specimen, off Vieques.

Family **Raninidæ**

RANINOIDES LŒVIS (Latreille)

Ranina loevis Latreille, Encyc. Méth., Entom., vol. X, 1825, p. 268.

Raninoides levis Milne Edwards, Hist. Nat. Crust., vol. II, 1837, p. 197.

Barbados; W. by N. of Pelican Island 2¾ miles and drifting off shore; 107 fathoms; bottom of fine sand; tangles; May 16; sta. 10; 1 small ♂, 1 young.

In the young specimen, carapace 6 mm. long, the supra-orbital margin between the two fissures is not produced in a spine but is obliquely truncate.

Family **Calappidæ**

CALAPPA ANGUSTA A. Milne Edwards

Bull. M. C. Z., vol. VIII, 1880, p. 18.

Barbados; Lazaretto E. by N. ½ N., Pelican Island S. E.; bottom of fine sand; June 7; sta. 88; 1 juv.

Taken at Barbados by the "Hassler," 100 fathoms, and by the "Blake," 103 fathoms.

CALAPPA GALLUS (Herbst)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 85.

Pelican Island, Barbados; in fish pot; 1 ♀.

CYCLOES BAIRDII Stimpson

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 85.

English Harbour, Antigua; 1 ♀, 10.4 mm. long.

One mile S. W. of Pelican Island, Barbados; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 juv.

In the West Indies, this species seems not to have been reported south of Guadeloupe; although it occurs in the Pacific at Panama.

Family **Leucosiidæ**

EBALIA STIMPSONII A. Milne Edwards

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 87.

Barbados; Cable Station E. S. by E., Paynes Bay Church N. E., off shore ¾ mile; 35–75 fathoms; bottom alternate sand and rocks; sta. 78; 1 ♂.

Described from off Barbados, 7 to 50 fathoms, "Blake."

ILIACANTHA SUBGLOBOSA Stimpson

Bull. M. C. Z., vol. II, 1871, p. 155.

W. by N. of Pelican Island, Barbados, 2 miles; 75–80 fathoms; sand bottom; sta. 3; 1 ♀ juv.

S. of St. Mathias Church, Barbados, 1 mile; 60 fathoms; bottom of coarse sand; May 20; sta. 21; 1 ♂.

W. by N. of Telegraph Station, Barbados, ½ mile or more off shore, about edge of drop off; 50–70 fathoms; bottom rocky; tangles; June 1; sta. 66 and 67; 2 ♀ juv.

Dredged by the "Blake" at Barbados, 56 to 94 fathoms.

Subtribe ***Brachygnatha***

Superfamily *Brachyrhyncha*

Family **Portunidæ**

PORTUNUS (PORTUNUS) SULCATUS (A. Milne Edwards)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 45.

English Harbour, Antigua; by electric light; July; 1 juv., 3.2 mm. long.

Bathsheba, Barbados; 1 ♂ juv.

Pelican Island, Barbados; tide pool; May 13; 1 ♂ juv.

PORTUNUS (ACHELOUS) ORDWAYI (Stimpson)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 46.

English Harbour, Antigua; electric light; July, 1918; 1 juv.

CALLINECTES ORNATUS Ordway

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 48.

Barbados; 1 adult ♀.

CRONIUS RUBER (Lamarck)

Charybdella rubra Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 51.

Antigua; 1 juv.

Family **Xanthidæ**

LIOMERA LONGIMANA A. Milne Edwards

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 25.

Barbados; May 15; 10 ♂ 9 ♀ ovig. On old coral; May 31; 8 ♂ 15 ♀. On old coral heads; June 4; 12 ♂ 11 ♀ (1 ovig.).

Needham Point, Barbados; May 18; 3 ♂ 1 ♀.

One mile S. of sta. 19, off Needham Point; 84 fathoms; rocky bottom; sta. 20; 2 ♂ 4 ♀.

Okra Reef, Barbados; May 13; 35 ♂ 44 ♀ (35 ovig.) 8 juv.

Not previously noted south of Guadeloupe.

LIOMERA DISPAR (Stimpson)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 25.

Pillars of Hercules, Antigua; 1 ♀.

Barbados; May 15; 6 ♂ 21 ♀ (8 ovig.). On old coral, May 31; 3 ♂ 13 ♀ 2 juv. On old coral heads; June 4; 4 ♂ 4 ♀.

One mile S. of sta. 19, off Needham Point, Barbados; 84 fathoms; rocky bottom; sta. 20; 2 ♂ 4 ♀ (2 ovig.).

Okra Reef, Barbados; May 13; 3 ♂ 14 ♀ (7 ovig.).

Not previously recorded south of Porto Rico.

PLATYPODIA SPECTABILIS (Herbst)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 26.

Needham's Point, Barbados; May 18; 1 ♂ 1 ♀ ovig.

LEPTODIUS FLORIDANUS (Gibbes)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 27.

Pillars of Hercules, Antigua; 1 ♀.

Barbados; 8 ♂ 3 ♀ ovig.

Pelican Island, Barbados; tide pools; 2 ♂. May 11; 3 ♂. May 13; 4 ♀ (3 ovig.). Shallow; 1 ♂ 1 ♀ juv.

Okra Reef, Barbados; May 13; 1 juv.

XANTHODIUS PARVULUS (Fabricius)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 27.

Pelican Island, Barbados; shallow; 2 ♂. In tide pool; May 11; 1 ♂ juv. 1 ♀.

Barbados; 1 ♂.

No label; 1 ♂.

CYCLOXANTHOPS DENTICULATUS (White)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 27.

Pillars of Hercules, Antigua; 1 ♂ juv.

Pelican Island, Barbados; tide pool; 1 ♂.

Bathsheba, Barbados; 2 juv.

PANOPEUS HERBSTII Milne Edwards

Eupanopeus herbstii Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 28.

English Harbour, Antigua; 1 ♂ juv.

Pillars of Hercules, Antigua; 1 ♂ thin shell, 2 juv.

Barbados; 2 ♂ 1 ♀.

PANOPEUS OCCIDENTALIS Saussure

Eupanopeus occidentalis Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 29.

Pillars of Hercules, Antigua; 1 ♀.

PANOPEUS AMERICANUS Saussure

Eupanopeus americanus Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 29.

Pillars of Hercules, Antigua; 1 ♂ small.

PANOPEUS HARTTII Smith

Eupanopeus harttii Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 29.

Pillars of Hercules, Antigua; 1 ♀.

Pelican Island, Barbados; shallow; 1 ♂.

EURYPANOPEUS ABBREVIATUS (Stimpson)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 30.

Pillars of Hercules, Antigua; 1 ♂ 1 ♀ 1 juv.

HEXAPANOPEUS HEMPHILLII (Benedict and Rathbun)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 31.

Barbados; from old coral head; June 4; 1 ♂ of medium size, identified with some doubt, as both sides of the body are infested with an isopod parasite which has so distorted the carapace that the lateral teeth are abnormal and unlike on the two sides.

Not before found south of St. Thomas and Porto Rico.

MICROPANOPE LOBIFRONS A. Milne Edwards

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 32.

S. W. of Pelican Island, Barbados, 1 mile; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 2 ♂ 2 ♀.

One-half mile W. of sta. 17; 40 fathoms; bottom coarse sand; May 18; sta. 18; 1 ♀.

W. N. W. of Lazaretto, Barbados; N. N. W. of Pelican Island; 33 fathoms; bottom rocky; dredge; May 27; sta. 51; 9 ♀ (1 ovig., 3 with Rhizocephalids).

Cable station, Barbados, bears E. by S., Lazaretto, E. S. E. ½ S.; 35–60 fathoms; bottom mostly rocky, on steep slope; tangles; June 3; sta. 75; 1 ♂.

Cable station E. S. by E., Paynes Bay Church N. E., off shore ¾ mile; 35–75 fathoms; bottom alternate sand and rocks; June 3; sta. 78; 1 ♀ with a small Rhizocephalid under the abdomen.

W. by N. of Telegraph Station, Barbados; little more than a half mile off; 30–65 fathoms; bottom of rocks and sand; June 5; sta. 79; 3 ♀ (2 with a Rhizocephalid larger than the abdomen but attached under it).

Taken at Barbados by the "Blake" in 94 fathoms.

ACTAEA RUFOPUNCTATA NODOSA Stimpson

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 33.

1¼ miles due W. from white lighthouse at Needham Point, Barbados; in line with red house; 67–70 fathoms; bottom stony; May 17; sta. 11; 1 ♂ juv.

Taken at Barbados by the "Blake" in 94 fathoms.

ACTAEA SETIGERA (Milne Edwards)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 34.

Pillars of Hercules, English Harbour, Antigua; 2 ♂.

English Harbour, Antigua; 1 ♂ 1 juv.

Okra Reef, Barbados; May 13; 1 ♂ 3 juv.

Pelican Island, Barbados; 1 ♀ juv.

Needham Point, Barbados; 1 ♂ juv. May 18; 1 ♀ juv.

Barbados; 1 ♂. May 15; 1 ♂ 4 juv. From old coral head; May 31; 1 ♀ juv., 1 juv. From coral heads; June 4; 1 ♂ 1 ♀ juv.

Not before recorded from so far south.

ACTAEA BIFRONS Rathbun

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 34.

Barbados; 1 ♂.

Shoal Bank, Barbados; 30 fathoms; bottom rough; June 12; sta. 96; 1 ♂.

Shoal Bank, about 3 miles W. of Needham Point; 20–40 fathoms; sponge bottom; sta. 101; 1 ♂.

This species has been found only off Porto Rico and Colon.

XANTHIAS NUTTING Rathbun

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 35.

Barbados; 1 small ♂.

XANTHIAM GRANULIMANUS (Stimpson)

Plate II, figs. 2 and 3.

Rathbun, Bull. Lab. Nat. Hist. State Univ. Iowa, vol. IV, 1898, p. 271.

Barbados; from coral heads; June 4; 1 ♀ ovigerous.

Known previously from Bahamas and Cuba.

Carapace suboval, front slightly advanced, regions indicated by shallow furrows; anterior and antero-lateral regions irregularly granulated, the coarser granules forming short lines near the lateral teeth. Edge of front bow-shaped, a short median slit. Upper margin of orbit transverse and a little sinuous. Four antero-lateral teeth beside the angle of the orbit, first tooth low, remote from orbit, remaining teeth sharp-pointed, edge of orbit and teeth granulate. Lower surface of carapace densely granulate, lower margin of orbit more advanced than upper, with a V-shaped outer sinus and a thick, triangular tooth at inner angle.

Chelipeds unequal, exposed surfaces of carpus, manus and proximal ends of fingers coarsely granulate; fingers deeply grooved, the granules extending more than half the length of the intervening ridges in the smaller chela. Legs hairy, especially the last three segments, upper margin of merus and upper surfaces of carpus and propodus denticulate.

The above description was made from a Bahama specimen (♀) in the U. S. National Museum. The Barbados specimen is much smaller but ovigerous. Length of carapace 3.7 mm., width 5.2 mm.

CHLORODIELLA LONGIMANA (Milne Edwards)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 36.

Barbados; May 15; 3 ♂ 7 ♀ (1 ovig.) 2 juv.

Coral heads; May 31; 1 ♂. On old coral heads; June 4; 3 ♂ 2 ♀.

Okra Reef, Barbados; May 13; 2 ♂ 2 ♀.

One mile S. of sta. 19, off Needham Point, Barbados; 84 fathoms; bottom rocky; sta. 20; 1 ♂.

Not previously recorded from Barbados; known from Guadeloupe and Curaçao.

OZIUS RETICULATUS (Desbonne and Schramm)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 37.

Barbados; 1 ♀.

Not previously recorded from Barbados; the nearest points are Guadeloupe and Puerto Colombia.

PILUMNUS CARIBAEUS Desbonne

In Desbonne and Schramm, Crust. Guadeloupe, 1867, p. 32.

Needham Point, Barbados; May 18; 1 ♀.

In this species the lateral spines are 4, including the spine at the outer angle of the orbit; the first and often the second spine is bifid. In the Barbados specimen, there is a spine immediately following the orbital spine, which is subequal to it, and the second spine also is double, composed of 2 separate spines, the hinder of the two being smaller; in short, the margin appears to be 6-spined. Two spines on the dorsal surface of the hepatic region and one on the branchial region near by, are larger than usual. The outer surface of the larger as well as of the smaller palm is rough all over.

Not previously known south of Guadeloupe.

PILUMNUS BARBADENSIS, sp. nov.

Plate I

Type-locality.—Barbados; from old coral heads; May 31; 3 ♂ 2 ♀; the largest ♂ has been selected as the holotype. (Cat. No. ——, Mus. Univ. Iowa.)

Additional lots.—Okra Reef, Barbados; May 13; 2 young. Barbados; from coral heads; June 4; 5 small.

Measurements.—Male holotype, length of carapace 6.7, width 9.4 mm. The largest ♀ is 12.3 mm. wide and too broken to permit measurement of the length; figured ♀, length 7.6, width 10.7 mm.

Description.—Carapace suboval, antero-lateral margin arched but shorter than the postero-lateral margin. Surface covered with a short, soft, sparse pubescence which does not conceal the carapace. Furrows between regions and gastric subregions well marked. Surface minutely roughened, especially along the front and antero-lateral regions where the granules are acutely pointed. The lobes of the front are oblique, slightly convex save at outer end which is right angled; edge crenulate. Inner orbital angle acute, elevated; upper orbital margin sloping obliquely outward and backward to a slight outer tooth. Edge of orbit finely denticulate. Antero-lateral margin armed with 3 slender, acuminate spines, each set in a stout, triangular, denticulate base. The carapace is widest at the posterior pair of these spines; the two interspaces are subequal; between the anterior spine and the orbital angle there is a spinule, little larger than the sharp denticles of the neighboring surface, and confused in dorsal view with several subhepatic spinules. Suborbital region covered with coarse, acute granules. Lower orbital region more advanced than upper, its spinules more elongate; spinule at inner angle a little larger and more pronounced.

Chelipeds very unequal, thinly clothed with longer hairs than the carapace; carpus covered with acute granules, and with two spinules, one above the other at the inner angle. Only the proximal third or less of the major palm is rough with granules, the roughness forming an oblique band bordering the carpus but stopping short of the lower margin; the proximal two-thirds of the lower edge is separately roughened; remainder of palm smooth and naked; fingers of ♂ dark brown with light tips, color not reaching quite to base of immovable finger, color line vertical; a narrow interdigital gape. In the minor cheliped the entire outer surface of the palm is very rough, the granules arranged for the most part longitudinally; the fingers are less gaping and are deeply grooved, the ridges very rough.

In the female, the fingers are a lighter brown and in the largest female the roughness on the major palm is less extensive.

Ambulatory legs slender, bordered with long hair; merus slightly enlarged, upper margin edged with slender spines. Dactyli noticeably slender.

Relationships.—Of the *Pilumnus* in the West Indian fauna, this approaches nearest to *P. spinipes* (= *Micropanope spinipes* A. Milne Edwards[1]) in many details such as the ornamentation of the antero-lateral margin, the partial roughness of the major palm, the slender legs. On the other hand, the carapace of *barbadensis* is more oval and more convex, front more deflexed, and the minor palm rough all over, while in *spinipes* the granulation is similar on the two palms.

P. andrewsii Rathbun[2] is a broad species with antero-lateral margin similar to that of *barbadensis,* but the interregional furrows are deeper, the upper orbital border has two small but distinct emarginations, the major palm is smooth, the minor one nearly so.

PILUMNUS FLORIDANUS Stimpson

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 40.

W. N. W. of Lazaretto, N. N. W. of Pelican Island, Barbados; dredged in from 80–100 fathoms to where rocks begin at about 35 fathoms; bag full of coarse sand; sta. 53; 1 ♀ ovig.

Not previously known south of Porto Rico and St. Thomas.

HETERACTAEA CERATOPUS (Stimpson)

Pilumnus ceratopus Stimpson, Ann. Lyc. Nat. Hist. N. Y., vol. VII, 1860, p. 215.

Needham Point, Barbados; by diver; 1 ♀.

Barbados; May 22; 1 juv. From coral heads; June 4; 1 ♂ 4 ♀.

Not recorded south of Guadeloupe.

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[1] Crust. Rég. Mex., 1880, p. 326, pl. LIV, fig. 3.

[2] Bull. Lab. Nat. Hist. State Univ. Iowa, vol. IV, 1898, p. 266, pl. V, fig. 2.

ERIPHIA GONAGRA (Fabricius)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 42.

Pillars of Hercules, English Harbour, Antigua; 1 juv.

Barbados; 1 ♂ 3 ♀ (all small).

Bathsheba, Barbados; 3 ♂ (the largest one with abnormal abdomen, which is intermediate in width between ♂ and adult ♀).

Needham Point, Barbados; 3 ♀ (1 ovig.).

Pelican Island, Barbados; tide pool; May 11; 1 ♀, 1 juv.

No label; 3 ♂ 4 ♀ (3 ovig.).

MELYBIA THALAMITA Stimpson

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 43.

Barbados; 2 ♂ 1 ♀ ovig. From broken coral; May 27; 1 ♀ ovig.

S. W. of Pelican Island, Barbados, 1 mile; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 ♀ ovig., 2 juv.

Not previously recorded from Barbados; found at Porto Rico and Colon.

DOMECIA HISPIDA Eydoux and Souleyet

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 43.

Barbados; May 15; 1 ♀ ovig. May 22; 1 juv. In coral heads; May 31; 1 ♀. From coral heads; June 4; 1 ♂. Living in *Acropora;* 1 ♂ 3 ♀ ovig. 1 young.

Okra Reef, Barbados; May 13; 1 ♂ 6 ♀ (4 ovig.).

Needham Point, Barbados; May 18; 1 ♂.

One mile S. of sta. 19, off Needham Point; 84 fathoms; bottom rocky; sta. 20; 1 ♂ 4 ♀ (2 ovig.).

W. by N. of Pelican Island, 1½ miles; 80 fathoms; bottom rocky; tangles without weight; May 16; sta. 7; 1 young.

Family **Goneplacidæ**

GONEPLAX BARBATA (A. Milne Edwards)

Rathbun, Bull. U. S. N. M., No. XCVII, 1918, p. 26, pl. IV, figs. 1 and 3; pl. V.

W. by N. of Pelican Island, Barbados, 2 miles; 75–80 fathoms; sand bottom; May 15; sta. 3; 1 ♀ immature.

This specimen unites the characters of *G. barbata*[1] and *G. sigsbei*,[2] as given in my monograph (pp. 26–27). It will be noted there that all the specimens (4) of *barbata* recorded are male, while both those of *sigsbei* are female. The specimen in hand has the lateral dentation of *barbata*, as shown in plate V, while lacking a branchial ridge, an orbital notch, and a patch of hair on the cheliped, which three characters link it to *sigsbei*. There is a very small but sharp spine on the upper margin of the arm and the inner angle of the wrist, not the prominent, curved spine of typical *barbata*, nor the blunt tooth of *sigsbei*.

Both *barbata* and *sigsbei* are recorded from off Grenada, and *barbata* also from Gulf of Mexico and Straits of Florida.

PANOPLAX DEPRESSA Stimpson

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 47, pl. XII, figs. 1 and 2, text-fig. 21.

Barbados; 1 ♂ 1 ♀. From broken coral; May 27; 1 ♂.

Not previously noted south of Porto Rico.

Family **Pinnotheridæ**

PARAPINNIXA HENDERSONI Rathbun

Bull. U. S. Nat. Mus., No. XCVII, p. 109, 1918, pl. XXVI, figs. 1–5.

English Harbour, Antigua; by electric light; July; 1 ♂ 2 ♀.

This extends the range of the species, which heretofore has been found in N. W. Cuba and on the west coast of Florida.

Family **Cymopoliidæ**

CYMOPOLIA AFFINIS (A. Milne Edwards and Bouvier)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 196, pl. XLVI, pl. XLVII, fig. 3, text-fig. 121.

S. W. of Pelican Island, Barbados, 1 mile; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 ♂ 1 ♀, both immature.

Previously taken off Barbados in 68 fathoms by the U. S. C. S. Str. "Blake."

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[1] Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 26, pl. IV, figs. 1 and 3, pl. V.

[2] *Op. cit.*, p. 26, pl. IV, figs. 2 and 4.

CYMOPOLIA BAHAMENSIS (Rathbun)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 200, pl. XLVII, figs. 1 and 2.

Barbados; Lazaretto bears S. E. by E., ½ mile off shore; 35 fathoms; bottom rocky; tangles; May 24; sta. 42; 1 ♀ ovig.

Known only from the Bahamas.

CYMOPOLIA SICA A. Milne Edwards

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 208, pl. XL, figs. 3 and 4, text-fig. 127.

1¼ miles W. of Telegraph Station, Barbados; 118 fathoms; bottom of fine sand; May 30; sta. 60; 1 ♀ ovig.

Taken by the "Blake" off Barbados in 82 fathoms.

Family **Grapsidæ**

GRAPSUS GRAPSUS (Linnaeus)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 227, pls. LIII and LIV, text-fig. 135.

Barbados; 3 ♂ 4 ♀ (2 ovig.).

GEOGRAPSUS LIVIDUS (Milne Edwards)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 232, pl. LV.

Pelican Island, Barbados; May 18; 1 ♀; nocturnal; color in life, light olive brown, marbled on carapace with dark Van Dyke brown; legs faintly spotted.

GONIOPSIS CRUENTATA (Latreille)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 237, pl. LVII, text-fig. 136.

Bridgetown, Barbados; mangrove swamp; 2 ♂ 1 ♀; 1 ♂ is shedding.

N. of Bridgetown, mangrove swamp; 1 ♀.

PACHYGRAPSUS TRANSVERSUS (Gibbes)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 244, pl. LVI, figs. 2 and 3.

Pillars of Hercules, Antigua; 4 ♂ 4 ♀ (3 ovig.).

English Harbour, Antigua; 1 ♂ 1 ♀ ovig.

Bathsheba, Barbados; 1 ♂.

Needham Point, Barbados; 1 ♀.

Barbados; 1 ♀ ovig.

EUCHIROGRAPSUS AMERICANUS A. Milne Edwards

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 282, pl. LXXIV, text-fig. 144.

W. of Telegraph Station, Barbados, 1 mile; 86 fathoms; bottom rocky; May 30; sta. 59; 1 ♂.

Cable station, Barbados, bears E. by S., Lazaretto E. S. E. ½ S.; 35–60 fathoms; bottom mostly rocky, working on steep slope; tangles; June 3; sta. 75; 1 ♀ 1 juv.

The type-locality is off Barbados, 69 fathoms, "Blake."

ARATUS PISONII (Milne Edwards)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 323, pl. XCVI.

English Harbour, Antigua; 1 ♀.

Pillars of Hercules, Antigua; 2 ♀ (1 ovig.).

PLAGUSIA DEPRESSA (Fabricius)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 332, pl. CI, text-fig. 154.

Barbados; 1 old male.

Bathsheba, Barbados; 1 small but mature ♀.

PERCNON GIBBESI (Milne Edwards)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 337, pl. CV.

Pillars of Hercules, Antigua; 2 ♂ 3 ♀ (1 juv.).

English Harbour, Antigua; 2 ♂ juv.

Okra Reef, Barbados; May 13; 1 ♂ juv.

Family **Gecarcinidae**

CARDISOMA GUANHUMI Latreille

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 341, pls. CVI and CVII, text-fig. 155.

Bridgetown, Barbados; 1 large, well-developed ♂, 1 adult ♀.

Mangrove swamp, north of Bridgetown; 1 young ♀.

UCIDES CORDATUS (Linnaeus)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 347, pls. CX–CXIII, pl. CLIX, figs. 3 and 4, text-fig. 158.

Barbados; 1 ♂ small.

Antigua; mangrove swamp; 2 large ♂. The larger has a carapace 73.7 mm. long, 100 mm. wide. The greatest width compared to the length is intermediate between that given in my monograph for a smaller specimen of *cordatus* and the width of *occidentalis.*

This Antigua specimen lacks the first ambulatory leg on the right side; the first leg on the left side is shorter than the second leg, but may not be normal.

The smaller specimen of the two has the ambulatory legs of the right side normal; the first leg on the left side is no longer than, indeed, a trifle shorter than the second leg.

Both these specimens have the palm straighter below than in the specimens previously described by me. In spite of these variations in *cordatus,* there is no likelihood of confusion with *occidentalis,* as the palms of the latter are longer and slenderer than any of the *cordatus* examined, and the carapace is narrower behind in proportion to its greatest width.

GECARCINUS LATERALIS (Freminville)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 355, pls. CXIX and CXX, text-fig. 161.

Barbados; 1 ♂ 1 ♀ 1 juv.

Family **Ocypodidae**

OCYPODE ALBICANS Bosc

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 367, pls. CXXVII and CXXVIII.

Barbados; beach on south coast; 2 ♂.

Pelican Island, Barbados; 1 ♀.

UCA MORDAX (Smith)

Rathbun, Bull. U. S. Nat. Mus., No. XCVII, 1918, p. 391, pl. CXXXIV, figs. 3 and 4, text-fig. 166.

English Harbour, Antigua; 2 ♂. In mangrove swamp; 1 ♂, large.

N. of Bridgetown, Barbados; mangrove swamp; 7 ♂ 6 ♀, of medium size.

Superfamily *Oxyrhyncha*

Family **Parthenopidæ**

PARTHENOPE (PLATYLAMBRUS) FRATERCULUS (Stimpson)

Lambrus fraterculus Stimpson, Bull. M. C. Z., vol. II, 1871, p. 130.

Off Lazaretto, Barbados; 20 fathoms; bottom rough; tangles; June 6; sta. 87; 1 ♂.

This specimen has the dorsal projections more acute than customary, and the chelipeds a little longer, with sharper teeth or spines.

Not before known from the West Indies. Its southern boundary has been Yucatan in the west, Miami in the east.

SOLENOLAMBRUS TENELLUS Stimpson

Bull. M. C. Z., vol. II, 1871, p. 134.

Barbados; Lazaretto bears S. E. by E., ½ mile off shore; 35 fathoms; bottom rocky; tangles; May 24; sta. 42; 1 ♀ ovig.

Dredged off Barbados by the "Hassler," 100 fathoms, and by the "Blake" in 56 to 103 fathoms.

Family **Inachidæ**

Subfamily **Inachinæ**

STENORYNCHUS SAGITTARIUS (Fabricius)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 53.

N. W. ½ N. of Pelican Island, Barbados, W. ½ S. of Lazaretto; 80 fathoms; bottom fine sand; May 27; sta. 49; 1 ♂.

Shoal Bank, Barbados, about 3 miles W. of Needham Point; 20–40 fathoms; sponge bottom; sta. 101; 1 ♂.

Taken at Barbados by the "Blake" in 94 fathoms.

PODOCHELA HYPOGLYPHA (Stimpson)

Podonema hypoglypha Stimpson, Bull. M. C. Z., vol. II, 1871, p. 127.

Barbados; Paynes Bay Church bears E. N. E. and the Lazaretto S. E. by S., off shore ½ mile; 50 fathoms; bottom rocky; tangles; May 31; sta. 64; 1 small but adult male.

Not before noted south of Guadeloupe.

PODOCHELA GRACILIPES Stimpson

Bull. M. C. Z., vol. II, 1871, p. 126.

Lazaretto, Barbados, bears S. E. by E., ½ mile off shore; 35 fathoms; bottom rocky; tangles; May 24; sta. 42; 1 ♂.

Cable station, Barbados, bears E. by S., Lazaretto E. S. E. ½ S.; 35–60 fathoms; bottom mostly rocky, working on steep slope; tangles; June 3; sta. 75; 1 ♂.

Not before found in the lesser Antilles, although off Yucatan and Colombia.

BATRACHONOTUS FRAGOSUS Stimpson

Bull. M. C. Z., vol. II, 1871, p. 122.

S. W. of Pelican Island, Barbados, 1 mile; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 ♂.

EUPROGNATHA GRACILIPES A. Milne Edwards

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 58.

2 miles due W. of Pelican Island, Barbados; 80 fathoms; bottom coarse sand; May 17; sta. 13; 1 small ♂.

Dredged by the ''Blake'' at Barbados in 69 to 76 fathoms.

ARACHNOPSIS FILIPES Stimpson

Bull. M. C. Z., vol. II, 1871, p. 121.

Barbados; W. N. W. of Lazaretto; N. N. W. of Pelican Island; 33 fathoms; bottom rocky; dredge; May 27; sta. 51; 1 ♀.

Subfamily **Pisinæ**

CHORINUS HEROS (Herbst)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 61.

Pelican Island, Barbados; tide pool; May 11; 1 ♀ immature.

HERBSTIA DEPRESSA Stimpson

Plate II, fig. 4.

Ann. Lyc. Nat. Hist. N. Y., vol. VII, 1860, p. 57.

Barbados; May 15; 1 ♀ ovig.; median length of carapace 14, width 12, length to tip of rostral horns 14.8 mm.

Besides the tubercles on the carapace mentioned by Stimpson there are 4 tubercles or granules forming a transverse oblong on the branchial region, 2 of the granules near the inner angle of this region and the other 2 granules in a line posterior to the middle of the cardiac region. There is also a granule on the dorsal surface which forms a triangle with the 2 marginal spines at the widest part of the carapace. The row of spines on the merus of the cheliped is on its upper margin.

Not before found south of St. Thomas.

LISSA BICARINATA Aurivillius

Plate II, fig. 1.

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 64.

S. W. of Pelican Island, Barbados, 1 mile; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 ♀ ovig.; carapace concealed dorsally by a calcareous coating which does not disguise the characteristic elevations.

Subfamily **Schizophrysinæ**

THOE PUELLA Stimpson

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 63.

Pillars of Hercules, Antigua; 2 ♂ 3 ♀ (1 ovig.).

MITHRAX SPINOSISSIMUS (Lamarck)

The Lazy Crab Hughes, Nat. Hist. Barbados, 1750, p. 262, pl. XXV, fig. 1 (part: chelipeds and legs only).

Mithrax spinosissimus Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 66.

Barbados: W. N. W. of Lazaretto; N. N. W. of Pelican Island; 33 fathoms; bottom rocky; dredge; May 27; sta. 51; 3 young.

The largest of these, about 9 mm. long in the median line, shows a small spine on the basal antennal segment at the base of the next segment.

MITHRAX ACUTICORNIS Stimpson?

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 66.

Barbados; May 22; 1 juv. with carapace less than 6 mm. long. Agrees in the main with *M. acuticornis* but the carapace is smoother than usual, the tubercles being fewer and lower.

MITHRAX PILOSUS Rathbun

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 66.

Pillars of Hercules, English Harbour, Antigua; 1 ♂ juv.

Barbados; 1 ♂.

Not before noted from Barbados, but occurring at Guadeloupe and Caracas.

MITHRAX HEMPHILLI Rathbun

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 69.

English Harbour, Antigua; shore; 1 ♂.

MITHRAX VERRUCOSUS Milne Edwards

Mag. Zool., vol. II, 1832, cl. VII, pl. IV and explanation.

Pillars of Hercules, English Harbour, Antigua; 1 ♂, medium size.

Fort Barclay, English Harbour; July 9; 1 ♀ juv.

English Harbour; shore; 1 ♀ juv.

Pelican Island, Barbados; 1 ♂ juv.

Not previously recorded from Barbados; occurs at Guadeloupe, Martinique and on the coast of Brazil.

MITHRAX DEPRESSUS A. Milne Edwards

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 68.

English Harbour, Antigua; shore; 1 ♂ medium, 1 juv.

MITHRAX PLEURACANTHUS Stimpson

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 68.

Barbados; 1 ♂ juv. From coral heads; May 27; 2 ♂ 1 ♀ ovig., all small.

Not recorded previously from Barbados, or farther south than Martinique.

MITHRAX CARIBBAEUS Rathbun

Plate III

Proc. Biol. Soc. Washington, vol. XXXIII, 1920, p. 23.

Barbados; 2 ♀, one rather large, the other middling small.

Length of carapace of larger ♀ on median line 53.5, extreme width 71 mm. Length of smaller ♀ 20.8, width 24.4 mm.

Approaches *M. hispidus* in its large size and general shape, but the carapace is a little narrower, and the crenulation of the prehensile edges of the fingers in the gape persists in the old, while it disappears in old *hispidus.*

Differs from all its allies in the arrangement of tubercles or tubercles and spines on the postero-lateral region. There is a postero-lateral spine in the young and middle-sized, which becomes a tubercle in the old; it is situated not far behind the spine at the lateral angle of the carapace, and forms the outermost of a transverse row of three, which is subparallel to another row of three tubercles.

Barbados is the furthest east for this species; it has been taken at Porto Rico, St. Thomas and Venezuela.

MITHRAX (MITHRACULUS) SCULPTUS (Lamarck)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 71.

Pillars of Hercules, English Harbour, Antigua; 14 ♂ 6 ♀ (4 ovig.).

English Harbour; 1 ♂.

Pelican Island, Barbados; 4 ♂.

Barbados; under sea anemone; 3 ♂ 1 ♀.

M. sculptus is usually olivaceous, the color persisting in alcohol. The 4 specimens taken from under sea anemones are an exception, as they are reddish brown, in alcohol.

MITHRAX (MITHRACULUS) CORYPHE (Herbst)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 71.

Pillars of Hercules; English Harbour, Antigua; 6 ♂ 7 ♀ (4 ovig.).

Ft. Barclay, English Harbour; July 9; 1 ♂.

Pelican Island, Barbados; 2 ♂ 1 ♀. Tide pool; May 11; 1 ♂ 2 ♀ ovig.

Barbados; 1 ♂. From coral head; June 4; 1 ♂. Shore; 1 ♀ ovig. Under sea anemones; 3 ♂ 5 ♀ (4 ovig.) 1 juv.

MITHRAX (MITHRACULUS) FORCEPS (A. Milne Edwards)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 70.

1 mile S. of sta. 19, off Needham Point, Barbados; 84 fathoms; bottom rocky; sta. 20; 1 ♀ ovig.

Barbados; 2 ♂ 3 juv.

MITHRAX (MITHRACULUS) RUBER (Stimpson)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 69.

Pelican Island, Barbados; 1 ♂ 1 ♀ juv.

Needham Point, Barbados; May 18; 3 ♂ 1 ♀ immature. By diver; 1 ♂.

1 mile S. of sta. 19, off Needham Point; 84 fathoms; bottom rocky; sta. 20; 2 ♂ 3 ♀.

Okra Reef, Barbados; May 13; 6 ♂ 6 ♀, all small.

Barbados; shore; 1 ♀. May 15; 7 ♂ 4 ♀ (2 ovig.) 2 juv. May 22; 1 ♂. On old coral; May 31; 1 ♂ 1 ♀ immature. From coral heads; June 4; 4 ♂ 1 ♀ ovig. 1 juv.

Not heretofore known south of Guadeloupe.

MITHRAX (MITHRACULUS) CINCTIMANUS (Stimpson)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 70.

English Harbour, Antigua; shore; 1 ♀, immature.

MICROPHRYS BICORNUTUS (Latreille)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 72.

Pillars of Hercules, English Harbour, Antigua; 10 ♂ 5 ♀ (2 ovig.) 1 juv.

English Harbour, Antigua; shore; 4 ♂ 2 ♀ (1 ovig.).

Antigua; 1 ♀ ovig., with the slender, slightly divergent, incurved horns figured by A. Milne Edwards, in Crust. Rég. Mex., 1873, pl. XIV, fig. 2.

Bathsheba, Barbados; 3 ♀ ovig., 1 juv.

Pelican Island, Barbados; May 11; 3 ♀ (1 ovig.) 1 juv. Tide pool; May 11; 2 ♂. May 13; 1 ♂.

Needham Point, Barbados; May 18; 1 ♀ juv.

Barbados; 4 ♂ 2 ♀ ovig. Under sea anemones: 1 ♂, soft shell.

MICROPHRYS INTERRUPTUS Rathbun

Plate II, fig. 5.

Proc. Biol. Soc. Washington, vol. XXXIII, 1920, p. 24.

Fort Barclay, English Harbour, Antigua, July 9; 1 ♂ 1 ♀ juv.

Needham Point, Barbados; May 18; 1 ♂.

Known previously only from Cuba, the type locality.

Measurements.—The male from Needham Point is only slightly larger than the type male; the male from Fort Barclay is considerably larger, total length of carapace 16.7, length of horns 2.4, width of carapace without spines 13.6, with spines 13.3 mm. The carapace is widest above the bases of the first ambulatory legs where it exceeds slightly the width between the tips of the postero-lateral spines, which are above the bases of the second ambulatory legs. The egg-bearing female is about the same size as the male and is concealed beneath a mass of algae and other small organisms.

Relationships.—*M. bicornutus* is very widespread and abundant, and a very variable species, but the form which I call *interruptus* appears to be consistently different. It differs from *bicornutus* in being wider in proportion to its length, and wider across the orbits in proportion to its posterior width; in the greater prominence of the oblique branchial protuberances which are in line with the postero-lateral spine; in the more transverse direction of the arch of four tubercles on the intestinal region; in the shorter and more transverse tooth at the antero-external angle of the basal antennal segment, which is very little advanced in dorsal view beyond the preorbital angle, and in ventral view gives the segment much greater relative width than in *bicornutus;* in the presence of a small but well-developed tooth or lobe on the infra-orbital margin, just outside the antennal segment; this tooth is lacking in *bicornutus.*

STENOCIONOPS FURCATA (Olivier)

The Horned Crab, Nat. Hist. Barbados, 1750, p. 266, pl. XXV, fig. 3.

Stenocionops furcata Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 73.

Barbados; in shore 200 yards from sta. 22 (¼ mile E. of sta. 21, in shore 400 to 500 yards); 35 fathoms; bottom rocky; tangles; May 20; sta. 24; 1 ♂.

MACROCOELOMA TRISPINOSUM (Latreille)

Milne Edwards, Hist. Nat. Crust., vol. I, 1834, p. 336.

English Harbour, Antigua; shore; 1 ♀ ovig., overgrown with sponge.

MACROCOELOMA TRISPINOSUM NODIPES (Desbonne)

In Desbonne and Schramm, Crust. Guadeloupe, 1867, p. 15, pl. V, fig. 13.

English Harbour, Antigua; shore; 1 ♂, 1 juv.

MACROCOELOMA SUBPARALLELUM (Stimpson)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 74.

Bathsheba, Barbados; 1 ♀ ovig.

Pelican Island, Barbados; tide pools; May 11; 1 ♀ immature.

Barbados; 1 ♀. Shallow water; under large anemone; 1 ♀ ovig.

The specimens are almost concealed by seaweed, alcyonarians and other foreign substances.

First occurrence at Barbados; known from Guadeloupe and Old Providence.

MACROCOELOMA EUTHECA (Stimpson)

Pericera eutheca Stimpson, Bull. M. C. Z., vol. II, 1871, p. 112.

S. W. of Pelican Island, Barbados, 1 mile; 38 fathoms; bottom of fine coral fragments; May 13; sta. 1; 1 ♂.

W. by N. of Telegraph Station, Barbados; ½ mile off shore about edge of drop off; 60–70 fathoms; tangles; June 1; sta. 66; 1 ♀.

First occurrence at Barbados, though taken at St. Croix and Colon.

MACROCOELOMA INTERMEDIUM Rathbun

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 75.

Off Lazaretto, Barbados; 20 fathoms; bottom rough; tangles; June 6; sta. 87; 1 ♀ immature.

First record at Barbados, though taken at Dominica and Colon.

PICROCEROIDES TUBULARIS Miers

Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 76.

Shoal Bank, Barbados, about 3 miles W. of Needham Point; 20–40 fathoms; sponge bottom; sta. 101; 1 juv.

Not before taken near Barbados, but off St. Thomas and the coast of Brazil.

PITHO MIRABILIS (Herbst)

Rathbun, Bull. U. S. F. C., vol. XX for 1900, part 2, 1901, p. 78.

Pillars of Hercules, English Harbour, Antigua; 1 ♀.

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Bull. Mus. Comp. Zoöl. at Harvard College, vol. II, Cambridge, 1871, pp. 109–160.

EXPLANATION OF PLATES

Plate III and plate II, fig. 1, are from photographs loaned by the U. S. National Museum. The other photographs on plate II were made by Mr. Clarence R. Shoemaker and retouched by Mr. Seward H. Rathbun who made the drawings on plate I.

Plate I

Pilumnus barbadensis, ♀, Barbados

Fig. 1. Major chela, × 8.
2. Minor chela, × 9.4.
3. An ambulatory leg, × 8.
4. Carapace, with eyes and antennae, × 7.

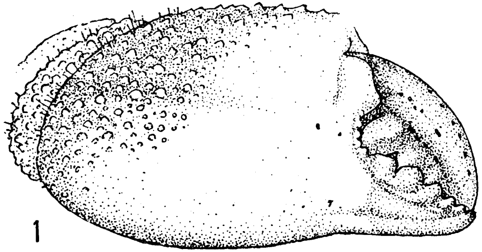
Plate II

Fig. 1. *Lissa bicarinata,* ♀, Cat. No. 24120, U. S. N. M., dorsal view, carapace 9.6 mm. long.
2. *Xanthias granulimanus,* ♀, Cat. No. 20052, U. S. N. M., ventral view, × 3. Carapace 9.2 mm. wide.
3. Same, dorsal view, × 3.
4. *Herbstia depressa,* ♀, Barbados, × 2 2-3.
5. *Microphrys interruptus,* ♂, Fort Barclay, × 3. Carapace, including horns, 16.7 mm. long.

Plate III

Mithrax caribbaeus, ♂ holotype, Cat. No. 50363, U. S. N. M., dorsal view, carapace, including horns, 66.3 mm. long.

PLATE I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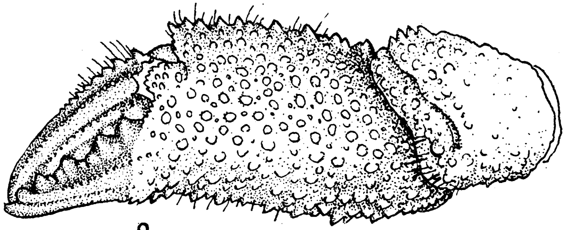
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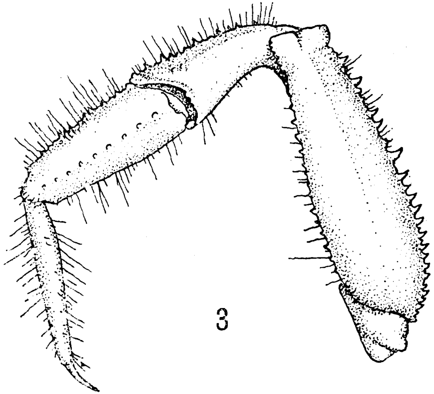
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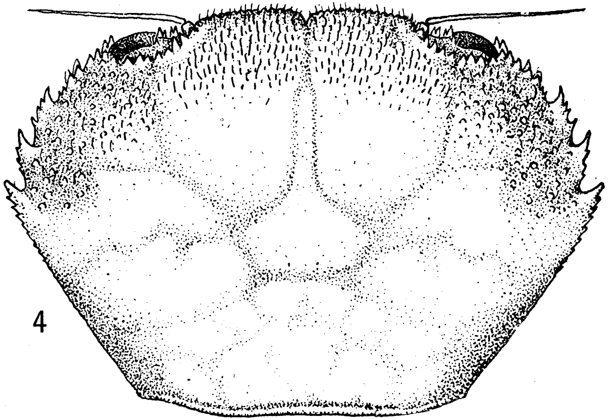
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PLATE II


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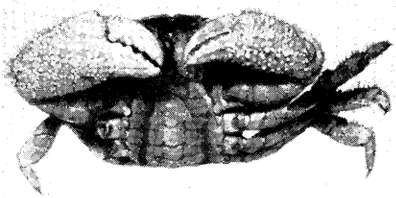
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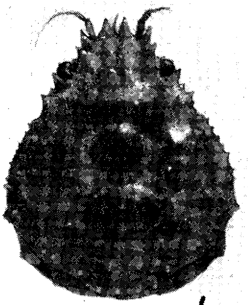
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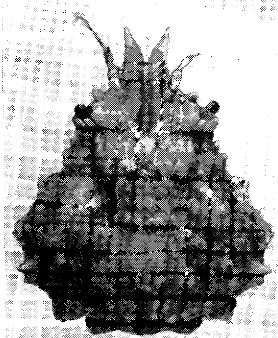
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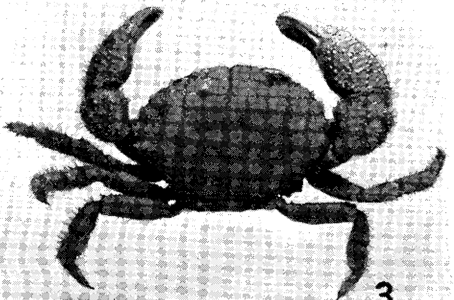
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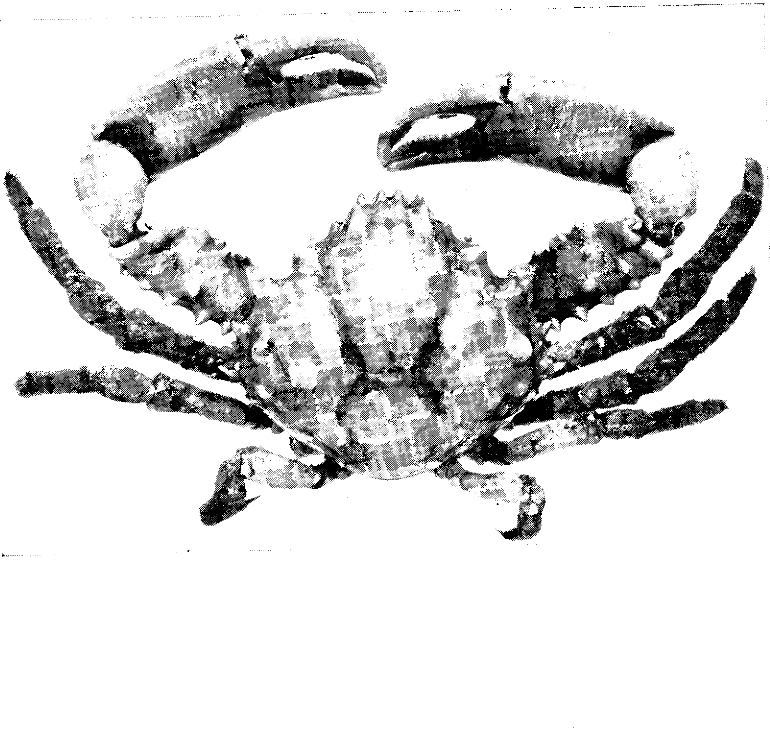
PLATE III



REPORT ON THE TANIDACEA AND ISOPODA

Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918

Pearl L. Boone

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The Isopod Crustacea of the Barbados-Antigua Expedition conducted by the State University of Iowa during the summer of 1918, though a small collection, has proven quite interesting. Of the six species represented, one, *Exosphaeroma nuttingi,* is new to science; another, *Porcellio parvicornis* Richardson, represents the second record of this species, which was described from a single specimen secured in the Bermudas in 1901.

A single representative of the Tanaidacea was taken; namely, *Apsuedes espinosus* Moore.

An annotated list of the material collected and discussion of the new species is herewith presented. The drawing of the latter was made by Mr. Seward H. Rathbun under my direction.

TANAIDACEA

Family **Apseudidæ**

Genus APSEUDES Leach

APSEUDES ESPINOSUS Moore

Apseudes espinosus Moore, Bull. U. S. Fish Commission XX, pt. 2, 1902, pp. 165–166, pl. 7, figs. 1–6. Richardson, Bull. 54, U. S. Nat. Mus., 1905, p. 38, figs. 34 a–f.

One male specimen of this species was collected at Station 1, Barbados, 1918, and is in the collection of the State University of Iowa.

Moore described the type from a female, taken by the U. S. Bureau of Fisheries steamer ''Fish Hawk'', at Station 6079, off St. Thomas, Porto Rico, 20 fathoms, on coral bottom.

Representatives of this species from the following localities are in the collections of the U. S. National Museum; from among algae, No Name Key, Fla.; off the Customs House, Mayaguez, Porto Rico, Station 6651, in 4–6 fathoms; also from Station 6090 off Culebra Island, S. W. Culebrita, Porto Rico, in 16 fathoms.

ISOPODA

Family **Cirolanidæ**

Genus CIROLANA Leach

CIROLANA MAYANA Ives

Cirolana mayana Ives, Proc. Acad. Nat. Sci. Phil., 1891, pp. 186–187, pl. VI, fig. 6, figs. 3–10.—Richardson, Bull. 54, U. S. Nat. Mus., 1905, p. 87, fig. 66.

A single adult specimen, collected in sand, June 2, 1918, Barbados, was secured and is in the collections of the State University of Iowa.

Type locality: Port of Silam, Yucatan, 3 specimens. Subsequent records for this species are: Boqueron Bay and Culebra, Porto Rico (H. F. Moore). Santa Marta, U. S. Colombia (Richardson). Brandon's, Barbados Beach; San Francisco Bay, Lower California (Richardson, 1905). I doubt the validity of this last locality.

There are no specimens of *Cirolana mayana* Ives in the collections of the U. S. National Museum.

CIROLANA PARVA Hansen

Cirolana parva Hansen, Vidensk. Selsk., Skr. (6), V, 1890, pp. 340–341, pl. 2, figs. 6–6b, pl. 3, figs. 1–1d. Richardson, American Naturalist, vol. 34, 1900, p. 217. Proc. U. S. Nat. Mus., vol. 23, 1901, p. 514. Bull. 54, U. S. Nat. Mus., 1905, p. 111, figs. 93–94. Moore, Bull. U. S. Fish Com., 20, pt. 2, 1902, p. 167, pl. 8, figs. 6–8.

Sixteen specimens from Pelican Island, Barbados, were collected June 13, 1918, 14 of which are in the collection of the State University of Iowa and two in the U. S. National Museum, Cat. No. 53882.

One specimen, taken with electric light at English Harbour, one taken at dredging station 1, Barbados, another from Station

11, Barbados, also one labeled "Barbados, May 15, 1918," are in the collections of the State University of Iowa.

Type localities:—Hansen states that he has examined representatives of the species from the following localities: St. Thomas, West Indies, 5 specimens (Krebs, 1867); St. Croix, West Indies, 2 specimens (Oersted); West Indies, 1 specimen (Kroyer); without locality but probably West Indies, 1 specimen; 25° N. B., 34° V. L., 2 specimens (Hygom); Samoa Islands, 1 specimen (Mus. Godeffroy). This last he offers with hesitation and fears the locality with specimen may be wrong, but states the specimens are identical with the West Indian material.

In addition, representatives of this species from the following localities are in the collections of the U. S. National Museum; between the delta of the Mississippi and Cedar Keys, Florida, Stations 2369–74, 25–74 fathoms depth; Station 2406, Gulf of Mexico, Lat. N. 28° 46′, Long. W. 84° 49′, 26 fathoms; Station 7293, Gulf of Mexico, off Northwest Channel, 7¼ fathoms depth, off Biscayne Key, Florida, 16–34 ft. depth; Grassy Key Lake, off Grassy Key, Florida, Station 7431, 8 feet depth, No Name Key, Florida, banks, low tide; off Knights Key Channel, N. E. Bahia Honda Key, Florida, Station 7411, 10 ft. depth; Pigeon Key Lake, Florida, Station 7404, 10½ ft. depth; Key West, Florida, among algae, below low tide; Key West, Florida; specimens from sponges, Lisbon Reef, Andros Island, Bahamas; in algae (*Panicillus capitatus*), Georgetown, Great Exuma, Bahama, shallow water about the keys, Esperanza, Cuba; from mangrove roots, Boque Islands, Montego Bay, Jamaica; Mayaguez, Porto Rico; from Porto Real, Porto Rico; Ponce, Porto Rico; Playa de Ponce, Porto Rico, on lighthouse reef, Arroyo, Porto Rico; Fajardo, Porto Rico; Boqueron Bay, Porto Rico; Ensenada Honda, Culebra, Porto Rico; off St. Thomas, Virgin Islands, U. S., Station 6080, 20 fathoms depth; St. Thomas, Virgin Islands, U. S.

Family **Excorallanidæ**

Excorallana Stebbing[2]

EXCORALLANA SUBTILIS (Hansen)

Corallana subtilis Hansen, Vidensk. Selsk. Skr. (6), V, 1890,

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[1] See Hansen for characters of family, Vidensk. Selsk. Skr. (6), V, 1890, pp. 311-313, 317, 376, Kjobenhavn.

[2] Fauna and Geography of the Maldive and Laccadive Archipelagoes, II, Pt. 3, 1904, p. 704.

pp. 382, 383, pl. 7, figs. 3–3c, Richardson, Proc. U. S. Nat. Mus., XXIII, 1901, p. 519.

Excorallana subtilis Richardson, Bull. 54, U. S. Nat. Mus., 1905, p. 146, fig. 130 a–d.

A single immature specimen of this species was taken at Okra Reef, Barbados, May 13, 1918, and is in the collections of the State University of Iowa.

Hansen described this species from a single young female specimen in the process of ecdysis labelled "St. Thomas, Krebs, Aug. 24, 1858", which is in the Copenhagen Museum.

Two male specimens collected in the harbor of Key West, Florida, by Dr. Edward Palmer, in 1884, Cat. No. 13581, are in the collections of the U. S. National Museum. These specimens agree with Hansen's description except that they lack the two large tubercles at the base of the abdomen, but it must be recalled that the type was an immature female in process of ecdysis.

EXCORALLANA OCULATA (Hansen)

Three specimens of this species were collected with electric light at English Harbour, Barbados, 1918; two of these are in the collections of the State University of Iowa, the third is in the collections of the U. S. National Museum, Cat. No. 53886.

Hansen described the species from two specimens collected in the West Indies, by Krebs, 1866, and deposited in the Copenhagen Museum.

Three specimens, collected by the steamer "Albatross" at Station 2758, in 20 fathoms of water, off Cape St. Roque, Brazil, are in the U. S. National Museum.

Family **Cymothoidæ**

Genus ANILOCRA Leach

ANILOCRA LATICAUDA Milne Edwards

Anilocra laticauda Milne Edwards, Hist. Nat. Crust. III, 1840, p. 259.

Anilocra mexicana Saussure, Rev. Mag. Zool., 1857, p. 505.

Anilocra leachii (Kroyer) Schiödte & Meinert, Naturhistorisk Tidsskrift (3), XIII, 1881–83, pp. 126–131, pl. IX, figs. 1–3. Richardson, American Naturalist, XXXIV, 1901, p. 528.—

Moore, Report U. S. Com. Fisheries XX, Pt. 2, 1902, p. 172, pl. X, figs. 3-4. Richardson, Bull. 54, U. S. Nat. Mus., 1905, p. 227, fig. 230.

Two adult and four young specimens of this well-known fish parasite were collected May 14, 1918, near Pelican Island, Barbados, and are in the collections of the State University of Iowa.

The type locality of the species was described "Habitat la mer des Antilles".

The species has been recorded as parasitic on *Ocyurus chrysurus, Bathystoma rimator, Haemulon plumieri, H. arcuatum, Upeneus martinicus,* and *Abudefduf saxtalis* from a series of localities establishing a geographic range from Maryland to the Straits of Magellan.

The representatives of the species from the following localities are in the collections of the U. S. National Museum: on "Grunt," Jewfish Bush Lake, Florida; "on fish," Key West, Florida; Arroyo and Vieques, Porto Rico; West End Santa Lucia Bay, Cuba; Cape Cajon, Cuba; on parrot-fish, Montego Bay, Jamaica; on eye of yellow-tail, *Ocyurus chrysurus,* Montego Bay, Jamaica; "from angle of mouth (external) of *Bathystoma rimator*", Jamaica; from small yellow-tail, Snug Harbor, Montego Bay, Jamaica; on head of *Haemulon arcuatum,* Cozumel, Yucatan; Cat. No. 7660, on fish, St. Thomas, West Indies; Buck Island, near St. Thomas, West Indies; 1 specimen on red-fish, St. Croix, West Indies; on *Abudefduf saxatilis,* Toso Point, Canal Zone, Panama; on *A. saxatilis,* Colon Reef, Panama; Cat. No. 20481, 2 specimens, Porlamar, Margarita Island, Venezuela; Rio de Janeiro, Brazil.

Genus Cymothoa Fabricius

Cymothoa oestrum (L.)

Oniscus oestrum Linnaeus, Syst. Nat., 10th Ed., I, 1758, p. 636, No. 2; Fauna suecica, 2nd ed., 1761, p. 499, No. 2053; Syst. Nat., 12 ed., I, 1767, pt. 2, p. 1059, No. 2.

Asellus oestrum Olivier, Encycl. Méthod. IV, 1789, p. 253.

Cymothoa oestrum Fabricius, Entom. Syst. II, 1798, p. 505, No. 6,—Leach, Trans. Linn. Soc. London, XI, 1815, p. 372; Dict. Sci. Nat. XII, 1818, p. 362.

Cymothoa dufresnei Leach, Dict. Sci. Nat. XII, 1818, p. 352.

Cymothoa immersa Say, Journ. Acad. Nat. Sci. Phila., I, 1818, pp. 399–400.

Cymothoa oestrum Desmarest, Consid. Gén. Crust., 1825, p. 309, pl. 47, figs. 6–7, Miers, Proc. Zool. Soc., 1877, pp. 671–672,—Schiödte and Meinert, Naturh. Tidsskr. (3), 14, 1883–84, pp. 271–279, pl. 8, figs. 5–13. Richardson, American Naturalist, 34, 1900, p. 221; U. S. Nat. Mus., 23, 1901, p. 530; Bull. 54, U. S. Nat. Mus., 1905, p. 254, fig. 263.

Four adult specimens of this species were found parasitic on the tongue of "horse-eye cavalli" (fish), May 28, 1918, Barbados. About twenty-five very young of the second stage were collected in sand, Barbados, June 2, 1918. One of the adults is in the collections of the U. S. National Museum, Cat. No. 53883. The remainder are in the collections of the State University of Iowa.

The type locality of this well-known parasite was recorded "Habitat in Oceano".

It has been recorded as taken from the following hosts: *Caranx latus, C. ruber,* "jack-fish", from branchial cavity; "red Fish" stomach, in the tongue of Scombroid fishes, parasitic on the mouth of *Priacanthus arenatus* and *Trachurops crumenopthalmus; Sparisoma abilgaardi, Cynocion ciorchus,* on *Strombus giganteus,* the various localities cited giving a geographic range from the shore of Virginia to the southern shores of the Caribbean Sea, also the coast of Peru.

The representatives of this species from the following localities are in the collections of the U. S. National Museum: from the mouth of *Caranx ruber,* Tortugas, Florida; Key West, Florida; parasitic on *Trachurops crumenopthalmus,* and on *Priacanthus arenatus,* Bermuda; Cat. No. 28678, from the "stomach of red-Fish", near Barbados; from parrot-fish, *Sparisoma abilgaardi,* Montego Bay, Jamaica; from the branchial cavity of jack fish, *Caranx* species, Jamaica; Curaçao, Feb., 1884; from mouth of fish, St. Thomas, Virgin Islands, U. S.; 1 young male specimen on the gills of *Cynocion ciorchus,* Colon market, Colon, Canal Zone, Panama; Swan Island, Caribbean Sea.

Family **Sphaeromidæ**

SPHAEROMINAE HEMIBRANCHIATAE

EXOSPHAEROMA NUTTINGI new species

Figures 1–2

Body elongate-ovate, smooth, ground color creamy yellowish, irregularly mottled with fine black splotches.

Head two-thirds as long as wide with frontal margin produced to a median point on either side of which it is moderately excavated and thence recurvate for the reception of the antennal joints. Eyes large, round, occupying the entire postlateral area of the head. First antennae with the basal article elongate, broad, flattened, second article half as long as the first, very convex; the third article slender, cylindrical, two-thirds as long as the first, and a flagellum of eight slender subequal articles and extends almost to the posterior margin of the first thoracic segment. The second antennae have the first and second joints short, subequal, the third and fourth joints each slightly longer than the second, the fifth joint slightly longer than the fourth and a flagellum of eleven tapering subequal articles which extends almost to the posterior margin of the third segment. The maxillipeds have the lobes of the distal four joints much produced.

The first thoracic segment is slightly longer than any of the others which are subequal, the epimera are easily distinguished and have their respective lateral margins rounded and sculptured. The seven pairs of legs are similar, subequal, irregularly, sparsely set with spines along the inner side.

The abdomen has the first thoracic segment a trifle longer than the seventh thoracic segment and bears three transverse lines indicating the coalescence of four segments, the terminal segment is convex, domelike, with the posterior marginal area on a slightly lower plane than the central area; the posterior margin is broadly rounded, the extreme median area has a broad shallow excavation on the ventral surface, the distal termination of this channel causes a vague almost invisible truncation of the dorsal margin. The uropoda have the peduncle rounded, knob-like, its articulation with the inner branch being difficult to distinguish; the inner branch has the inner lateral margin relatively straight, the outer margin broadly rounded, the distal margin crenulate; the outer blade is four-fifths as long as the inner blade and is broadly oval with its posterior margin crenulate.

Pleopoda one and two are subequal, similar, fringed; pleopoda three has the exopod two-jointed; pleopoda four and five have the endopods thick, of fleshy aspect, with deep, essentially transverse folds, the exopods submembraneous and rather pellucid, two jointed.

The present species may be distinguished from *Exosphaeroma crenulatum* Richardson* by the fact that it has three transverse lines on the first abdominal segment indicating the coalescence of four segments; these lines

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**Exosphaeroma crenulatum* Richardson, Bull. 54, U. S. Nat. Mus., 1905, p. 298, figs. 317-318.

are quite differently placed from the two lines of coalescence of *Exosphaeroma crenulatum;* the posterior margin of the telson is different, the uropoda have both blades slightly crenulate only on the distal end, and the lobes of the second, third and fourth joints of the palp of the maxilliped are much produced.

The holotype and eleven paratypes are in the collections of the State University of Iowa. Six additional paratypes are in the collections of the U. S. National Museum, Cat. No. 53884. All were collected from among the spines of a sea-urchin, Barbados. Named for Professor C. C. Nutting.

ONISCOIDEA

Family **Oniscidæ**

Genus PORCELLIO Latreille

PORCELLIO PARVICORNIS Richardson

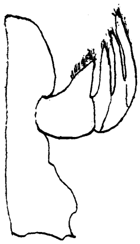
Porcellio parvicornis Richardson, Trans. Conn. Acad. Sciences, XI, 1902, p. 302, pl. 40, fig. 57.—Bull. 54, U. S. Nat. Mus., 1905, p. 616, fig. 667.

Three specimens of this species were collected at Indian River, Barbados, May 21, 1918. Two specimens are in the collections of the State University of Iowa and one in the U. S. National Museum, Cat. No. 53885. These represent the second record of this species, which was described from a single specimen collected by Prof. A. E. Verrill at the Bermudas in 1901, and deposited in the collections of Peabody Museum, Yale University.

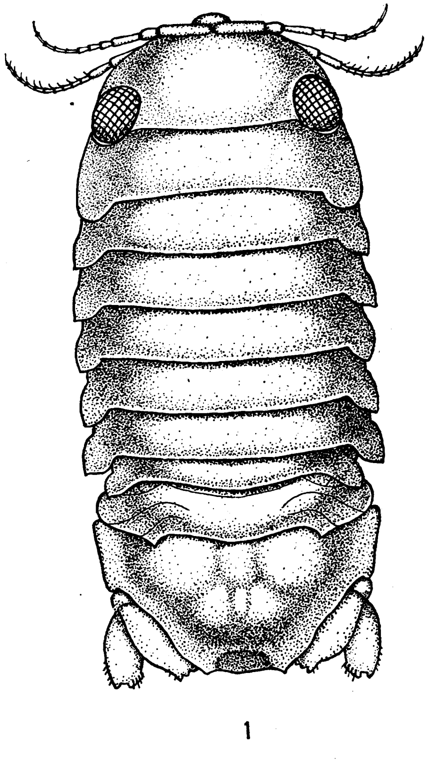
EXPLANATION OF PLATE

Fig. 1. *Exosphaeroma nuttingi* new species, type.
Fig. 2. *Exosphaeroma nuttingi* maxilliped.

PLATE I



2



1

REPORT ON THE AMPHIPODS

Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918

CLARENCE R. SHOEMAKER
Aid, Division of Marine Invertebrates, U. S. National Museum

The Amphipod collection of the expedition is represented by 191 specimens which are included in sixteen species. The records are all new for Barbados and four of the species (*Ampelisca lobata, Lembos concavus, Chevalia aviculae,* and *Ampithoe intermedia*) are reported for the first time from the east coast of America.

1. LYSIANOPSIS ALBA Holmes

Station 1, one mile S. W. of Pelican Island, Barbados,
May 13, 1918, 38 fms. 2 specimens

This species was described by S. J. Holmes in 1905 from Woods Hole, Mass. It was reported by Arthur S. Pearse in 1912 from Gulf of Mexico. J. B. Henderson and Paul Bartsch found it off Cape San Antonio, Cuba, in 1914, and in 1915 it was collected by myself at St. Thomas, W. I.

2. AMPELISCA LOBATA Holmes

Station 1, one mile S. W. of Pelican Island, Barbados,
May 13, 1918, 38 fms. 1 specimen

This is the first report of the occurrence of this species upon the east coast of North America, the species having been described by S. J. Holmes off San Nicolas Island, Southern California, in 1908.

3. AMPHILOCHUS, species

Pelican Island, Barbados, May 13, 1918. 2 specimens

These specimens are too imperfect for identification.

4. LEUCOTHOE SPINICARPA (Abildgaard)

Pelican Island, Barbados, May 13, 1918. 1 specimen (immature)

This species is found throughout the Arctic Ocean, on the coast of Norway, northern coast of Europe, British Isles, Azores, Bermuda, Mediterranean, Ceylon, Seychelles, British East Africa, Red Sea, McMurdo Sound (Antarctic), South Georgia, Cape Agulhas, South Orkneys, East coast of North America, Gulf of Mexico, St. Thomas, Jamaica, Cuba, and South Africa. This is the first mention of its occurrence at Barbados. *Leucothoe spinicarpa* frequently lives commensal in the branchial chamber of Ascidians.

5. BATEA CATHARINENSIS Müller

Pelican Island, Barbados, May 13, 1918. 3 specimens

Batea catharinensis was discovered at Desterro, Brazil, and in 1865 Fritz Müller created the genus for it. No members of the genus were again met with until 1900 when some specimens were found near Woods Hole, Mass., and described by S. J. Holmes as *Batea secunda.* The specific differences which this author points out, however, are very slight and the two species will probably prove to be the same. *Batea catharinensis* has also been found at Chesapeake Bay, Skull Creek, S. C., mouth of May River, S. C., and now at Pelican Island, Barbados.

6. PONTOGENEIA VERRILLI Kunkel

Pelican Island, Barbados, May 13, 1918. 1 specimen

In 1910 B. W. Kunkel described this species from Bermuda and this single specimen now from Barbados marks the second record.

7. MAERA INAEQUIPES (A. Costa)

Pelican Island, Barbados, May 13, 1918. 46 specimens

This species has been reported from the Azores, Mediterranean, Bermuda, Cuba, and South Africa; and the present record is the first for Barbados.

8. ELASMOPUS RAPAX A. Costa

Pelican Island, Barbados, May 13, 1918. 48 specimens

This species has been reported from Norway, British Isles, France, Azores, Bermuda, Gulf of Mexico, Jamaica, Cuba, and now for the first time from Barbados.

9. ORCHESTIA PLATENSIS Kroyer

Station 1, one mile S. W. of Pelican Island, Barbados,
May 13, 1918, 38 fms. 1 specimen
Beach near Pelican Island, Barbados, May 27, 1918. 10 specimens

This Amphipod has been found upon the beaches of nearly all the temperate and tropical regions of the earth; this, however, is the first record for Barbados.

10. LEMBOS CONCAVUS Stout

Pelican Island, Barbados, May 13, 1918. 17 specimens

In 1913 Vinnie Ream Stout described this species from Laguna Beach, California. The specimens taken at Barbados are smaller but agree very well with the description. This is the first appearance of this species on the east coast of America.

11. EURYSTHEUS LINA Kunkel

Pelican Island, Barbados, May 13, 1918. 35 specimens

The first specimens of this species were found at Bermuda in 1903 and described by B. W. Kunkel in 1910. Specimens have been taken also at Tortugas, Florida, and Porto Rico and this record from Barbados extends the range much to the south.

12. EURYSTHEUS, species

Station 1, one mile S. W. of Pelican Island, Barbados.
May 13, 1918, 38 fathoms. 1 specimen

This single, female specimen is in too imperfect a condition for specific identification.

13. CHEVALIA AVICULAE Walker

Pelican Island, Barbados, May 13, 1918. 18 specimens

This species was found by Herdman and Hornell at Ceylon in pearl oyster washings, and described by A. O. Walker in 1904. It was later taken at Saya de Malha Bank, Cargados Islands, and South Africa. Walker thinks this is probably a tube-building species but nothing yet is known of its habits. The species described by Arthur S. Pearse as *Chevalia mexicana* in 1912 from the Gulf of Mexico will probably prove to be the same as Walker's species. This is the first record for Barbados.

14. AMPHITHOE INTERMEDIA Walker

Barbados, under sea anemones. 3 specimens

A. O. Walker described this species from Ceylon in 1904, and in 1905 he reported it from the Maldive Islands. Chevreux in 1907 reported it from the Tuamotu Islands. In 1909 A. O. Walker recorded it from Praslin Reef, Zanzibar, and Red Sea. The specimens from Barbados agree with those figured by Chevreux in having the broad rounded lobe on the lower, anterior corner of the second joint of the second gnathopods.

15. GRUBIA COMPTA (Smith)

Barbados, June 4, 1918 (from coral heads). 1 specimen

This species was described by S. I. Smith in 1873 and was said to range from North Carolina to Cape Cod. In 1912 Arthur S. Pearse reported it from Harbor Key and Key West, Florida. The present record is the first from Barbados.

16. PODOCERUS BRASILIENSIS (Dana)

Pelican Island, Barbados, May 13, 1918. 1 specimen

This is a tropical Atlantic species which heretofore has been reported only from Rio Janeiro and Antigua.

REPORT ON THE ECHINOIDEA

Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918

HUBERT LYMAN CLARK

Museum of Comparative Zoölogy, Cambridge

The collection of Echinoidea made by the party from the University of Iowa, which under the leadership of Professor C. C. Nutting, visited Barbados and Antigua in the summer of 1918, is not a large one but it represents well the typical littoral West Indian fauna. The 229 specimens belong to 18 species, all but two of which are known, characteristic forms of the Caribbean region. The two exceptions are notable indeed, for each represents a genus not hitherto reported from the West Indies: one (*Pseudoboletia*) is recorded from the eastern Atlantic (Ascension Island) and the other (*Centrostephanus*) occurs on the western coast of Mexico.

Of the 229 specimens, 178 belong to three very common West Indian species, *Echinometra lucunter, Echinoneus cyclostomus* and *Brissus brissus.* The equally common species, *Centrechinus antillarum, Tripneustes esculentus* and *Lytechinus variegatus,* are represented by very few specimens, presumably because their large size made extensive series undesirable and their commonness made such series unnecessary. These six common species occurred at both Barbados and Antigua. The only other echini found at the latter island were *Eucidaris tribuloides* and *Clypeaster rosaceus,* which are also common and widespread species. But no *Clypeaster* was taken at Barbados.

The 18 species fall naturally into two divisions, those which occur along shore, or on reefs easily accessible at low tide, and those which are gotten only by dredging, trawling or the use of tangles. The former are the strictly "littoral" group; the latter belong rather to the "continental" fauna; of course members of the littoral group are often taken in deeper water, sometimes down to 50 or even 100 fms., but the species of the continental group do not seem to ever come up into the very shallow water.

The following list shows the echini of the present collection which belong to the strictly littoral group:

Eucidaris tribuloides
Centrechinus antillarum
Lytechinus variegatus
Tripneustes esculentus
Echinometra lucunter
Clypeaster rosaceus
Mellita sexiesperforata
Echinoneus cyclostomus
Brissus brissus

In a recent study of the littoral echinoderms of the West Indies (1919, Publ. 281, Carnegie Inst., pp. 51–74), I have recorded 7 of these 9 species from Barbados and 6 from Antigua, relying mainly on the field notes of Dr. W. K. Fisher who was a member of the Iowa party. The present collection adds *Lytechinus variegatus* to the fauna of Barbados and *Clypeaster rosaceus* and *Echinoneus cyclostomus* to the fauna of Antigua.

Of the remaining nine species, eight unquestionably belong to the continental groups. The ninth, the unique *Pseudoboletia*, may possibly prove to be littoral but the depth at which it was found is not recorded. The nine species are:

Stylocidaris affinis
Tretocidaris bartletti
Coelopleurus floridanus
Centrostephanus rubicingulus
Lytechinus callipeplus
Lytechinus euerces
Genocidaris maculatus
Pseudoboletia occidentalis
Agassizia excentrica

Excepting only the two new forms, all these species were taken by the "Blake" near Barbados, and also near Dominica, Montserrat or St. Cruz. Hence their occurrence in the present collection was quite to have been expected. There are no specimens however of any of them from Antigua, all having been taken off the southwest coast of Barbados in 25–100 fms. But practically no dredging was done at Antigua except in the shallow harbors and bays, owing to the high seas outside those sheltered areas.

LIST OF SPECIES

EUCIDARIS TRIBULOIDES

Cidarites tribuloides Lamarck, 1816. Anim. s. Vert., **3**, p. 56.

Cidaris tribuloides A. Agassiz, 1872. Rev. Ech., p. 253; pl. I*d* and pl. II, figs. 1–3.

Eucidaris tribuloides Döderlein, 1887. Jap. Seeigel, p. 42.

There are three specimens of this well-known sea-urchin at hand; one, 38 mm. in diameter with primary spines 35–38 mm. long, from Falmouth Harbor, Antigua; one 25 mm. with spines of about that length, from Carlisle Bay, Barbados, 30 fms.; and an interesting young individual, about 16 mm. in diameter, without a locality label but apparently from Barbados. This last specimen has the primary spines very stout (15 mm. long by 2.5 mm. in thickness) and more or less flaring at tip. Owing to the unusually well developed longitudinal ridges, the tips are quite florescent. The peculiarities of this specimen are probably associated with its youth, as the wear on the spines during maturity and their tendency to become the abiding-place of bryozoans and other fixed animals in their old age usually obliterate such features as are here noted.

STYLOCIDARIS AFFINIS

Cidaris affinis Philippi, 1845. Arch. Naturg., jhg. 11, **1**, p. 351. See Mortensen, 1903, Ingolf Ech., pt. 1, pl. I, fig. 1.

Dorocidaris papillata A. Agassiz, 1872. Rev. Ech., p. 254 (*in part*); pl. I, fig. 5.

Stylocidaris affinis Mortensen, 1909. Ech. Deutsch. Südpolar-Exp., p. 52.

All of the 5 specimens of this cidarid in the present collection are young, the largest being scarcely half grown. The diameter of the test is 9–17 mm. and the primary spines are 2–2.3 times as much, as a rule. In one specimen, however, 11 mm. in diameter, the primaries are scarcely 15 mm. long. There is some diversity in the coloration of these individuals, for in some the brownish-red lines and markings in the interambulaca and on the abactinal system are quite distinct and in others they are nearly or quite wanting. The youngest primaries (i. e., those on the uppermost coronal plates) are normally quite different from the typical spines of the midzone, lacking the longitudinal dentate ridges. Occasionally the difference is emphasized by color; in one of the present series, these young spines are distinctly pink and unbanded. Fully developed primaries are more than twice the test-diameter, nearly cylindrical or terete, with the distinct, dentate, longitudinal ridges equally developed on all sides. In specimens less than half grown they are often conspicuously banded with 5–8 ill-defined reddish-brown zones.

The specimens in the present collection were taken at the following stations off the southwestern coast of Barbados.

Station 9. May 16, 1918. W. by N. Pelican Island, 2½ miles, 100 fms. Rocky bottom. Tangles. 2 specimens.

Station 34. May 23, 1918. S. E. of Hastings, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 36. May 23, 1918. S. W. of Carlisle Bay, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 46. May 25, 1918. N. N. W. Pelican Island, due west of Prospect, 2 miles off shore, 100 fms. Tangles. Bottom not recorded. 1 specimen.

TRETOCIDARIS BARTLETTI

Dorocidaris bartletti A. Agassiz, 1880. Bull. M. C. Z., **8**, p. 69.
Tretocidaris bartletti Mortensen, 1903. INGOLF Ech., p. 16. 1910, Bull. 74 U. S. Nat. Mus., pls. 2 and 3.

As with the preceding cidarid, all of the half-dozen individuals of this fine species are young, not nearly half grown, the test diameter ranging from 10 to 17 mm., with the primary spines 15–27 mm. The color is commonly brighter than in *affinis,* the reddish tints being usually quite red and the test and small spines being often quite greenish. The bands on the spines are generally distinct and their number may be 8 or 9, although the spines are shorter than in *affinis.* The two species seem to occur together and the young are easily confused. But aside from any matters of coloration, the form of the primary spines is sufficient for separating the two species, even if the very different globiferous pedicellariae cannot be found. In *bartletti,* the typical primaries are flattened and the lateral dentate ridges are more conspicuous, with bigger dentations, than those of either dorsal or lower surface. This makes a noticeable contrast to the cylindrical, uniformly ridged and generally longer spines of *affinis.*

Barbados is the type-locality for *bartletti* and all of the specimens at hand came from there. At two of the following stations *Stylocidaris* was also taken.

Station 7. May 16, 1918. W. by N. Pelican Island, 2 miles, 80 fms. Rocky bottom. Tangles. 1 specimen.

Station 34. May 23, 1918. S. E. of Hastings, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 35. May 23, 1918. S. W. of Needham Point, 2½ miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 36. May 23, 1918. S. W. of Carlisle Bay, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 37. May 23, 1918. Off Pelican Island, 2½ miles, 100 fms. Rocky bottom. Tangles. 1 specimen.

Station 44. May 25, 1918. N. W. Pelican Island and S. W. Lazaretto, 2½ miles off shore, 90–100 fms. Medium coarse sand. Dredge. 1 specimen.

CENTRECHINUS ANTILLARUM

Cidaris (Diadema) antillarum Philippi, 1845. Arch. Naturg., jhg. 11, **1**, p. 355.

Diadema setosum A. Agassiz, 1872. Rev. Ech., p. 274 (*in part*).

Centrechinus antillarum H. L. Clark, 1918. Bull. Lab. Nat. Hist. Iowa, **7**, No. 5, p. 24.

Only a single small specimen of this most characteristic West Indian sea-urchin is in the present collection. It has the test about 30 mm. in diameter while the primary spines are some 55 mm. in length. They still show traces of the youthful banding, so striking a feature of much smaller specimens, but the general impression of this specimen is unicolor, though it is by no means really black.

In the "Narrative", Professor Nutting says this "black nuisance" is found "almost everywhere in shallow water, both on sandy and rocky bottom", about Barbados, while it is also "abundant" at Antigua. Apparently it is abundant wherever it occurs, for it is very common at the Tortugas and along the southern Florida coast, while at the other extreme of the West Indian region, on Buccoo Reef, Tobago, it is more abundant than at any other place where I have personally seen it.

CENTROSTEPHANUS RUBICINGULUS[1] sp. nov.

Plate I, figs 1 and 2.

Test 12 mm. in horizontal diameter, 5 mm. high, decidedly flattened both above and below. Coronal plates 8 or 9 in each column, with no essential difference between ambulacra and interambulacra in this particular, but the interambulacra are about 4 mm. wide at ambitus while the ambulacra are scarcely 3.5. Abactinal system large, 5 mm. in diameter, covered with a fairly thick skin; all the oculars are *insert;* genital plates large, each with a long genital papilla, the length of which about equals the width of the plate; periproct about 2.3 mm. across, covered with small roundish plates, set in thick skin. Uppermost abactinal primary spines, usually two of each vertical series, very small (1 mm. long, more or less), smooth and club-shaped; all the other primaries, especially those of midzone which are the longest (12–14 mm.), very rough with the usual rings of minute spinelets. Peristome 7 mm. in diameter, quite closely covered with non-ambulacral plates among which the five pairs of buccal plates are easily distinguished by their larger size and their clusters of pedicellariae and the spinelets so characteristic of *Centrostephanus.*

Pedicellariae of only two kinds so far as observed, ophicephalous and globiferous. The former have valves .25–.40 mm. long, with the loops 10–30 per cent more. These pedicellariae occur on the buccal plates and scattered about sparsely on the test; those on the test are considerably larger than those on the peristome. The globiferous pedicellariae, as in the other members of the genus, have the valves imbedded in heavily pigmented glands; these pedicellariae therefore, though very small, are made conspicuous by their black tips; the valves are .22–.32 mm. long and terminate in 4 short, subequal, somewhat spreading

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[1] *Rubus* = red + *cingulus* = a zone or band, in reference to the banded spines.

teeth; the general form of the valves is very similar to that found in *C. rodgersii* (See Mortensen, 1904. Siam Ech., pl. IV, fig. 19) except that in the Australian species there are *six* terminal teeth.

Peristome nearly white, but thick skin near mouth, tube-feet and gills yellowish. Pedicellariae pale reddish-yellow. From below ambitus upward the epidermis becomes thicker and steadily more and more pigmented until on the periproct it is quite black, especially at center. Primary spines whitish or glassy with 2–5 ill-defined but very distinct bands of red; the shade of red is between nopal-red and garnet-brown of Ridgway's pl. 1 (Color Standards and Nomenclature, 1912), and is quite free from any violet or purple tinge. The little club-shaped primaries on the abactinal plates have their distal halves bright rose-purple in striking contrast to their surroundings; the shade is very near the rhodamine purple of Ridgway's pl. XII.

Holotype from Station 101. June 13, 1918. On Shoal Bank, about 3 miles W. of Needham Point, 25–40 fms. Sponge bottom. Dredge.

It is a great pity that only a single specimen of this pretty little urchin was taken, for the genus, although occurring on the western coast of Mexico and also in the Mediterranean, has never been found hitherto in the West Indian region. Moreover it is probable that this is a very young specimen and it would be interesting to know to how large a size the species grows. The Australian species, *rodgersii,* is the largest, reaching a diameter of 100 mm., while the Mediterranean and Mexican species attain less than half that size, so far as we yet know. Neither species is at all well known. In every way, the West Indian species is nearest to that of the Mexican coast (*coronatus*) but it differs in several minor particulars. The coloration is noticeably different for in *coronatus,* the red which bands the spines is distinctly purplish and there is no trace of purple on the primaries of *rubicingulus.* More important is the difference in the globiferous pedicellariae; in *coronatus,* the narrow part of the blade is short and the terminal teeth are very long (see A. Agassiz and H. L. Clark, 1908, Mem. M. C. Z., **34**, pl. 51, figs. 18, 19) while in *rubicingulus,* the narrow part of the blade is longer and the teeth are very much shorter. Of course, more material is needed before all the differences between the two species can be clearly set forth.

COELOPLEURUS FLORIDANUS

A. Agassiz, 1872. Rev. Ech., p. 102. 1883, "Blake" Ech., pl. VII.

The specimens of this fine sea-urchin are all from the deeper water off southwestern Barbados. All are very young, the tests measuring only 6–13 mm. in horizontal diameter. The spines are generally more or less badly broken but when these are intact they are usually 4–4.5 times the test diameter. The only diversity these individuals show is in the degree of brightness of their coloration. Some have no trace of blue or lavender abactinally while others, larger ones, have it quite well marked. The 7 specimens were taken at the following stations:

Station 7. May 16, 1918. W. by N. Pelican Island, 2 miles, 80 fms. Rocky bottom. Tangles. 1 specimen.

Station 19. May 18, 1918. 1½ miles west of Needham Point, 80 fms. Rocky bottom. Dredge. 1 specimen.

Station 26. May 20, 1918. Due W. of Pelican Island, 75 fms. Rough, stony bottom. Dredge. 1 specimen.

Station 34. May 23, 1918. S. E. of Hastings, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 36. May 23, 1918. S. W. of Carlisle Bay, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 2 specimens.

Station 88. June 7, 1918. Lazaretto E. by N. ½ N., Pelican Island S. E. Depth (?). Fine sandy bottom. Dredge. 1 specimen.

LYTECHINUS CALLIPEPLUS

H. L. Clark, 1912. Mem. M. C. Z., **34**, p. 251; pl. 96, figs. 4–6.

The rediscovery of this interesting little species by Professor Nutting's party is of real importance and the five specimens obtained throw a great deal of light on the specific characters, for the holotype was only 8.5 mm. in diameter and the largest known specimen was only 11.5 mm., while the largest in the present series is 20 mm. and another is 17. These larger specimens show that the coloration is more striking and more distinctive than was suggested by the types. Each of the five specimens deserves separate consideration.

The smallest is only 7 mm. in diameter and 4 mm. high. The whole abactinal surface is more or less reddish with indefinite and inconspicuous blotches in the ambulacra and interambulacra. The periproct, the proximal part of the oculo-genital ring and a large blotch at upper end of each interambulacrum are greenish-white. The abactinal spines are nearly all coral-red, but some have whitish tips.

The next specimen is 9 mm. by 5, and has a somewhat different coloration, very similar to that of a third specimen, 11 mm. by 6.75. In these individuals, the general color abactinally is greenish-white but this is largely obliterated by the development of the red blotches in both the ambulacra and interambulacra. These blotches are more or less coalesced so that the median two-thirds of each interambulacrum and about half of each ambulacrum are quite reddish. The larger spines are greenish with red only at the base but the small spines are often tinged with red throughout.

The specimen 17 mm. in diameter is 10 mm. high and its coloration is much like that of the largest specimen but it is somewhat greener, the red shades are paler, the markings are less distinct and all the spines, even the actinal, have a reddish tinge.

The superb specimen from station 35 is 20 mm. in diameter and 12 mm. high; the abactinal system is not quite 6 mm. across but the heavily plated peristome is 9; the primary spines are 4–5 mm. long. There are 14 interambulacral and 15 ambulacral plates in each column. Ocular I is broadly insert but the other oculars are completely excluded from contact with the periproct. The test is greenish-white, nearly white abactinally, with large, squarish but irregular blotches of orange-brown or rusty-red at and above the ambitus. The shade varies according to moisture; it is brightest when wet. There are typically three blotches in each interambulacrum but the one at ambitus is low and imperfect. There are four in each ambulacrum but the one at ambitus is rather faint. In both series, the next to the lowest is largest and brightest. The periproctal plates are nearly white but the plates of the oculo-genital ring are variegated with greenish and reddish tints. Most of the abactinal tubercles are pale red. The actinal spines are nearly white but the bases of the larger ones and more or less of the entire length of small ones have a more or less marked greenish tinge. At and above the ambitus some of the spines become more or less pale red, the color being confined to the base of the spine or extending its whole length. The pedicellariae are white, as are the plates which cover the peristome.

The additional data which these Barbadian specimens furnish show that *callipeplus* is a very well marked species quite distinct from any other member of the genus. In its coloration, it is more like *pictus* and *anamesus* of the western coast of Mexico, or *verruculatus* of the Indo-Pacific region, than it is like its West Indian congeners but the shade of red shown by the tubercles, spines and abactinal spots is entirely different from anything exhibited by the other spotted species.

Station 7. May 16, 1918. W. by N. Pelican Island, 2 miles, 80 fms. Rocky bottom. Tangles. 1 specimen.

Station 11. May 17, 1918. 1¼ miles due west from white lighthouse at Needham Point, in line with red house, 67–70 fms. Stony bottom. Dredge. 1 specimen.

Station 35. May 23, 1918. S. W. of Needham Point, 2½ miles off shore, 80–90 fms. Rocky bottom. Tangles. 1 specimen.

Station 36. May 23, 1918. S. W. of Carlisle Bay, 2 miles off shore, 80–90 fms. Rocky bottom. Tangles. 2 specimens.

LYTECHINUS EUERCES

H. L. Clark, 1912. Mem. M. C. Z., **34**, p. 247; pl. 107, figs. 4–6.

This typically West Indian sea-urchin is represented in the present collection by only a single specimen. It is 11 mm. in diameter, with the abactinal system 3½ mm. across, and ocular I nearly or quite insert. A few of the actinal spines show traces of red. The periproctal plates are light apple-green, but elsewhere both test and spines are white or whitish.

Station 6. May 15, 1918. North of Insane Asylum off spring garden or freshwater bathing place, 100 fms. Rough bottom. 1 specimen.

LYTECHINUS VARIEGATUS

Cidaris variegata Leske, 1778. Add. ad Klein, p. 85.
Lytechinus variegatus A. Agassiz, 1863. Bull. M. C. Z., **1**, p. 24.
Toxopneustes variegatus A. Agassiz, 1872. Rev. Ech., pt. 1, p. 298; pl. IV*a*, figs. 5, 6.

In the Narrative of the expedition, Professor Nutting refers to the occurrence of this well-known species at several places in Antigua but does not speak of finding it at Barbados. Yet the only two specimens in the collection bear the label "Barbados". They are of about equal size (78 mm. in diameter with primary spines 13–15 mm. long) but differ strikingly in color and were evidently selected as examples of the extremes in coloration. One has the test pale brownish-white with only traces of green; the tubefeet are very pale brown; the pedicellariae, muscles and small spines are whitish; the peristome, heavily plated, is pale brownish with traces of green; the primary spines are light green, whitish at base, dark at tip; many have one or two faint dusky bands close to the tip; of many, the tips are regenerating. The other specimen has the test dull light green and whitish; the tubefeet are pale brown; the pedicellariae, muscles and miliary spines are white or whitish; the heavily plated peristome is dull greenish; the primary spines are deep, dark green, the tips becoming purplish but not markedly so; the secondary spines are pale yellow-green. In the Narrative (p. 189), Professor Nutting makes the interesting suggestion that the habit which both this species and *Tripneustes esculentus* have, of holding bits of sea-weed and other rubbish all over the dorsal surface, may be for the purpose of protection from the sun. It would be easy to ascertain whether this is the case and the habits of these sea-urchins would well repay careful investigation.

TRIPNEUSTES ESCULENTUS

Cidaris esculenta Leske, 1778. Add. ad Klein, p. XVII.
Hipponoë esculenta A. Agassiz, 1872. Rev. Ech., pt. 1, pp. 135, 301; pl. VI*a*, figs. 1–3.

Tripneustes esculentus Bell, 1879. Proc. Zool. Soc. London, p. 657.

In the Narrative, Professor Nutting refers often to this well-known ''sea-egg'', one of the very few sea-urchins which have any economic importance. In some cases, the sea-egg is called *Hipponoë* and in others, the correct name *Tripneustes* is used. Complaint is made (p. 188) that I have given no clue to the reason for abandoning *Hipponoë,* but this is hardly fair since I have given the full reference to Bell's paper where the matter was amply elucidated over forty years ago. It is no innovation of mine, to make use of *Tripneustes. Hipponoë* is preoccupied and there is no good reason for persisting in its use.

Professor Nutting calls attention (pp. 80, 188) to two interesting color forms of the sea-egg, and both are represented among the eight specimens in the present collection. The two forms seem to be reasonably distinct and further investigation of their differences and the causes thereof is worth while. Apparently in the pallid form the development of pigment is inhibited, only a little on the triphyllous pedicellariae being visible, while the peristome and gills are brown. In the melanistic form, pigment is markedly developed, especially on the peristome (particularly, close to the teeth), in the pedicellariae, in the tube-feet (except the white tips), in the tips of the branches of the gills and even to some extent in the epidermis of the test. The development of the pigment is not correlated with *size* but whether it is correlated with *age* is as yet unknown.

The specimens at hand range from 34 mm. in diameter to 132 mm. The primary spines on the smallest specimen are notably long (9 mm.), more than one-fourth the test-diameter. As a rule, they are hardly half as much as that.

Of the eight specimens, seven are from Barbados and one is from English Harbour, Antigua.

GENOCIDARIS MACULATA

A. Agassiz, 1869. Bull. M. C. Z., **1**, p. 262. 1872, Rev. Ech., pl. VIII, figs. 1–18 (as *Temnechinus maculatus*).

Two bare, dead tests, without buccal membrane or periproctal plates, are the only representatives of this little sea-urchin in the collection. Both the "Hassler" and the "Blake" took *Genocidaris* off Barbados, but in each case three specimens taken together was the total capture, so it is obviously not common in that region. One of the bare tests of the present collection is 7 mm. in diameter but the other is only 3.5.

Station 84. June 6, 1918. Spring Garden bears E. N. E., Needham Point Light, S. E. Off shore 1½ miles, 100 fms. Fine, sandy bottom. Dredge. 2 specimens.

PSEUDOBOLETIA OCCIDENTALIS, sp. nov.

Plate II, figs. 1 and 2

Test 54 mm. in diameter, 27 mm. high, only a little concave orally and rather flat abactinally. Coronal plates 25 in each interambulacral column and 30 in the ambulacra; the interambulacra are about 19 mm. wide at ambitus and the ambulacra about 14. Each interambulacral plate in the midzone has 4 large primary tubercles, the outermost is slightly the largest, the innermost is smallest; a large secondary tubercle occupies the outer end of the plate, encroaching on the ambulacra; there are 8–10 much smaller secondary tubercles, chiefly along upper margin of plate, and about a dozen irregularly scattered miliaries; orally the number of primary tubercles becomes reduced to 3 and then to 2 and on the lowest plate to one; the gill slits are very deep, reaching up between the tubercles of the third plate (from the peristome); aborally there are 4 primaries to the tenth plate (from the genital), 3 to the seventh and 2 to the fourth or fifth. Each ambulacral plate in the midzone has 2 primary tubercles and a secondary tubercle at each end; the outer secondary encroaches much on the poriferous area; it is wanting only on the lowest two plates and on the uppermost three or four; the inner secondary occurs only in the midzone; the inner primary occurs first on about the twelfth plate from the ocular. Pore-pairs in strongly curved arcs of *four,* the lowest distinctly nearer the ambulacral mid-line than the uppermost.

Abactinal system small, only 9 mm. across, the periproct only 4 mm.; oculars I and V broadly insert, the others not nearly so;

genital pores large near outer end of plate; ocular pores very small, about half way between center and distal margin; genital plates each with a large secondary tubercle, 3–6 large miliaries, and half a dozen or more minute miliaries; oculars with 3–6 large, and a number of minute miliaries. Periproct covered with about 20 plates, among which the suranal is scarcely distinguishable; the larger plates each carry 1–3 large miliaries.

Peristome large, about 22 mm. across, with deep gill-slits; it is well plated but not heavily so; buccal plates large, nearly circular, the two of a pair close together, the pairs separated from each other by about a millimeter. Each buccal plate carries about half a dozen slightly club-shaped miliary spines, besides numerous small stout tridentate pedicellariae. Most of the non-ambulacral plates of the peristome carry one or more miliary spines besides small stout tridentate pedicellariae.

Primary spines about 12 mm. long at ambitus, terete basally and becoming flattened only slightly near tip; the tip itself is concave, not pointed; each spine has 20–22 well marked striations. Secondary and miliary spines, slender, cylindrical, bluntly pointed.

Pedicellariae numerous and diversified but only the small stout tridentate are at all common. In size and form the pedicellariae offer no characters by which they can certainly be distinguished from those of *P. maculata.* Globiferous pedicellariae rare, of two sizes, one with valves about .80 mm. in length, the other with valves about half as large. Ophicephalous pedicellariae rare, with valves about .50 mm. long and loops .15 mm. more. Tridentate pedicellariae in at least three forms: (a) slender, with valves, 1.25 mm. long; (b) small stout, with valves about .50 mm. long; and (c) big, stout, with valves over a millimeter long, half a millimeter wide and very serrate margins; only one of these big pedicellariae was noted. Triphyllous pedicellariae with valves .22 mm. long and about .18 mm. wide near tip.

Color (in alcohol) pale brown with a distinctly greenish cast, the midzone with about 20 large irregular blotches of a distinctly darker shade; there are two of these blotches in each ambulacrum and interambulacrum but they vary in size and distinctness. Primary spines pale fawn-color, decidedly greenish basally and very faintly pinkish at tips; on the dark blotches the primaries are deep brownish-green, light only at the tips, but there is much diversity in the relative proportions of green and pale fawn-color.

Holotype labelled only "Barbados", but Professor Nutting tells me that "in all probability it came from a depth of between 30 and 100 fms."

The discovery of *Pseudoboletia* in the West Indian region is certainly one of the most noteworthy results of the Barbados-Antigua Expedition, for the genus is not known on the western coast of tropical America and is really characteristic of the Indo-Pacific fauna. On June 10, 1904, the "Scotia" took two specimens of a *Pseudoboletia* in 40 fms. off the island of Ascension, in mid-Atlantic but well south of the equator. It is remarkable that the new species from Barbados is not very close to this Atlantic species,[1] which has *five* pairs of pores to an arc and banded actinal spines, but is so very close to *P. maculata* of the Philippines that one hesitates to call them distinct. The following differences however warrant keeping them separate, at least until more material is available. In *maculata,* the inner primary tubercle of the ambulacra appears first on the seventh, eighth or ninth plate from the ocular, in specimens 52–55 mm. in diameter, while in *occidentalis* it occurs first on the tenth–twelfth plate; this is not an important character and will probably prove inconstant and unreliable. In *maculata* the periproct is covered by about 30 plates and the oculo-genital ring is more granulated than in *occidentalis.* The primary spines of the midzone in *maculata* are markedly flattened, with bluntly chisel-shaped tips (though with a terminal concavity), and are 14–16 mm. long. Their color too, green at base and red-purple or reddish at tip, is quite different from the pale colors of *occidentalis.*

In view of the insignificance of these differences, the question naturally arises whether the Barbados specimen was not accidentally brought from the East Indian region (or possibly from Hawaii). Professor Nutting assures me there is no doubt whatever that the specimen at hand was collected at Barbados. It is not inconceivable that a small specimen of *maculata* might have been brought on a very foul ship bottom through the Panama

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[1] Kœhler called the specimens from Ascension *P. maculata* but they really represent quite a different species, which I have proposed (1912, Mem. C. Z., 34, p. 344) to call *atlantica.*

Canal to Barbados, but that seems so highly improbable that we are better justified in believing that *Pseudoboletia* is a natural member of the Barbadian fauna. It is strange that neither the "Blake", the "Hassler", nor the "Albatross", nor any other collector in the West Indies, has met with the genus but the reason may be that the vessels mentioned did nearly all their collecting outside the 100 fms. line while the other collectors have done very little dredging at any depth. The teeming area between 10 and 100 fms. has scarcely been touched as yet.

ECHINOMETRA LUCUNTER

Echinus lucunter Linné, 1758. Sys. Nat. ed. 10, p. 665.

Echinometra subangularis A. Agassiz, 1872. Rev. Ech., p. 283, pl. X*a*, figs. 2–4.

Echinometra lucunter Lovén, 1887. Ech. Linnaeus, p. 157.

Of this very common species, there are 94 specimens in the collection, of which 7 are bleached bare tests. Only three are from Barbados, the remaining 91 being from the Pillars of Hercules and English Harbour, Antigua. The largest specimen is 53 mm. long, 43 mm. wide and 28 mm. high, while the smallest is about 9×8×4.5. Some of the specimens from English Harbour are very dark-colored, a very dark purple-drab or a violet-black. They are also quite wide in proportion to the length and look as though the ambitus were a circle, but examination shows the width is always 1.5–3 mm. less than the length. The Barbados specimens are of two types of coloration: 2 are fawn-color becoming purplish-red at spine tips, while the third is dark olive, the primaries with purple tips.

At English Harbour, specimens taken from the rocks near the entrance show the effects of the heavy surf in which they spend so much of their lives. The primary spines are nearly all distorted or regenerating at the tip. In the Narrative (p. 189), Professor Nutting describes the conditions under which the Echinometras flourish at Antigua. In speaking of their occurrence at Barbados (p. 83) he says that *E. viridis* is a "very common form" and that *E. lucunter* is "less common". As there are no specimens of *viridis* in the collection and both Barbados and Antigua are well outside its known range, I think dark greenish specimens of *lucunter* have been mistaken for *viridis*.

CLYPEASTER ROSACEUS

Echinus rosaceus Linné, 1758. Syst. Nat. ed. 10, p. 665.

Clypeaster rosaceus Lamarck, 1801. Syst. Anim. s. Vert., p. 349.

Echinanthus rosaceus A. Agassiz, 1872. Rev. Ech., p. 311; pl. XI*d*, figs. 1, 2.

The only evidence of the occurrence of this well known species in the region visited by the Iowa party, is a group of fragments of a bare test about 80 mm. long, taken at English Harbour, Antigua.

MELLITA SEXIESPERFORATA

Echinodiscus sexiesperforata Leske, 1778. Add. ad Klein, p. 135.

Mellita sexiesperforata Meissner, 1904. Bronn's Thierreichs, **2**, abb. 3, buch 4, p. 1384.

There are three fine specimens of this well-known "key-hole urchin" from Barbados. Their color in alcohol is bright yellow-brown. While one specimen is longer than wide, 78×76 mm., the other two are distinctly wider than long, 80×82 mm. and 66×69 mm. The labels do not indicate just where or under what conditions these urchins were taken, and there is no mention of them in the "Narrative".

ECHINOEUS CYCLOSTOMUS

Leske, 1778. Add. ad Klein, p. 109.

This well-known cosmopolitan echinoid has taken on new interest recently from the fact that it is now fairly well demonstrated that it is a Holectypoid, the genus *Echinonëus* and its near relative *Micropetalon* being the only living representatives of that order (See Hawkins, 1920, Phil. Trans. Roy. Soc. (B), **209**, p. 442). Both at Barbados and Antigua, *Echinonëus* was found in its customary habitat, in the sand beneath rock fragments. There are 3 specimens in the collection from Barbados and 33 (of which 18 are bleached, bare tests) from English Harbour, Antigua. The smallest specimen is 7 mm. long by 5 mm. wide; the largest is 35×29 mm. The form of the test shows much diversity, the width ranging from .66 to .77 of the length and the height from .39 to .48.

AGASSIZIA EXCENTRICA

A. Agassiz, 1869. Bull. M. C. Z., **1**, p. 276. 1883, Mem. M. C. Z., **10**, pl. XXV.

Twice during the dredging off Barbados, the bare dead tests of this species were met with. All are small, ranging from 5.5 to 9.5 mm. in length; the largest is 8.5 mm. wide and 8 mm. high.

Station 48. May 27, 1918. S. W. of Lazaretto, W. by N. of Pelican Island, 25–72 fms. Coarse coral sand. Dredge. 3 specimens.

Station 77. June 3, 1918. Cable station bears 3½ S. 1 mile off shore. 40–50 fms. Dead bottom—coarse sand. 2 specimens.

BRISSUS BRISSUS

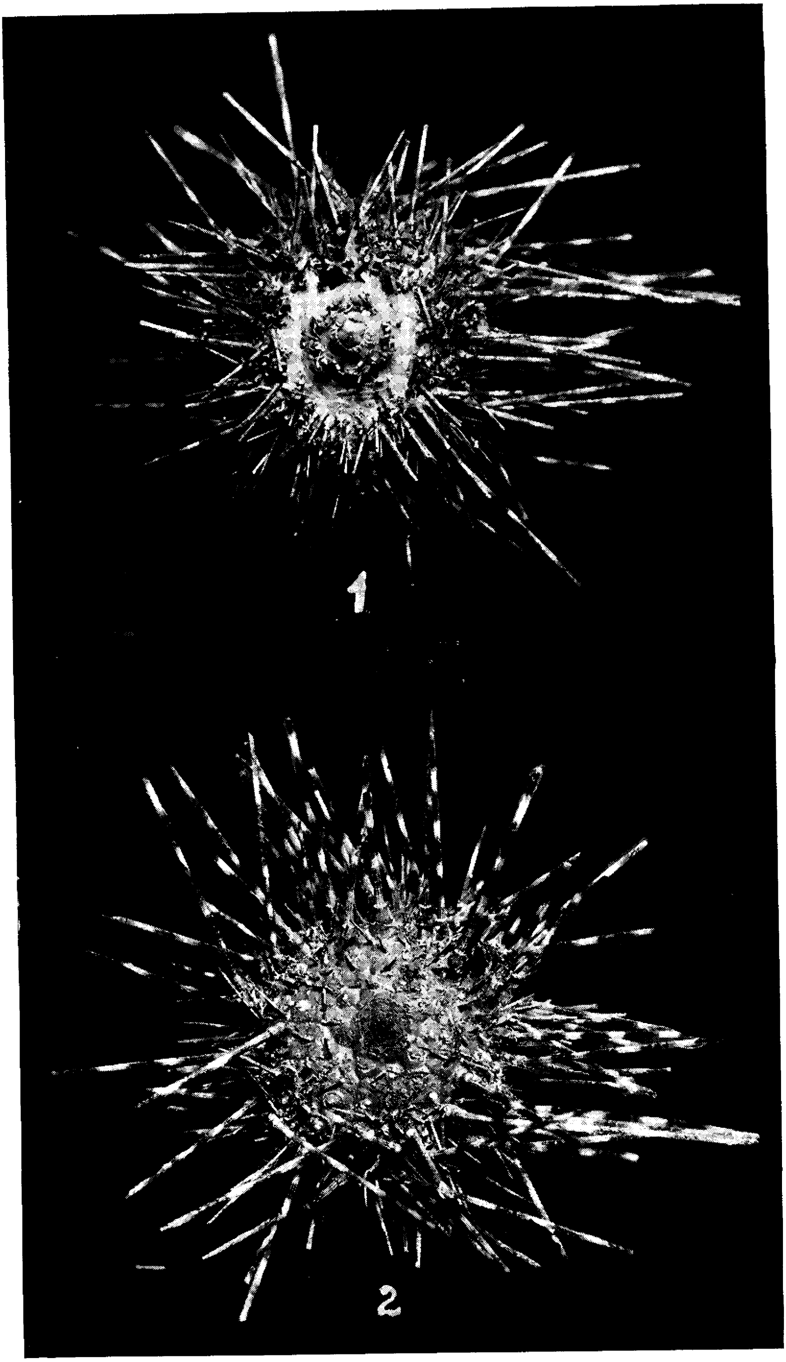
Spatangus brissus (var. *unicolor*) Leske, 1778. Add. ad Klein, pp. xx, 182.

Brissus brissus H. L. Clark, 1917. Mem. M. C. Z., **46**, p. 218.

This spatangoid, almost always found associated with *Echinonëus,* was not taken at Barbados, although it is recorded from that island and probably occurs there. From Antigua there are 48 specimens, of which 4 are bare tests. One was taken at the Pillars of Hercules but all the others are from English Harbour. The smallest specimen is 22 mm. long, 17 mm. wide and 11 mm. high, while the largest is 61×45×36 mm. One specimen is peculiarly deformed, as a result of a serious injury at some time in interambulacrum 4, which is now entirely healed; this specimen measures 42×35×25 mm. In the Narrative (pp. 190–192), Professor Nutting discusses in a very interesting way the peculiar subsurface habits of *Brissus* and *Echinonëus.* My own observations of these species agree well with those of the Iowa party, but I have not noted that the depth below the surface was as great as six inches. In many cases the animals are just below the surface. As a rule the larger the animal the more deeply it is buried. Probably the animals move up and down in the sand with changes in temperature and tidal conditions, and no doubt the larger individuals move more rapidly and greater distances than the smaller ones. The food is certainly in large part diatoms and other unicellular organisms.

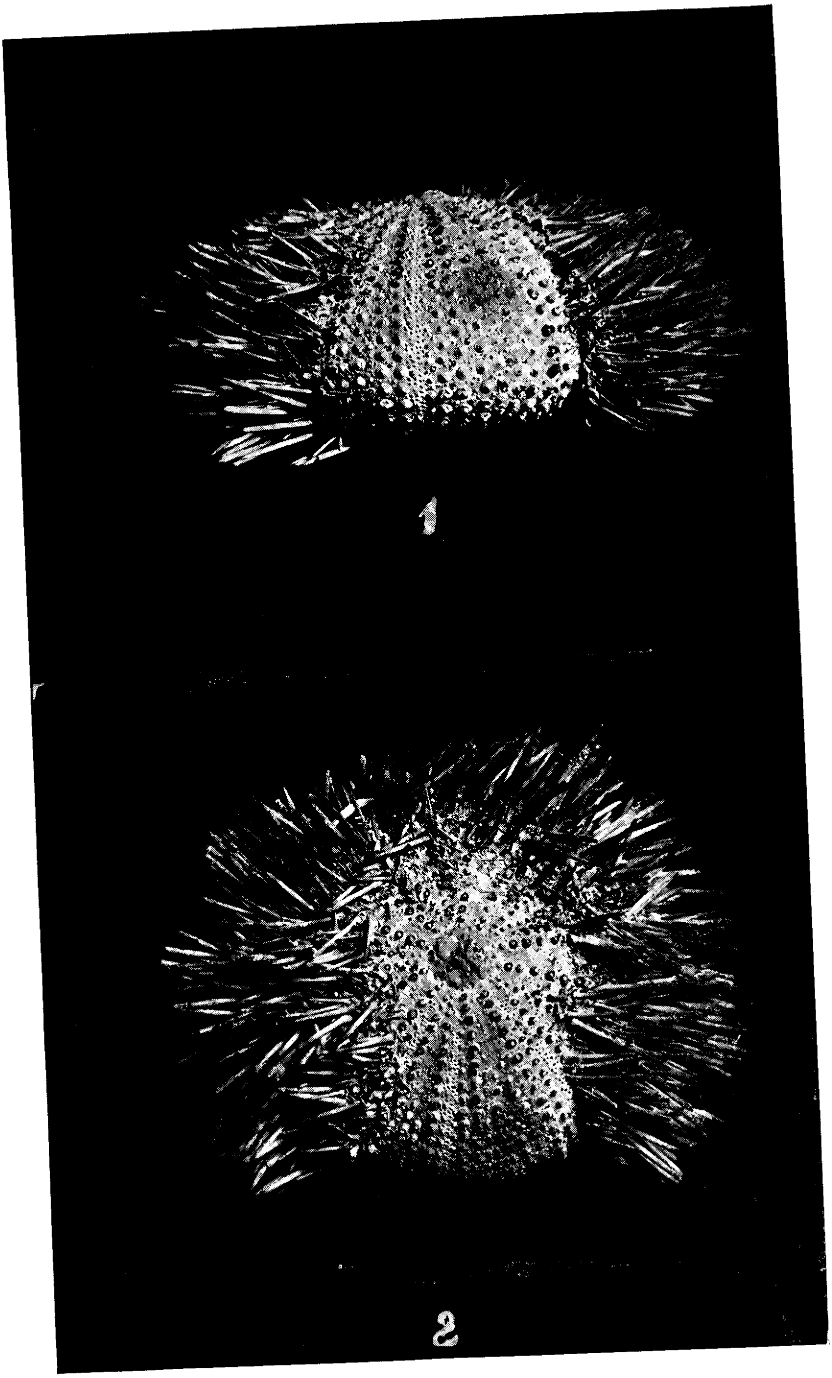
Museum of Comparative Zoölogy
Cambridge, Mass.
May 28, 1920

PLATE 1



Centrostephanus rubicingulus. ×3.
1. Oral view. 2. Aboral view.

PLATE II



Pseudoboletia occidentalis. Nat. size.
1. Side view. 2. Aboral view.

Obtainable from the University
Librarian; Price, $1.50